

HP InfoTech

CodeVisionAVR

VERSION 3.28

User Manual

CodeVisionAVR V3.28 User Manual

Revision 63/08.2016

Copyright © 1998-2016 Pavel Haiduc and HP InfoTech S.R.L. All rights reserved.

No part of this document may be reproduced in any form, except by written permission of the author.

All rights of translation reserved.

CodeVisionAVR

Table of Contents

1. Introduction.....	13
1.1 Credits	14
2. Using the CodeVisionAVR Extension for Atmel Studio	15
2.1 Working with Projects and Solutions	15
2.1.1 Creating a New Project using the CodeWizardAVR.....	15
2.1.2 Creating a New Project without using the CodeWizardAVR	19
2.1.3 Opening an Existing Project or Solution	22
2.1.4 Importing a CodeVisionAVR V2 Project	23
2.1.5 Configuring the Project	25
2.1.6 Obtaining an Executable Program.....	26
2.1.6.1 Building the Project	27
2.1.6.2 Cleaning Up the Project Output Directories.....	30
2.1.6.3 Using the Function Call Tree	30
2.1.6.4 Transferring the Compiled Program to the AVR Chip after Build	31
2.1.7 Debugging the Executable Program.....	34
2.2 The Tools Menu.....	35
2.2.1 The CodeWizardAVR Automatic Program Generator	35
2.2.2 The Arduino Program Uploader.....	36
2.2.3 The LCD Vision Font and Image Editor/Converter.....	37
3. The CodeVisionAVR Integrated Development Environment	38
3.1 Using the Integrated Development Environment Workspace	38
3.2 Working with Files	49
3.2.1 Creating a New File	49
3.2.2 Opening an Existing File.....	50
3.2.3 Files History	50
3.2.4 Editing a File	51

3.2.4.1 Searching/Replacing Text.....	52
3.2.4.2 Setting Bookmarks.....	52
3.2.4.3 Jumping to a Symbol Definition or Declaration.....	52
3.2.4.4 Jumping to a Specific Line Number in the Edited File.....	53
3.2.4.5 Printing a Text Selection.....	53
3.2.4.6 Indenting/Unindenting a Text Selection.....	53
3.2.4.7 Commenting/Uncommenting a Text Selection	53
3.2.4.8 Match Braces.....	53
3.2.4.9 Inserting Special Characters in the Text.....	54
3.2.4.10 Using the Auto Complete Functions	55
3.2.4.11 Formatting the C Source Code.....	56
3.2.4.12 Using Code Folding	57
3.2.5 Saving a File	57
3.2.6 Renaming a File.....	58
3.2.7 Printing a File.....	59
3.2.8 Closing a File	59
3.2.9 Closing Multiple Files.....	60
3.2.10 Comparing Files.....	61
3.2.11 Using the Code Templates	63
3.2.12 Using the Clipboard History.....	64
3.3 Working with Projects	65
3.3.1 Creating a New Project.....	65
3.3.2 Opening an Existing Project	69
3.3.3 Exporting a Project	70
3.3.4 Exporting a Project to the CodeVisionAVR Extension for Atmel Studio.....	71
3.3.5 Adding Notes or Comments to the Project	71
3.3.6 Configuring the Project.....	72
3.3.6.1 Adding or Removing a File from the Project.....	72

3.3.6.2 Setting the Project Output Directories	74
3.3.6.3 Setting the C Compiler Options	75
3.3.6.4 Setting the 1 Wire Library Options.....	90
3.3.6.5 Setting the Bit-Banged I ² C Library Options	91
3.3.6.6 Setting the MMC/SD/SD HC Card Library Options	92
3.3.6.7 Setting the Alphanumeric LCD Library Options.....	94
3.3.6.8 Setting the Graphic Display Library Options.....	95
3.3.6.9 Setting the Resistive Touchscreen Library Options.....	96
3.3.6.10 Setting the USB Library Options.....	97
3.3.6.11 Executing an User Specified Program before Build	98
3.3.6.12 Transferring the Compiled Program to the AVR Chip after Build	99
3.3.6.13 Executing an User Specified Program after Build	102
3.3.7 Obtaining an Executable Program.....	104
3.3.7.1 Checking Syntax.....	105
3.3.7.2 Compiling the Project.....	106
3.3.7.3 Building the Project.....	108
3.3.7.4 Cleaning Up the Project Output Directories.....	113
3.3.7.5 Using the Code Navigator.....	114
3.3.7.6 Using the Code Information	116
3.3.7.7 Using the Function Call Tree	118
3.3.8 Closing a Project.....	119
3.4 Tools	120
3.4.1 The AVR Debugger	120
3.4.2 The AVR Chip Programmer.....	121
3.4.3 The Arduino Program Uploader.....	124
3.4.4 The Serial Communication Terminal	125
3.4.5 The LCD Vision Font and Image Editor/Converter	126
3.4.6 Executing User Programs.....	126

CodeVisionAVR

3.4.7 Configuring the Tools Menu	126
3.5 IDE Settings.....	128
3.5.1 The View Menu.....	128
3.5.2 General IDE Settings	128
3.5.3 Configuring the Editor	129
3.5.3.1 General Editor Settings.....	129
3.5.3.2 Editor Text Settings	131
3.5.3.3 Syntax Highlighting Settings	132
3.5.3.4 Auto Complete Settings	133
3.5.4 Setting the C Source Code Formatting Options	134
3.5.5 Setting the Debugger Path	145
3.5.6 AVR Chip Programmer Setup	146
3.5.7 Serial Communication Terminal Setup	148
3.6 Accessing the Help.....	149
3.7 Connecting to HP InfoTech's Web Site	149
3.8 Quitting the CodeVisionAVR IDE	149
4. CodeVisionAVR C Compiler Reference	150
4.1 The C Preprocessor	150
4.2 Comments	154
4.3 Reserved Keywords	155
4.4 Identifiers	156
4.5 Data Types	156
4.6 Constants and FLASH Memory Access	157
4.7 Variables.....	161
4.7.1 Specifying the RAM and EEPROM Storage Address for Global Variables.....	163
4.7.2 Bit Variables.....	164
4.7.3 Allocation of Variables to Registers	165
4.7.4 Structures	166

CodeVisionAVR

4.7.5 Unions.....	170
4.7.6 Enumerations.....	172
4.8 Defining Data Types.....	173
4.9 Type Conversions.....	174
4.10 Operators.....	175
4.11 Functions.....	176
4.12 Pointers.....	177
4.13 Compiler Directives.....	180
4.14 Accessing the I/O Registers.....	186
4.14.1 Bit level access to the I/O Registers.....	188
4.15 Accessing the EEPROM.....	191
4.16 Using Interrupts.....	194
4.17 RAM Memory Organization and Register Allocation.....	196
4.18 Using an External Startup Assembly File.....	200
4.19 Including Assembly Language in Your Program.....	202
4.19.1 Calling Assembly Functions from C.....	203
4.20 Creating Libraries.....	205
4.21 Using the AVR Studio 4.19 Debugger.....	208
4.22 Using the Command Line Compiler.....	209
4.23 Compiling the Sample Code of the XMEGA Application Notes from Atmel.....	211
4.24 Hints.....	211
4.25 Limitations.....	211
5. Library Functions Reference.....	212
5.1 Character Type Functions.....	213
5.2 Standard C Input/Output Functions.....	214
5.3 Standard Library Functions.....	222
5.4 Mathematical Functions.....	224
5.4.1 64-bit Integer Mathematical Functions.....	227

5.5 String Functions.....	235
5.6 Variable Length Argument Lists Macros	241
5.7 Non-local Jump Functions	242
5.8 BCD Conversion Functions	244
5.9 Gray Code Conversion Functions	244
5.10 Memory Access Macros	245
5.11 Alphanumeric LCD Functions.....	246
5.11.1 LCD Functions for displays with up to 2x40 characters	246
5.11.2 LCD Functions for displays with 4x40 characters	249
5.11.3 LCD Functions for displays connected in 8 bit memory mapped mode	252
5.12 Graphic Display Functions.....	255
5.12.1 Graphic LCD Functions Specific to the ILI9225 Controller.....	282
5.12.2 Graphic LCD Functions Specific to the ILI9325 and RM68090 Controllers	287
5.12.3 Graphic LCD Functions Specific to the ILI9328 Controller.....	295
5.12.4 Graphic LCD Functions Specific to the ILI9331 Controller.....	303
5.12.5 Graphic LCD Functions Specific to the ILI9340 Controller.....	311
5.12.6 Graphic LCD Functions Specific to the ILI9341 Controller.....	319
5.12.7 Graphic LCD Functions Specific to the PCD8544 Controller	327
5.12.8 Graphic LCD Functions Specific to the RA8875 Controller.....	329
5.12.9 Graphic LCD Functions Specific to the S1D13700 Controller.....	337
5.12.10 Graphic LCD Functions Specific to the S6D0164 Controller.....	338
5.12.11 Graphic LCD Functions Specific to the S6D1121 Controller.....	343
5.12.12 Graphic LCD Functions Specific to the SED1335 Controller	348
5.12.13 Graphic LCD Functions Specific to the SED1530 Controller	350
5.12.14 Graphic LCD Functions Specific to the SPLC501C Controller.....	353
5.12.15 Graphic LCD Functions Specific to the SSD1289 Controller	356
5.12.16 Graphic OLED Display Functions Specific to the SSD1303 and SH1101A Controllers	363

5.12.17 Graphic OLED Display Functions Specific to the SSD1306 Controller.....	366
5.12.18 Graphic OLED Display Functions Specific to the SSD1322 Controller.....	369
5.12.19 Graphic OLED Display Functions Specific to the SSD1331 Controller.....	375
5.12.20 Graphic OLED Display Functions Specific to the SSD1332 Controller.....	380
5.12.21 Graphic OLED Display Functions Specific to the SSD1351 Controller.....	385
5.12.22 Graphic LCD Functions Specific to the SSD1963 Controller	391
5.12.23 Graphic LCD Functions Specific to the SSD2119 Controller	399
5.12.24 Graphic LCD Functions Specific to the ST7565 Controller	407
5.12.25 Graphic LCD Functions Specific to the ST7567 Controller	410
5.12.26 Graphic LCD Functions Specific to the ST7781 Controller	413
5.12.27 Graphic LCD Functions Specific to the ST7789 Controller	420
5.12.28 Graphic LCD Functions Specific to the ST7920 Controller	427
5.12.29 Graphic LCD Functions Specific to the T6963C Controller	433
5.12.30 Graphic LCD Functions Specific to the UC1608 Controller	435
5.12.31 Graphic LCD Functions Specific to the UC1610 Controller	439
5.12.32 Graphic LCD Functions Specific to the UC1701 Controller	443
5.13 Resistive Touchscreen Functions	446
5.14 Capacitive Touchscreen Functions	461
5.15 1 Wire Protocol Functions	472
5.16 Two Wire Interface Functions for non-XMEGA Devices	475
5.16.1 Two Wire Interface Functions for Master Mode Operation.....	475
5.16.2 Two Wire Interface Functions for Slave Mode Operation.....	477
5.17 Two Wire Interface Functions for XMEGA Devices.....	481
5.17.1 Two Wire Interface Functions for Master Mode Operation.....	482
5.17.2 Two Wire Interface Functions for Slave Mode Operation.....	486
5.18 Software Bit-Banged I ² C Bus Functions.....	491
5.19 SPI Functions	494
5.20 USB Device Mode Functions.....	498

CodeVisionAVR

5.20.1 USB CDC Virtual Serial Port Functions.....	510
5.20.2 Accessing an USB Generic HID	523
5.20.2 USB HID Keyboard Functions	527
5.20.3 USB HID Mouse Functions.....	535
5.20.4 USB HID Joystick Functions.....	539
5.21 Power Management Functions.....	543
5.22 Delay Functions	545
5.23 MMC/SD/SD HC FLASH Memory Card Driver Functions.....	546
5.24 FAT Access Functions.....	555
5.25 Peripheral Chips Functions	581
5.25.1 Philips PCF8563 Real Time Clock Functions.....	581
5.25.2 Philips PCF8583 Real Time Clock Functions.....	588
5.25.3 Maxim DS1302 Real Time Clock Functions.....	594
5.25.4 Maxim DS1307 Real Time Clock Functions.....	598
5.25.5 Maxim DS3231 Real Time Clock Functions.....	603
5.25.6 Maxim DS1621 Thermometer/ Thermostat Functions	611
5.25.7 Maxim DS1820/DS18S20 Temperature Sensors Functions.....	616
5.25.8 Maxim DS18B20 Temperature Sensor Functions.....	620
5.25.9 Maxim DS2430 EEPROM Functions.....	623
5.25.10 Maxim DS2433 EEPROM Functions.....	626
5.25.11 Texas Instruments LM75 Temperature Sensor Functions	629
5.25.12 Bosch Sensortec BMP085 Digital Pressure Sensor Functions.....	635
5.25.13 Bosch Sensortec BMP180 Digital Pressure Sensor Functions.....	642
5.25.14 Bosch Sensortec BMP280 Digital Pressure Sensor Functions.....	649
5.25.15 Bosch Sensortec BME280 Digital Pressure and Humidity Sensor Functions.....	657
5.25.16 Measurement Specialties MS5611-01BA Digital Pressure Sensor Functions.....	666
5.25.17 ROHM Semiconductor BH1750FVI Digital Light Sensor Functions.....	671
6. CodeWizardAVR Automatic Program Generator	677

6.1 Setting the AVR Chip Options	682
6.2 Setting the External SRAM	683
6.3 Setting the Input/Output Ports	684
6.4 Setting the External Interrupts	685
6.5 Setting the Timers/Counters	686
6.6 Setting the UART or USART	696
6.7 Setting the Analog Comparator	699
6.8 Setting the Analog to Digital Converter	701
6.9 Setting the ATmega406 Voltage Reference	703
6.10 Setting the ATmega406 Coulomb Counter	704
6.11 Setting the SPI Interface	705
6.12 Setting the Universal Serial Interface - USI	706
6.13 Setting the Bit-Banged I ² C Bus	707
6.13.1 Setting the LM75 devices	708
6.13.2 Setting the DS1621 devices	709
6.13.3 Setting the PCF8563 devices	710
6.13.4 Setting the PCF8583 devices	711
6.13.5 Setting the DS1307 devices	712
6.13.6 Setting the DS3231 devices	713
6.14 Setting the 1 Wire Bus	714
6.15 Setting the Two Wire Bus Interface	715
6.16 Setting the Two Wire Bus Slave Interface for the ATtiny20/40 chips	716
6.17 Setting the CAN Controller	718
6.18 Setting the ATmega169/329/3290/649/6490 LCD Controller	720
6.19 Setting the Alphanumeric LCD	721
6.20 Setting the Graphic Display	722
6.21 Setting the Resistive Touchscreen Controller	723
6.22 Setting the Capacitive Touchscreen Controller	724

CodeVisionAVR

6.23 Setting the USB Controller	725
6.24 Setting Bit-Banged Peripherals	728
6.25 Specifying the Project Information.....	729
7. CodeWizardAVR Automatic Program Generator for the XMEGA Chips.....	730
7.1 Setting the General Chip Options.....	735
7.2 Setting the System Clocks.....	737
7.3 Setting the External Bus Interface	742
7.4 Setting the Event System	746
7.5 Setting the Input/Output Ports	747
7.6 Setting the Virtual Ports.....	749
7.7 Setting the Timers/Counters.....	750
7.8 Setting the Watchdog Timer	757
7.9 Setting the 16-Bit Real Time Counter.....	758
7.10 Setting the 32-Bit Real Time Counter and Battery Backup System.....	760
7.11 Setting the USARTs	762
7.12 Setting the Serial Peripheral Interfaces.....	767
7.13 Setting the USB Interface	769
7.14 Setting the 1 Wire Bus.....	773
7.15 Setting the Two Wire Interfaces	774
7.16 Setting the Analog to Digital Converters	776
7.17 Setting the Digital to Analog Converters	783
7.18 Setting the Alphanumeric LCD	787
7.19 Setting the Graphic Display	788
7.20 Setting the Resistive Touchscreen Controller	789
7.21 Setting the Capacitive Touchscreen Controller	790
7.22 Specifying the Project Information.....	791
8. Licensing System	792
8.1 Activating the License.....	792

CodeVisionAVR

8.2 Transferring or Deactivating the License.....	794
8.3 Upgrading the License.....	795
9. License Agreement	797
9.1 Software License	797
9.2 Liability Disclaimer	797
9.3 Restrictions	797
9.4 Operating License	797
9.5 Back-up and Transfer	798
9.6 Terms.....	798
9.7 Other Rights and Restrictions.....	798
10. Technical Support and Updates	799
11. Contact Information	800

1. Introduction

CodeVisionAVR is a C cross-compiler, Integrated Development Environment and Automatic Program Generator designed for the Atmel AVR family of microcontrollers.

It is designed to run under the Windows XP, Vista, 7, 8 and 10, 32bit and 64bit operating systems.

The C cross-compiler implements all the elements of the ANSI C language, as allowed by the AVR architecture, with some features added to take advantage of specificity of the AVR architecture and the embedded system needs.

The compiled COFF object files can be C source level debugged, with variable watching, using the Atmel Studio and AVR Studio debuggers.

The Integrated Development Environment (IDE) has built-in AVR Chip In-System Programmer software that enables the automatic transfer of the program to the microcontroller chip after successful compilation/assembly. The In-System Programmer software is designed to work in conjunction with the Atmel STK500, STK600, AVRISP, AVRISP MkII, AVR Dragon, JTAGICE MkII, JTAGICE 3, Atmel-ICE, AVRProg (AVR910 application note), Kanda Systems STK200+, STK300, Arduino, Dontronics DT006, Vogel Elektronik VTEC-ISP, Futurlec JRAVR and MicroTronics' ATCPU, Mega2000 development boards.

For debugging embedded systems, which employ serial communication, the IDE has a built-in Terminal.

CodeVisionAVR can be also used as an extension in Atmel Studio 6.2 or 7.0, allowing seamless editing, compiling and debugging projects in this IDE.

Besides the standard C libraries, the CodeVisionAVR C compiler has dedicated libraries for:

- Alphanumeric and Graphic LCD/OLED displays
- Philips I²C bus
- Texas Instruments LM75 Temperature Sensor
- Philips PCF8563, PCF8583, Maxim DS1302, DS1307, DS3231 Real Time Clocks
- Maxim/Dallas Semiconductor 1 Wire protocol
- Maxim DS1820, DS18S20 and DS18B20 Temperature Sensors
- Maxim DS1621 Thermometer/Thermostat
- Maxim DS2430 and DS2433 EEPROMs
- SPI
- TWI for both XMEGA and non-XMEGA chips
- USB for both XMEGA and non-XMEGA chips
- Power management
- Delays
- Gray code conversion
- MMC/SD/SD HC FLASH memory cards low level access
- FAT acces on MMC/SD/SD HC FLASH memory cards
- ADS7843 and ADS7846 Resistive touchscreen controllers
- FT5206, FT5306 and FT5406 Capacitive touchscreen controllers
- BMP085, BMP180 and MS5611-01BA Digital Pressure sensors.

CodeVisionAVR

CodeVisionAVR also contains the CodeWizardAVR Automatic Program Generator, that allows you to write, in a matter of minutes, all the code needed for implementing the following functions:

- External memory access setup
- Chip reset source identification
- Input/Output Port initialization
- External Interrupts initialization
- Timers/Counters initialization
- Watchdog Timer initialization
- UART (USART) initialization and interrupt driven buffered serial communication
- Analog Comparator initialization
- ADC and DAC initialization
- SPI Interface initialization
- Two Wire Interface initialization
- USB Initialization
- CAN Interface initialization
- I²C Bus, LM75 Temperature Sensor, DS1621 Thermometer/Thermostat and PCF8563, PCF8583, DS1302, DS1307, DS3231 Real Time Clocks initialization
- 1 Wire Bus and DS1820/DS18S20 Temperature Sensors initialization
- Alphanumeric and graphic displays initialization
- Touchscreen controllers initialization.

CodeVisionAVR is © Copyright 1998-2016 Pavel Haiduc and HP InfoTech S.R.L., all rights reserved. The MMC, SD, SD HC and FAT File System libraries are based on the FatFS open source project from <http://elm-chan.org> © Copyright 2006-2009 ChaN, all rights reserved.

The CodeVisionAVR IDE uses the freeware TDiff Delphi component © Copyright 2001-2008 by Angus Johnson.

For C source style formatting the CodeVisionAVR IDE calls the [Artistic Style](#) program © Copyright 2014 by Jim Pattee.

1.1 Credits

The HP InfoTech team wishes to thank:

- Mr. Jack Tidwell for his great help in the implementation of the floating point routines
- Mr. Yuri G. Salov for his excellent work in improving the Mathematical Functions Library
- Mr. Olivier Wuillemin and Mr. Franc Marx for their help in beta testing
- Mr. Lee H. Theusch for his support in improving the compiler
- Mr. ChaN from Electronic Lives Mfg. <http://elm-chan.org> for the open source **MMC/SD/SD HC FLASH Memory Card Driver** and **FAT File System** functions.

2. Using the CodeVisionAVR Extension for Atmel Studio

The CodeVisionAVR extension allows editing, building and program debugging of the C source files grouped in projects, from within the Atmel Studio 6.2 or 7.0 IDE.

The following chapters cover only the specific aspects of CodeVisionAVR integrated in Atmel Studio. For more details about using Atmel Studio, please refer to its documentation.

2.1 Working with Projects and Solutions

The Project groups the source file(s) and compiler settings that you use for building a particular program.

Project files have the **.cproj** extension.

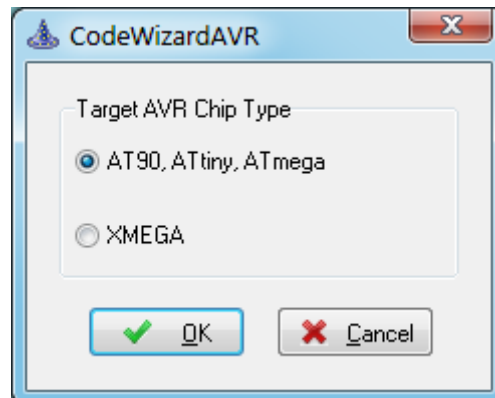
In Atmel Studio several projects can be grouped in a Solution.

Solution files have the **.atsln** extension.

2.1.1 Creating a New Project using the CodeWizardAVR

New CodeVisionAVR projects can be created in Atmel Studio by invoking the CodeWizardAVR automatic program generator, using the **File|New|Project using CodeWizardAVR...** menu command.

The following dialog box will open:



allowing to select between the AVR chip families for which automatic code generation will be performed.

After the chip configuration was specified, as outlined in the chapters:

6. CodeWizardAVR Automatic Program Generator

7. CodeWizardAVR Automatic Program Generator for the XMEGA Chips

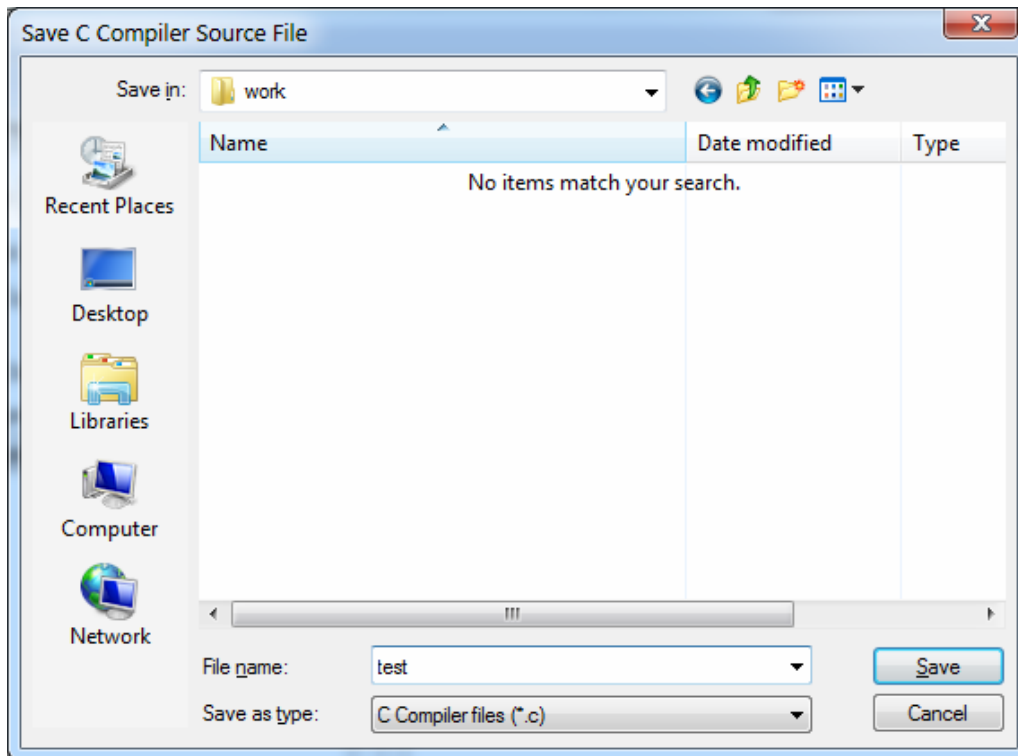
the **Program|Generate, Save and Exit** menu option must be selected or the  toolbar button must be clicked in CodeWizardAVR.

It will generate the main **.c** source, Atmel Studio project **.cproj** and it's own **.cwp** (for non-XMEGA chips) or **.cwx** (for XMEGA chips) project files.

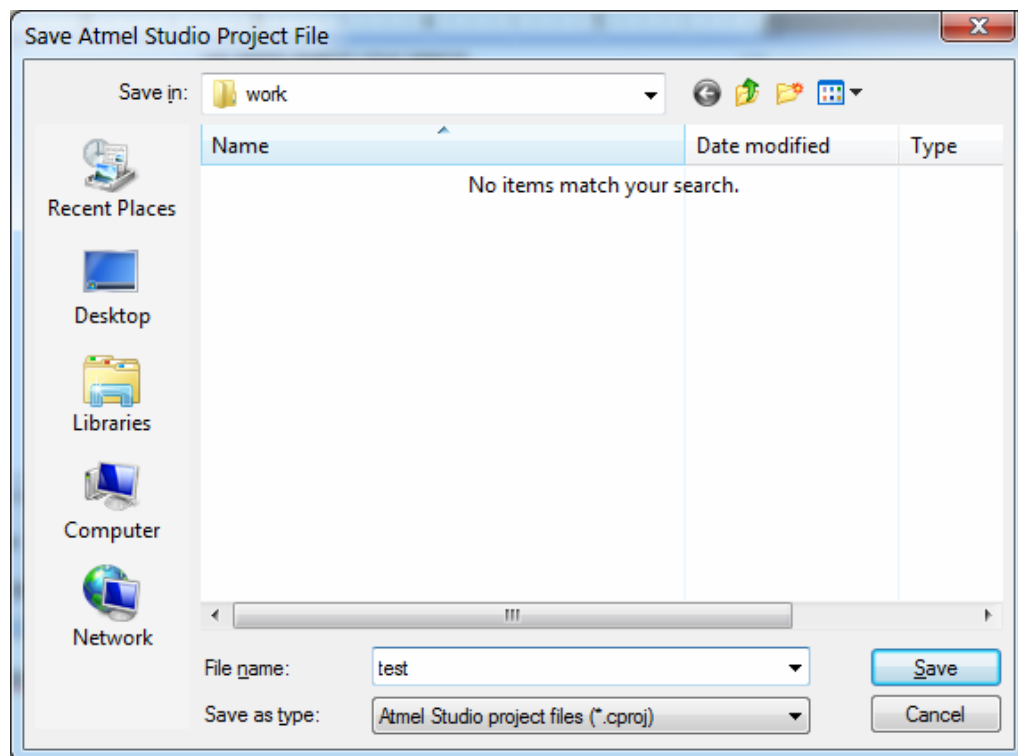
Eventual peripheral configuration conflicts will be prompted to the user, allowing him to correct the errors.

CodeVisionAVR

In the course of program generation the user will be prompted for the name of the first .c source file of the project:

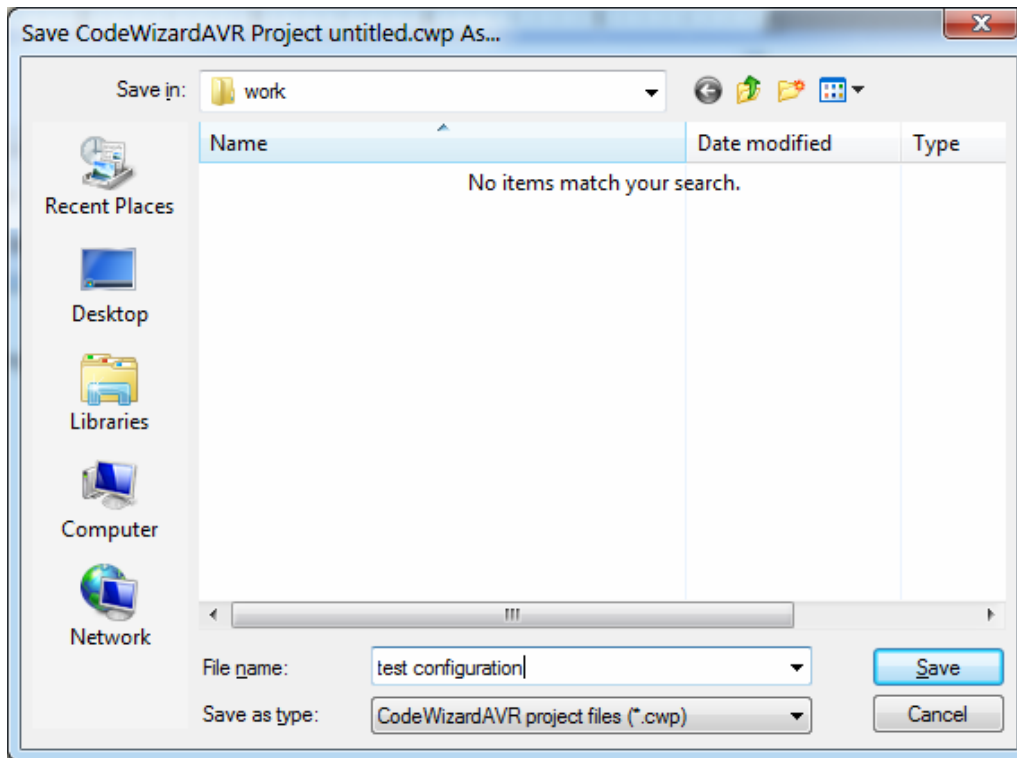


and for the name of the CodeVisionAVR project for Atmel Studio file:

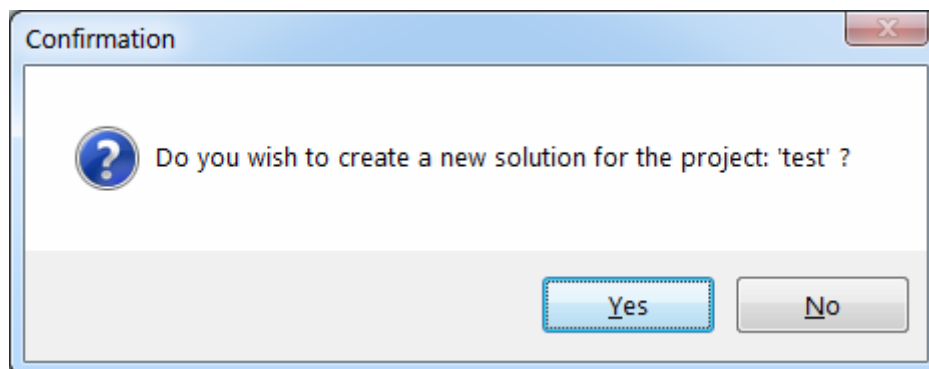


CodeVisionAVR

The user will be also prompted to save the current chip configuration in a CodeWizardAVR **.cwp** or **.cwx** project file:

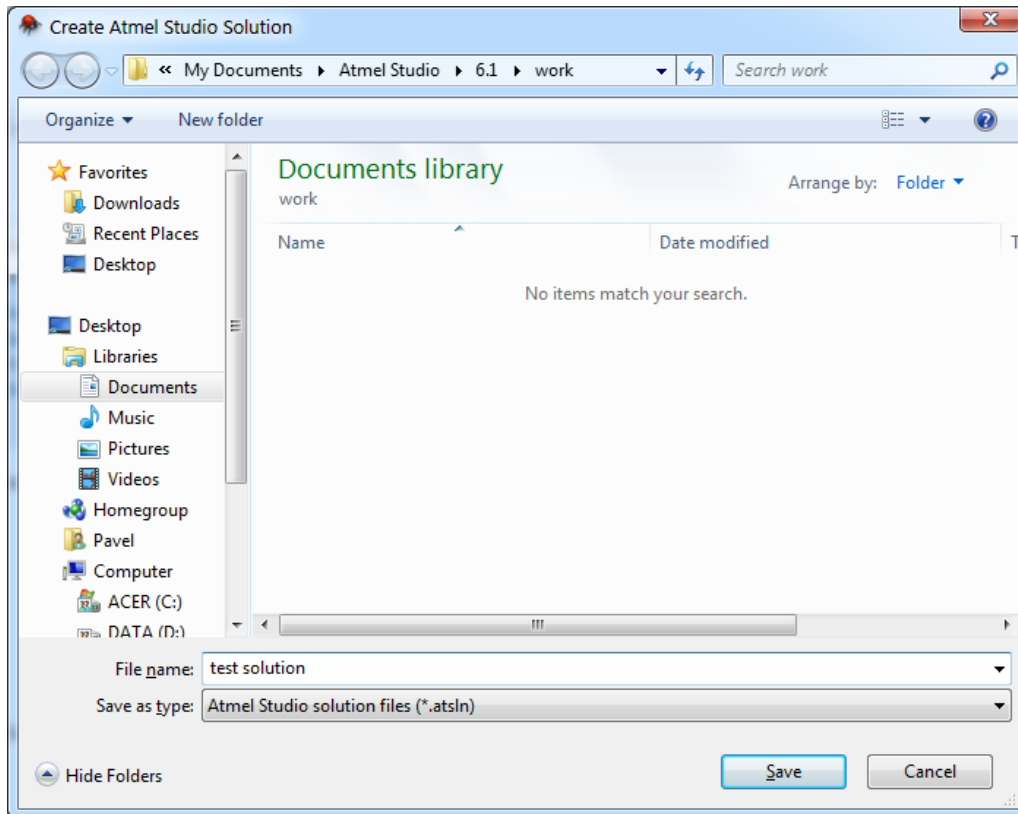


Once all these files were created, the user will be prompted for creating an Atmel Studio solution which will incorporate the new CodeVisionAVR project:



CodeVisionAVR

If the answer is affirmative, the user will be prompted for the Atmel Studio solution name:



If a solution is already opened, the user will be prompted for the inclusion of the new project in that solution, without creating a new one.

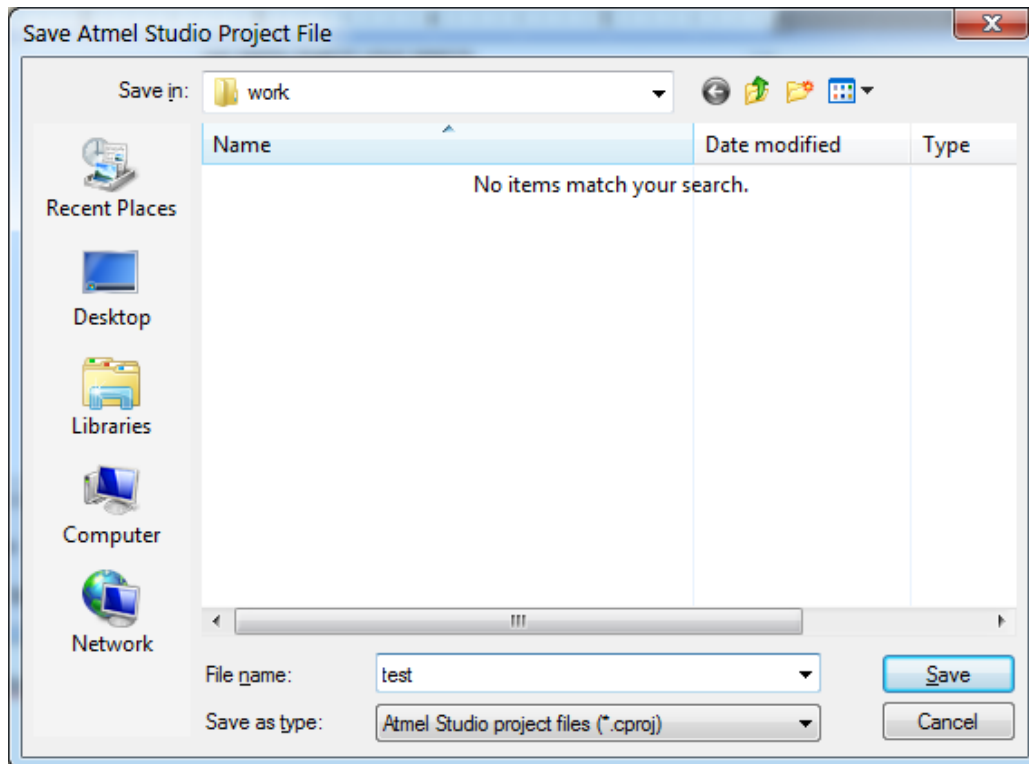
Note: When an Atmel Studio **.cproj** project is created, a corresponding **.prj** project file for the CodeVisionAVR IDE will be created too.
This allows editing/compiling the same project in both Atmel Studio and CodeVisionAVR IDE.

CodeVisionAVR

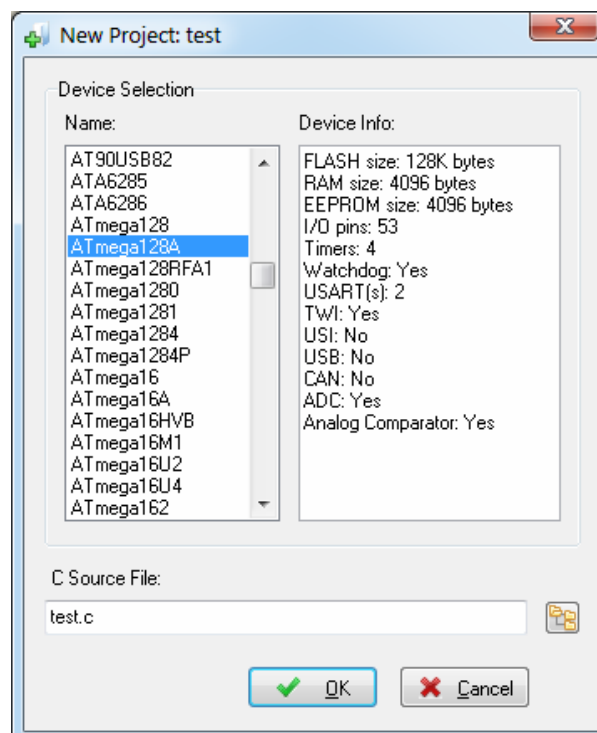
2.1.2 Creating a New Project without using the CodeWizardAVR

New CodeVisionAVR projects can be created in Atmel Studio using the **File|New|Project for CodeVisionAVR...** menu command.

The user will be prompted for the project file name:

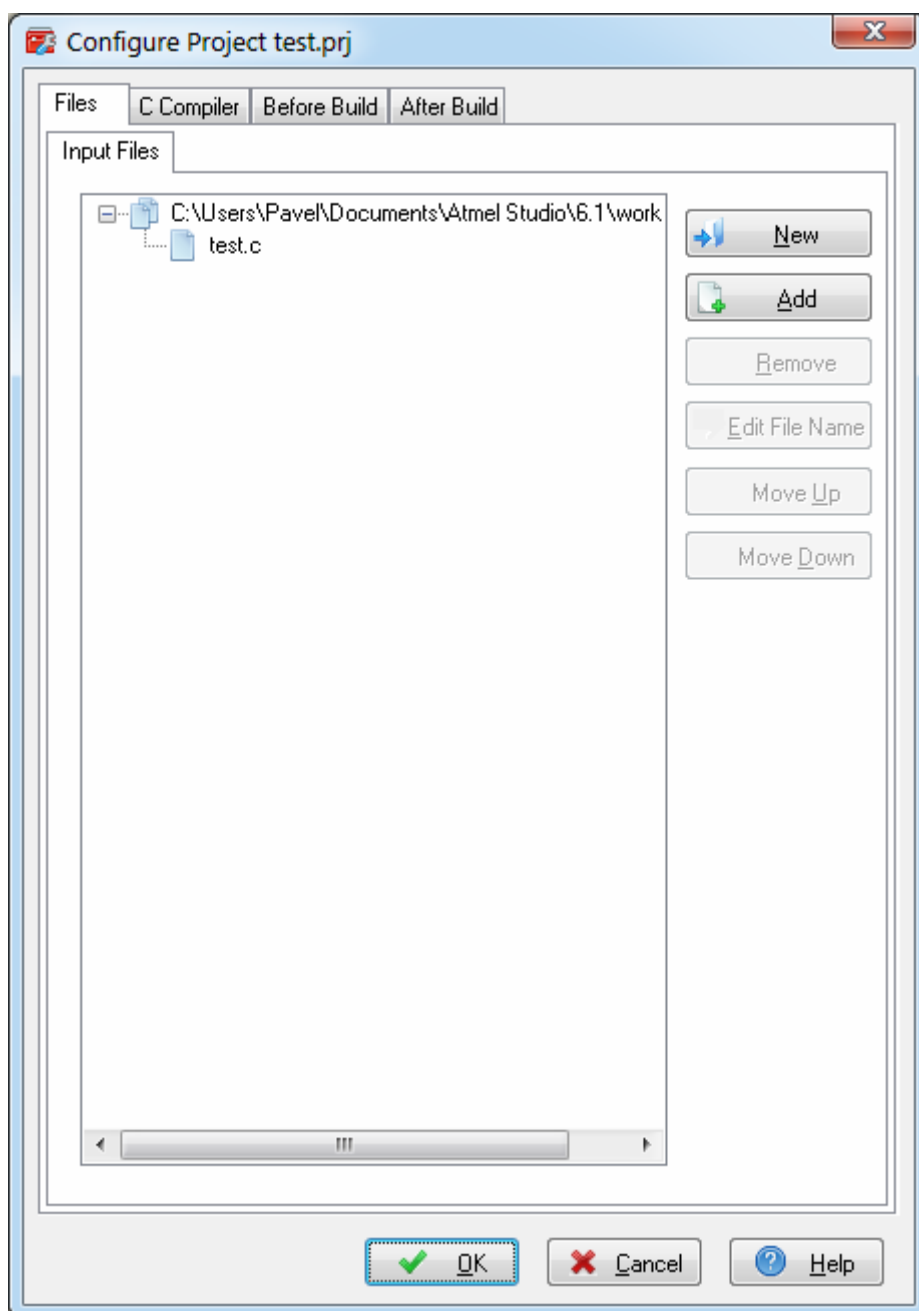


After the project file name was specified, the user will be prompted to select the target chip type and the name of the first .c source file of the project:



CodeVisionAVR

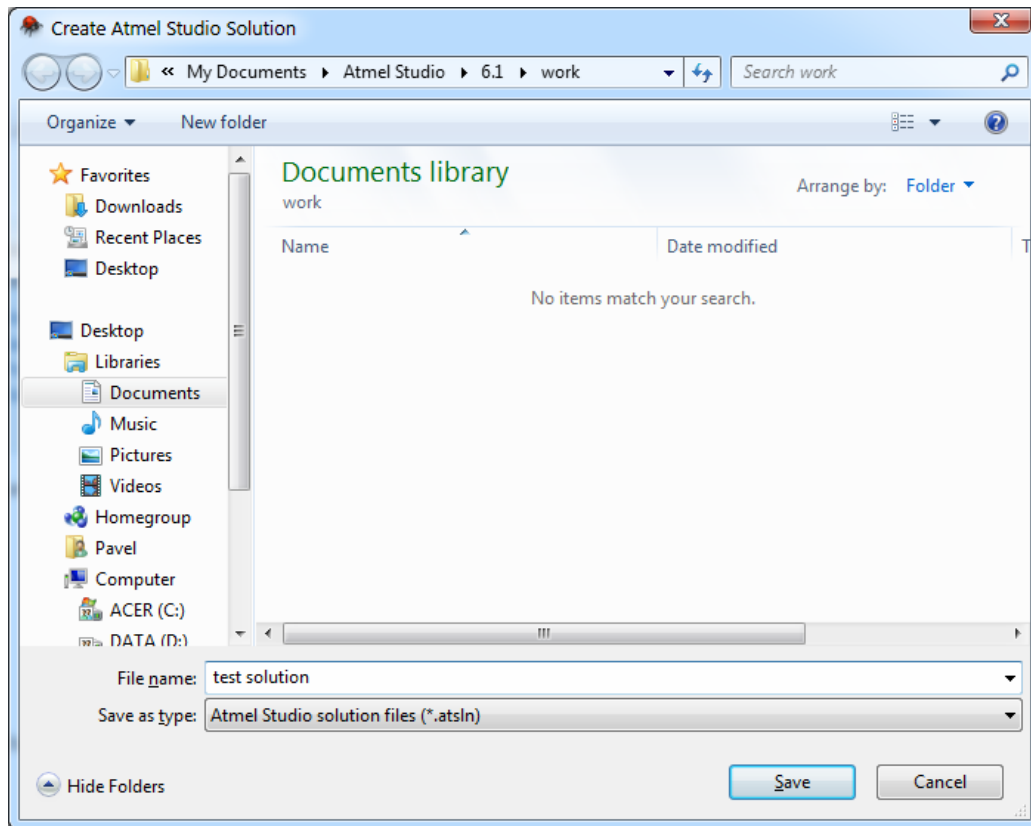
Once these are specified, a configuration window for the newly created project will be displayed:



More details can be found in the chapter: **3.3.6 Configuring the Project**.

CodeVisionAVR

After the project configuration was specified, the user will be prompted for the name of the Atmel Studio solution that will hold the new project:



If a solution is already opened, the user will be prompted for the inclusion of the new project in that solution, without creating a new one.

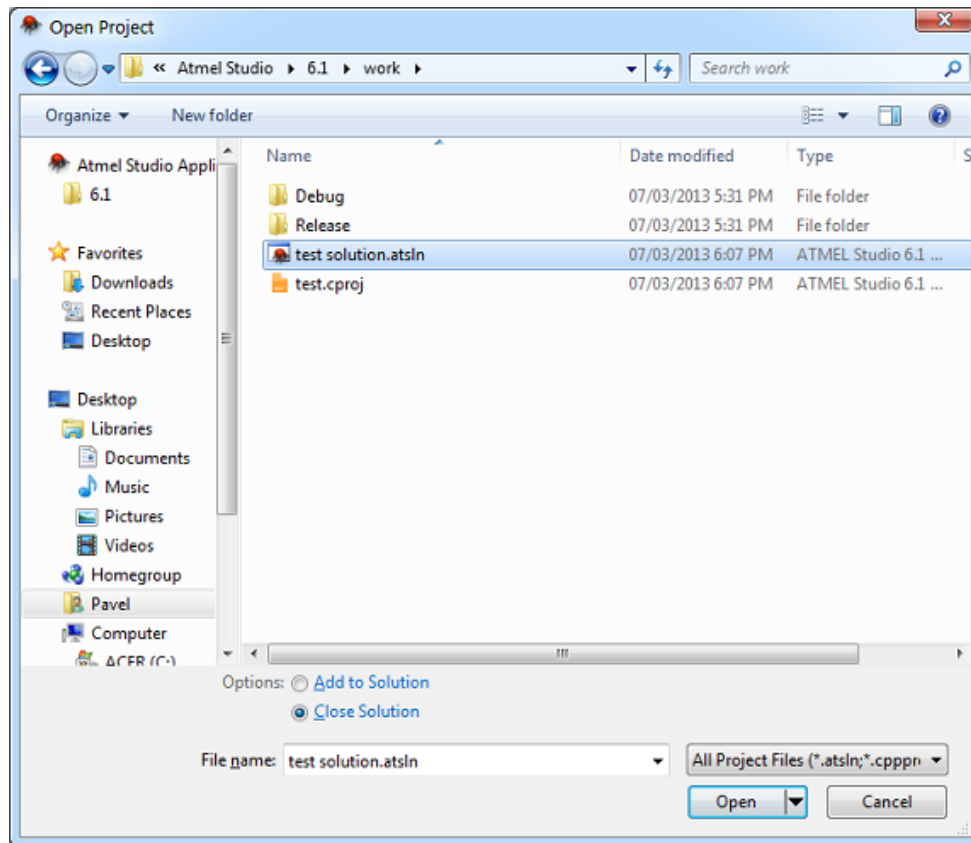
Note: When an Atmel Studio **.cproj** project is created, a corresponding **.prj** project file for the CodeVisionAVR IDE will be created too.

This allows editing/compiling the same project in both Atmel Studio and CodeVisionAVR IDE.

2.1.3 Opening an Existing Project or Solution

An existing project or solution can be opened in Atmel Studio using the **File|Open|Project/Solution** menu command.

The following dialog window will be displayed:



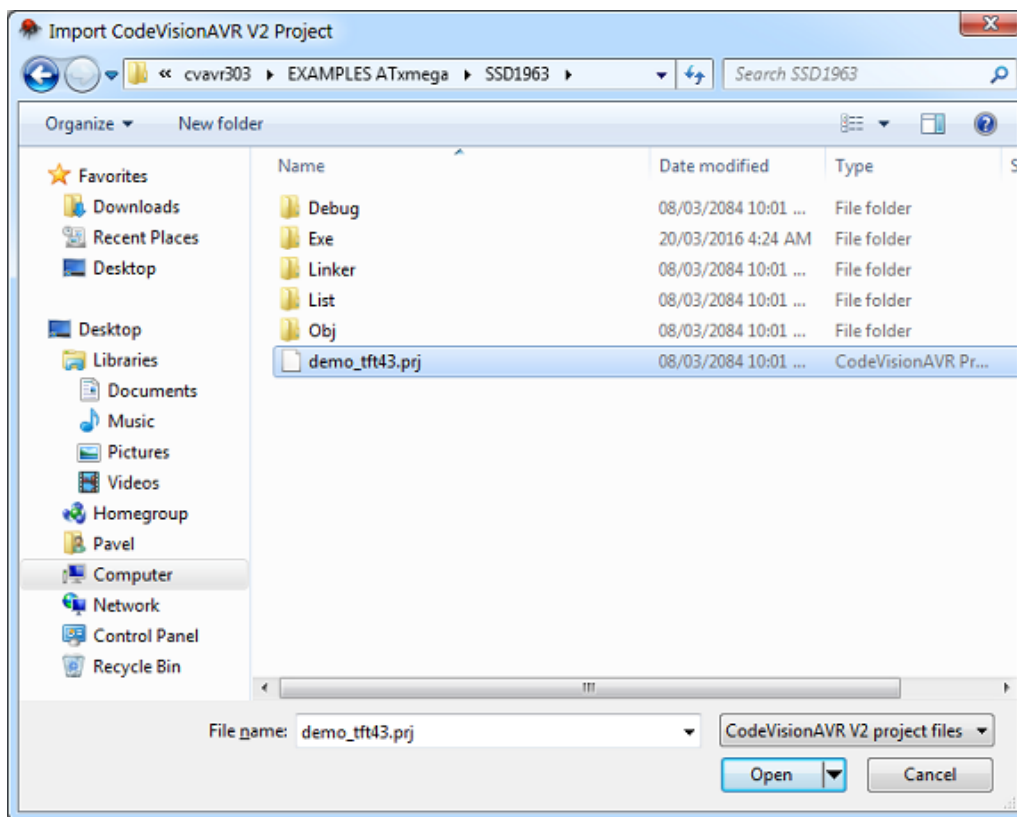
allowing the user to select the project or solution he wishes to open.

CodeVisionAVR

2.1.4 Importing a CodeVisionAVR V2 Project

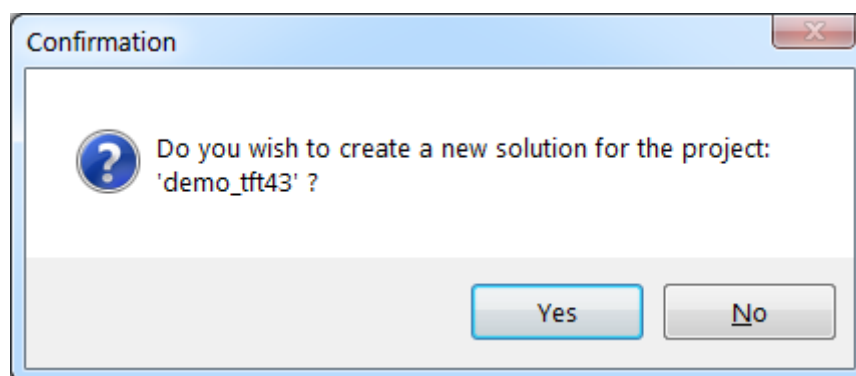
A project .prj file created for the CodeVisionAVR V2.xx compiler can be imported in Atmel Studio using the **File|Open|Import CodeVisionAVR V2 Project...** menu command.

A dialog window will be displayed, allowing the user to select the project to be imported:



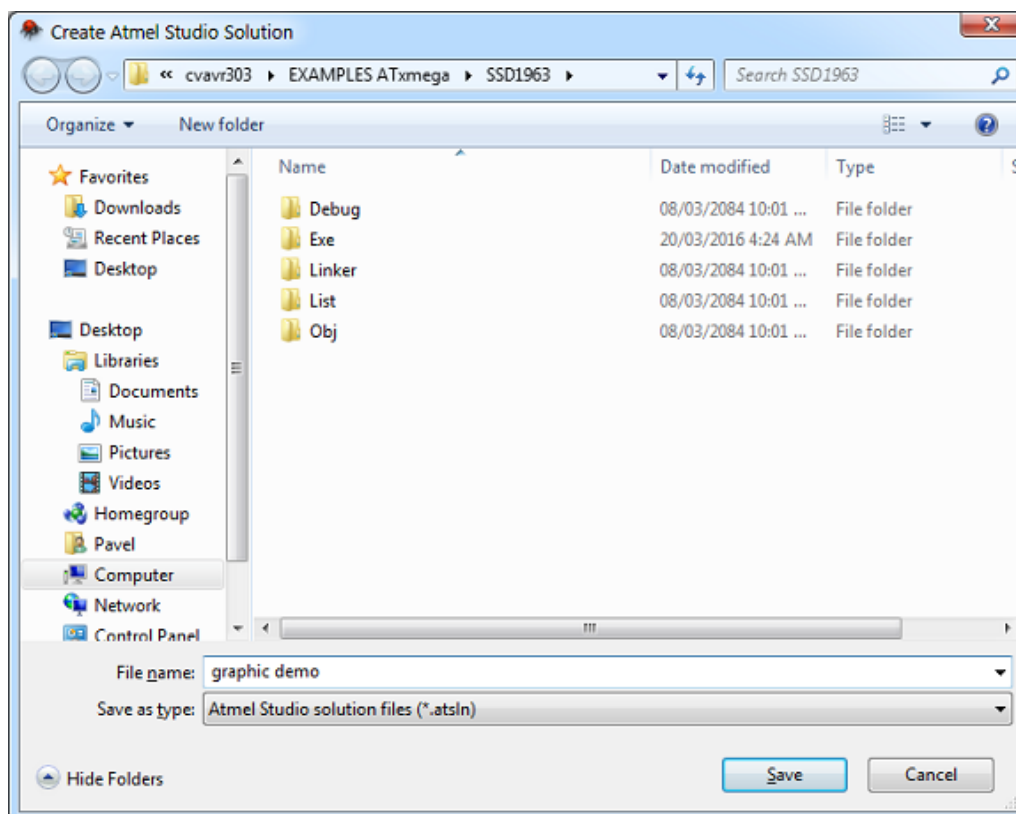
A corresponding Atmel Studio .cproj project file will be created.

If no solution is currently opened, the user will be prompted to create a new one:



CodeVisionAVR

If the answer is affirmative, the user will be prompted to specify the name of the new solution that will hold the imported project:



If a solution is already opened, the user will be prompted for the inclusion of the imported project in that solution, without creating a new one.

2.1.5 Configuring the Project

The Project can be configured using the **Project|Configure *project name*** menu command. The available options are detailed in the chapters:

- 3.3.6.1 Adding or Removing a File from the Project
- 3.3.6.2 Setting the Project Output Directories
- 3.3.6.3 Settings the C Compiler Options
- 3.3.6.4 Setting the 1 Wire Library Options
- 3.3.6.5 Setting the I2C Library Options
- 3.3.6.6 Setting the MMC/SD/SD HC Card Library Options
- 3.3.6.7 Setting the Alphanumeric LCD Library Options
- 3.3.6.8 Setting the Graphic Display Library Options
- 3.3.6.9 Executing an User Specified Program before Build
- 2.1.6.4 Transferring the Compiled Program to the AVR Chip after Build
- 3.3.6.11 Executing an User Specified Program after Build.

2.1.6 Obtaining an Executable Program

Obtaining an executable program requires the following steps:

1. Compiling the Project's C program modules, using the CodeVisionAVR C Compiler, and obtaining object files needed by the linker
2. Linking the object files created during compilation and obtaining a single assembler source file
3. Assembling the assembler source file, using the Atmel AVR assembler AVRASM2.

The resulting **.rom**, **.hex**, **.eep** and **.elf** files will be placed in the **Executable Files** directory.

If the **Project|Configure|After Build|Action:Program the Chip** option is enabled, then the **.elf** production file will also contain, besides the FLASH and EEPROM data, the settings for programming the lock and fuse bits.

Alternatively the lock, respectively fuse bits, can be specified in the program source using the **#pragma lock_bits**, respectively **#pragma fuses** compiler directives.

The object files, including the **.cof** COFF object file used for debugging, will be placed in the **Object Files** directory.

The **.asm**, **.lst** and **.map** files will be placed in the **List Files** directory.

Various files created by the linker during the **Build** process will be placed in the **Linker Files** directory.

The **Executable Files**, **Object Files**, **List Files** and **Linker Files** directories are specified in the **Project|Configure|Files|Output** menu.

2.1.6.1 Building the Project

To build the Project you must use the **Build|Build project name** menu command or the  button of the toolbar.

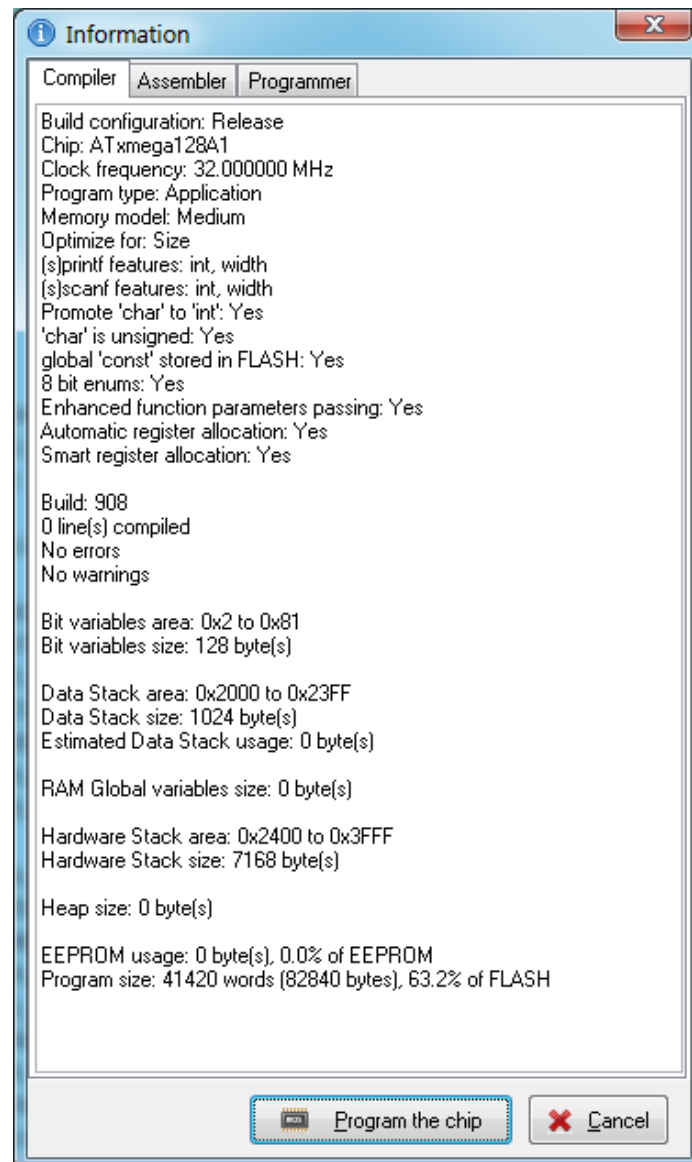
The CodeVisionAVR C Compiler will be executed, producing the object files needed by the linker. Compilation will be performed only for the program modules that were modified since the previous similar process.

If the complete recompilation of all the program modules is needed, then the **Build|Rebuild project name** menu command must be used.

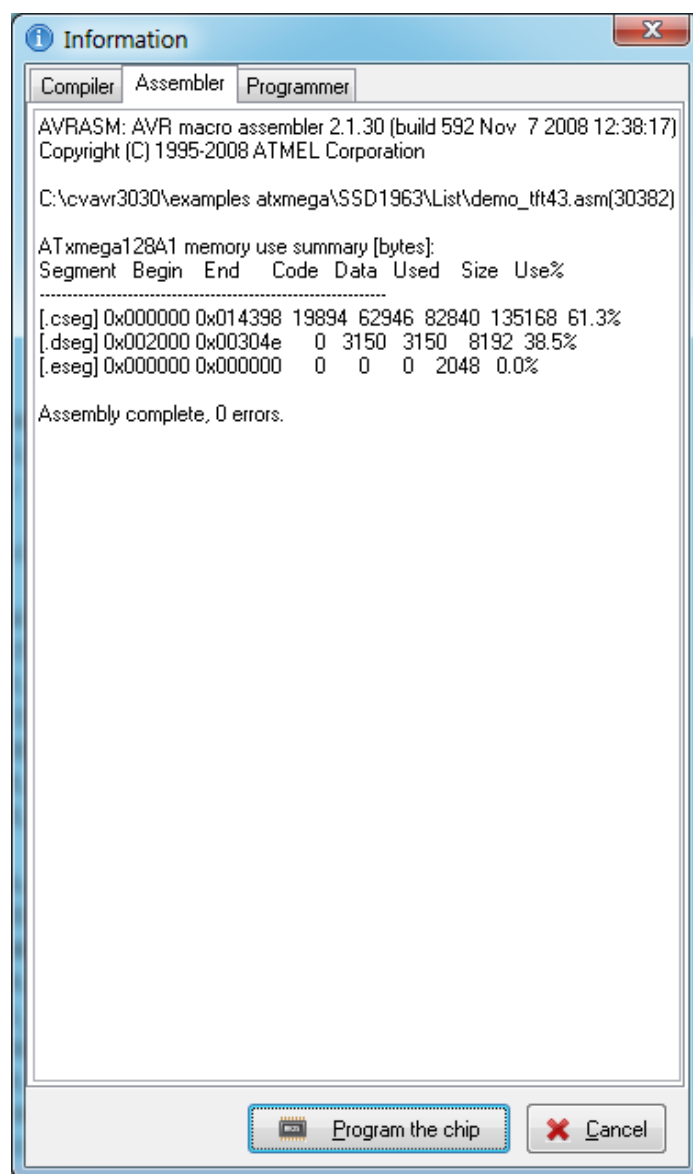
After successful compilation the object files will be linked and an assembly .asm file will be produced. If no compilation or linking errors were encountered, then the Atmel AVR assembler AVRASM2 will be executed, obtaining the output file types specified in **Project|Configure|C Compiler|Code generation|File Output Formats**.

Eventual compilation errors and/or warnings will be listed in Atmel Studio's **Output** window.

After the build process is completed, an Information window will open showing the build results. Pressing the **Compiler** tab will display compilation results.

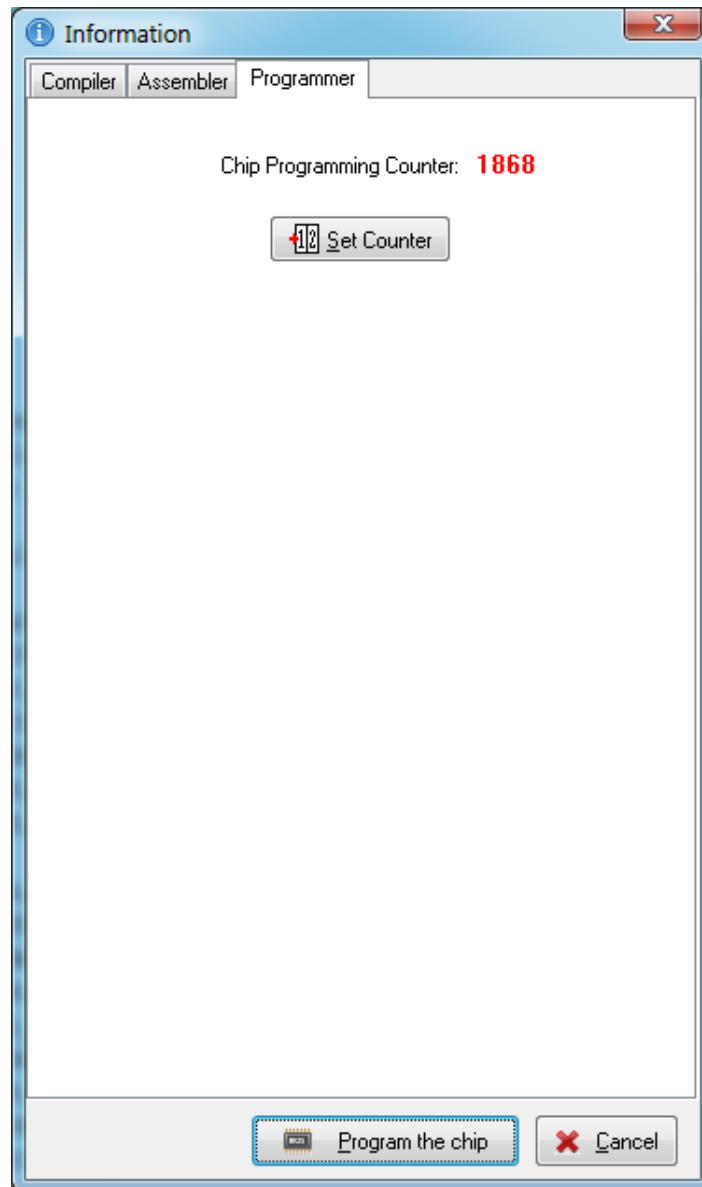


Pressing the **Assembler** tab will display assembly results.

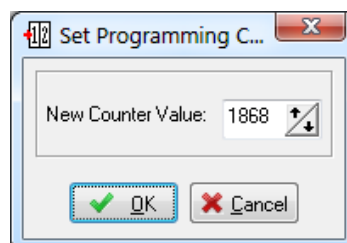


CodeVisionAVR

Pressing the **Programmer** tab will display the **Chip Programming Counter**, which shows how many times was the AVR chip programmed so far.



Pressing the **Set Counter** button will open the **Set Programming Counter** window:



This dialog window allows setting the new **Chip Programming Counter** value. Pressing the **Program the chip** button allows automatic programming of the AVR chip after successful build. Pressing **Cancel** will disable automatic programming.

The Information window for the last build, can be always displayed using the **Project|Build Information for project name** menu.

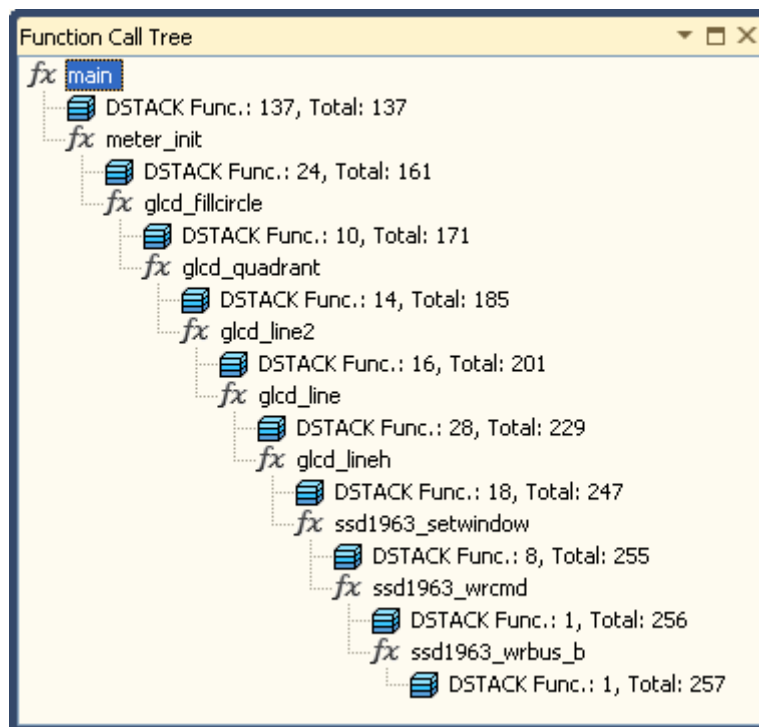
2.1.6.2 Cleaning Up the Project Output Directories

The various files created during the **Build** process can be deleted using the **Build|Clean** menu. The following **Project Output Directories** will be cleaned:

- **Object Files** directory - all files will be deleted, except the **.cof** COFF object file
- **List Files** directory - all files will be deleted, except the **.asm** and **.vec** assembly source files
- **Linker Files** directory – all files will be deleted.

2.1.6.3 Using the Function Call Tree

The **Function Call Tree** window displays the function call sequence that uses the largest amount of Data Stack during program execution.



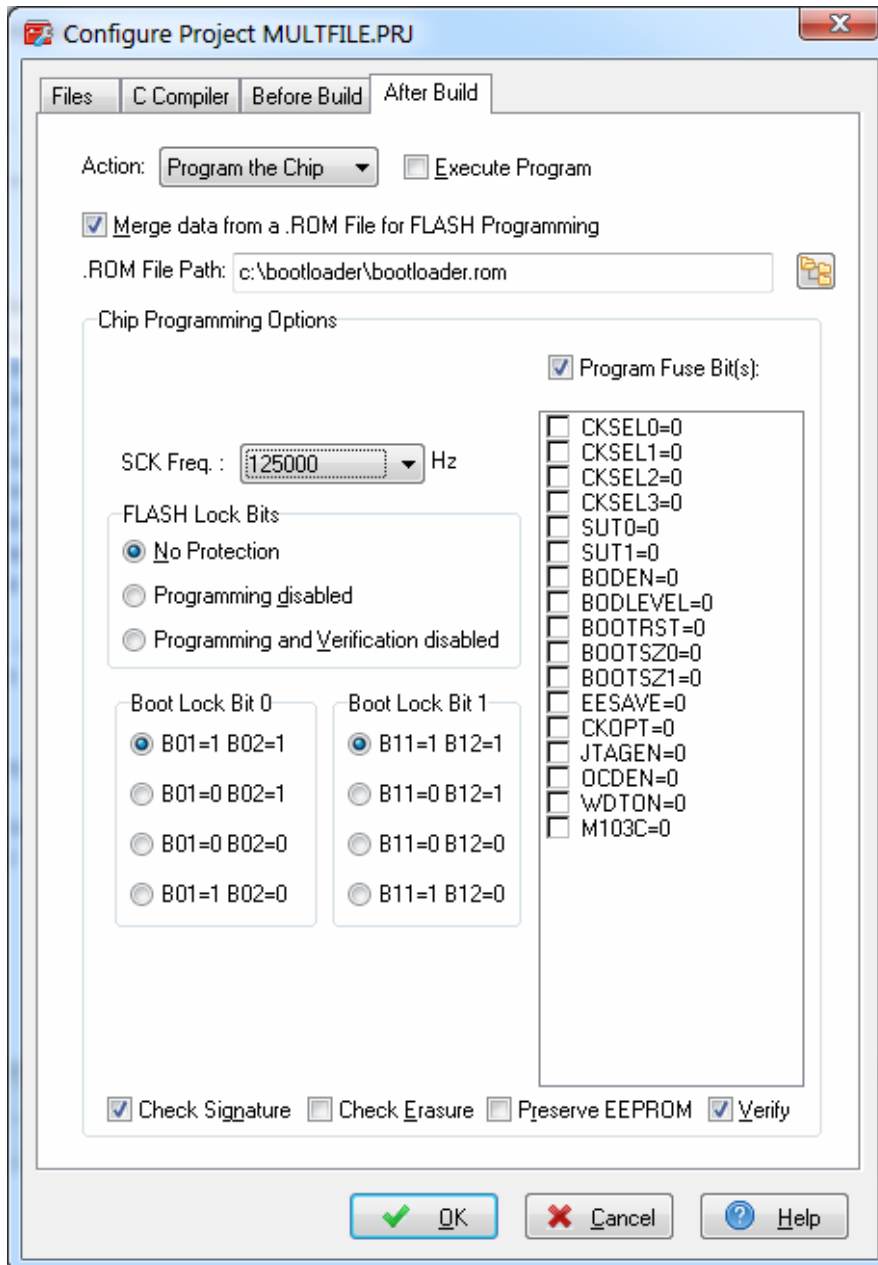
The **Function Call Tree** window is accessed using the **Project|Function Call Tree** menu command and appears after the first **Build** process of the currently opened project.

The Data Stack usage information is represented in the form of a tree with two types of nodes:

- **Function** *fx* nodes. Clicking on a function name moves the cursor to the corresponding definition in the source file.
- **DSTACK**  nodes display the data stack used by the parent function and the total level of the Data Stack when the program is executed inside the function.

2.1.6.4 Transferring the Compiled Program to the AVR Chip after Build

This option is available by invoking the **Project|Configure project name** menu command and selecting the **After Build** tab in the Configure Project window.



If the **Action|Program the Chip** option is selected, then after successful compilation/assembly your program will be automatically transferred to the AVR chip using the built-in Programmer software.

The following steps are executed automatically:

- Chip erasure
- FLASH and EEPROM blank check
- FLASH programming and verification
- EEPROM programming and verification
- Fuse and Lock Bits programming

The **Merge data from a .ROM File for FLASH Programming** option, if checked, will merge in the FLASH programming buffer the contents of the .ROM file, created by the compiler after Make, with the data from the .ROM file specified in **.ROM File Path**.

This is useful, for example, when adding a boot loader executable compiled in another project, to an application program that will be programmed in the FLASH memory.

You can select the type of the chip you wish to program using the **Chip** combo box.

The SCK clock frequency used for In-System Programming with the STK500, AVRISP or AVRISP MkII can be specified using the **SCK Freq.** listbox. This frequency must not exceed $\frac{1}{4}$ of the chip's clock frequency.

If the chip you have selected has Fuse Bit(s) that may be programmed, then a supplementary **Program Fuse Bit(s)** check box will appear.

If it is checked, then the chip's Fuse Bit(s) will be programmed after **Build**.

The Fuse Bit(s) can set various chip options, which are described in the Atmel data sheets.

If a Fuse Bit(s) check box is checked, then the corresponding fuse bit will be set to 0, the fuse being considered as programmed (as per the convention from the Atmel data sheets).

If a Fuse Bits(s) check box is not checked, then the corresponding fuse bit will be set to 1, the fuse being considered as not programmed.

If you wish to protect your program from copying, you must select the corresponding option using the **FLASH Lock Bits** radio box.

If you wish to check the chip's signature before programming you must use the **Check Signature** option.

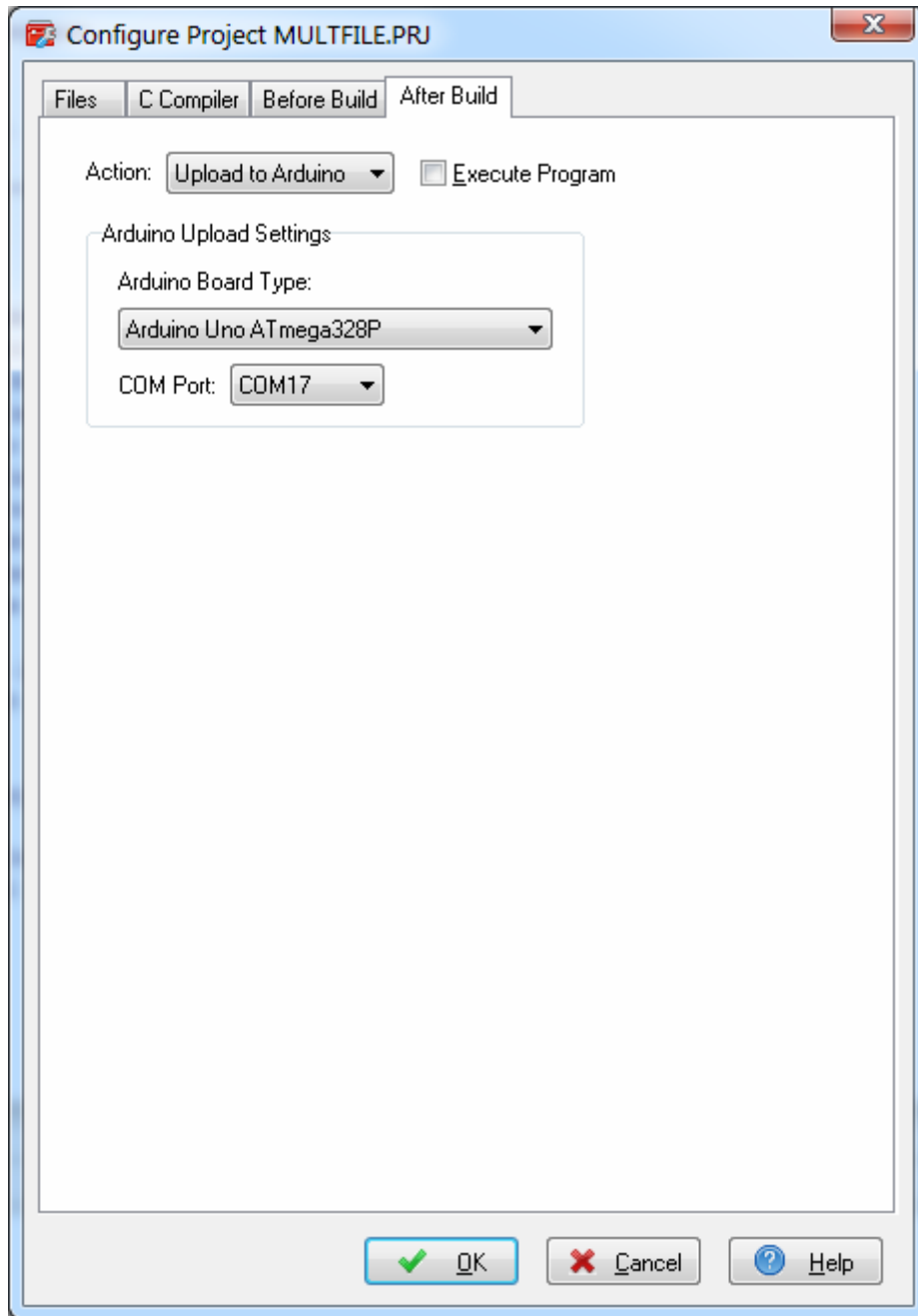
To speed up the programming process you can uncheck the **Check Erasure** check box. In this case there will be no verification of the correctness of the FLASH erasure.

The **Preserve EEPROM** checkbox allows preserving the contents of the EEPROM during chip erasure.

To speed up the programming process you can uncheck the **Verify** check box. In this case there will be no verification of the correctness of the FLASH and EEPROM programming.

CodeVisionAVR

If the project's target chip type is an ATmega8, ATmega168, ATmega328, ATmega1280 or ATmega2560, then there's also the possibility to upload the .hex FLASH contents, respectively .eep EEPROM contents, files to an Arduino compatible development board. This option is selected using **Action|Upload to Arduino**.



The above dialog window allows selecting the **Arduino Board Type** and the serial **COM Port** used for communication with the development board.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

2.1.7 Debugging the Executable Program

Once the program was successfully built, it can be debugged in source level form, using the Atmel Studio's **Debug|Start Debugging and Break** menu command, the  toolbar button or by pressing the **Alt+F5** keys.

If the source files were modified since the last **Build**, a **Rebuild** will be automatically performed, before the debugging session will be started.

Atmel Studio uses the **.cof** object file produced by CodeVisionAVR for debugging.

Therefore it is important that this file is created, by selecting in the **Project|Configure|C Compiler|Code generation|File Output Formats** list box the following formats for the files generated by the compiler: **COFF, ROM, Intel HEX and EEP**.

The following commands can be used when debugging:

- **Debug|Step Into**, F11 key or  toolbar button to execute one instruction
- **Debug|Step Over**, F10 key or  toolbar button to execute one instruction.
If the instruction contains a function call, the function is executed as well.
- **Debug|Step Out**, Shift+F11 keys or  toolbar button to continue execution until the current function has completed
- **Debug|Run To Cursor**, Ctrl+F10 keys or  toolbar button to continue execution until the current cursor position in the source file or disassembly view is reached
- **Debug|Reset**, Shift+F5 keys or  toolbar button to restart program execution from the beginning
- **Debug|Restart** or  toolbar button to restart the debugger and reload the debugged program
- **Debug|Toggle Breakpoint** or F9 key to set a breakpoint at the current cursor position in the C source file or disassembly view
- **Debug|New Breakpoint|Break at Function** to set a breakpoint at the beginning of a particular function
- **Debug|Delete All Breakpoints** or Ctrl+Shift+F9 keys to delete all the breakpoints that were set
- **Debug|Disable All Breakpoints** to temporarily disable all the breakpoints that were set
- **Debug|Enable All Breakpoints** to re-enable all the breakpoints that were set
- **Debug|Continue**, F5 key or  toolbar button to continue execution after a breakpoint
- **Debug|Break All**, Ctrl+F5 keys or  toolbar button to stop program execution
- **Debug|Windows** allow displaying specific windows for watching variables, processor registers, I/O and peripheral registers, memory contents, code disassembly, etc.

To obtain more information about using the debugger, please consult the Atmel Studio Help.

Note: The compiler applies some optimization techniques that may prevent correct debugging of the executable program.

Therefore it is recommended to select the **Project|Configure|C Compiler|Code generation|Optimize for: Speed** option for code debugging.

If the program fits in the chip's FLASH, this option must be left enabled for **Release** too, as the program will execute faster this way.

2.2 The Tools Menu

The CodeVisionAVR extension for Atmel Studio adds several useful programs to the **Tools** menu and toolbar.

2.2.1 The CodeWizardAVR Automatic Program Generator

The CodeWizardAVR Automatic Program Generator allows you to easily write all the code needed for implementing the following functions:

- External memory access setup
- Chip reset source identification
- Input/Output Port initialization
- External Interrupts initialization
- Timers/Counters initialization
- Watchdog Timer initialization
- UART initialization and interrupt driven buffered serial communication
- Analog Comparator initialization
- ADC initialization
- SPI Interface initialization
- Bit-Banged I²C Bus, LM75 Temperature Sensor, DS1621 Thermometer/Thermostat, PCF8563, PCF8583, DS1302, DS1307 and DS3231 Real Time Clocks initialization
- TWI, LM75 Temperature Sensor, DS1621 Thermometer/Thermostat, PCF8563, PCF8583, DS1302, DS1307, DS3231 Real Time Clocks, BMP085, BMP180, MS5611-01BA Pressure Sensors initialization
- 1 Wire Bus and DS1820/DS18S20 Temperature Sensors initialization
- Alphanumeric LCD module initialization
- Graphic display module initialization
- Resistive touchscreen controller initialization.

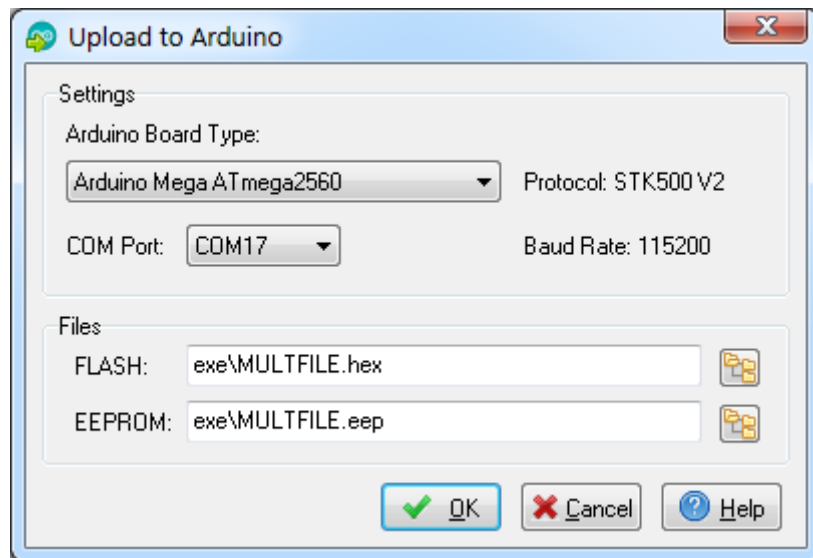
The Automatic Program Generator is invoked using the **Tools|CodeWizardAVR** menu command or by clicking on the Tools  toolbar button.

More details about using CodeWizardAVR can be found in **Chapter 6** of the User Manual.

2.2.2 The Arduino Program Uploader

The CodeVisionAVR extension for Atmel Studio has a built-in **Arduino Program Uploader**, that lets you easily transfer your compiled program to the microcontroller located on an Arduino compatible development board for testing.

The uploader is executed by selecting the **Tools|Upload to Arduino** menu command or by pressing the  button on the Atmel Studio Tools toolbar.



The **Settings** group box allows selecting the **Arduino Board Type** and the serial **COM Port** used for communication with the development board.

The **Files** group box allows specifying the **.hex** FLASH and **.eep**, EEPROM contents files to be uploaded to the AVR microcontroller.

Pressing the  button will open a dialog window, allowing to select the appropriate file.

Pressing the **OK** button will start the uploading process.

The **Arduino Uploader** window can be closed using the **Cancel** button.

The **Help** button will invoke the corresponding Help topic.

Note: The boot loaders from some Arduino boards don't support EEPROM programming, therefore the **Files|EEPROM** option is disabled in such cases.

2.2.3 The LCD Vision Font and Image Editor/Converter

LCD Vision is an application designed for creating, editing font and image data, and exporting it in form of C source code, compatible with the CodeVisionAVR **Graphic LCD Functions**.

Fonts can be created from scratch or imported from the installed system fonts.

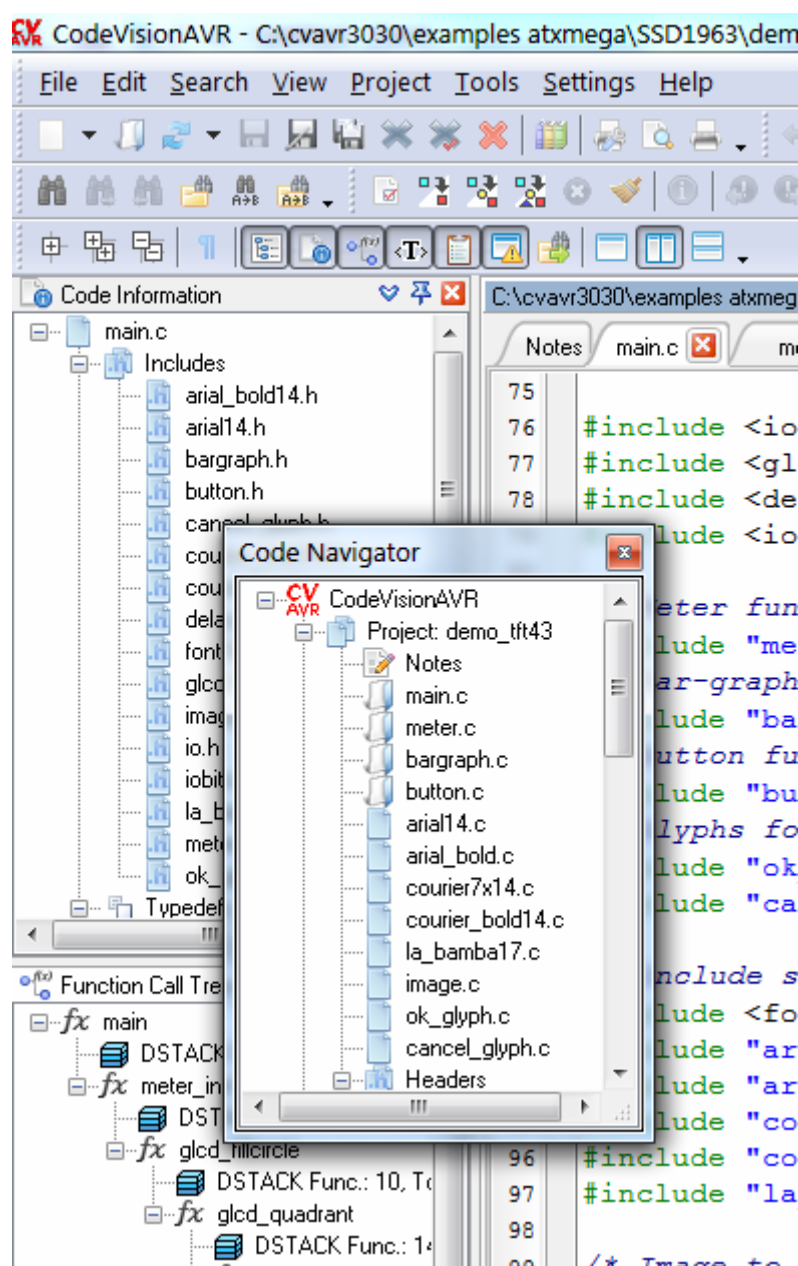
Images can be also created from scratch or imported from popular graphics formats like: BMP, JPG, GIF, PNG, ICO, WMF, EMF.

LCD Vision is invoked using the Atmel Studio **Tools|LCD Vision** menu command or the  button on the Tools toolbar.

Note: The LCD Vision editor/converter can be used only with an Advanced CodeVisionAVR license.

CodeVisionAVR

In order to undock a window, its top bar must be clicked with the left mouse button and keeping the button pressed, dragged to any suitable position on the desktop.



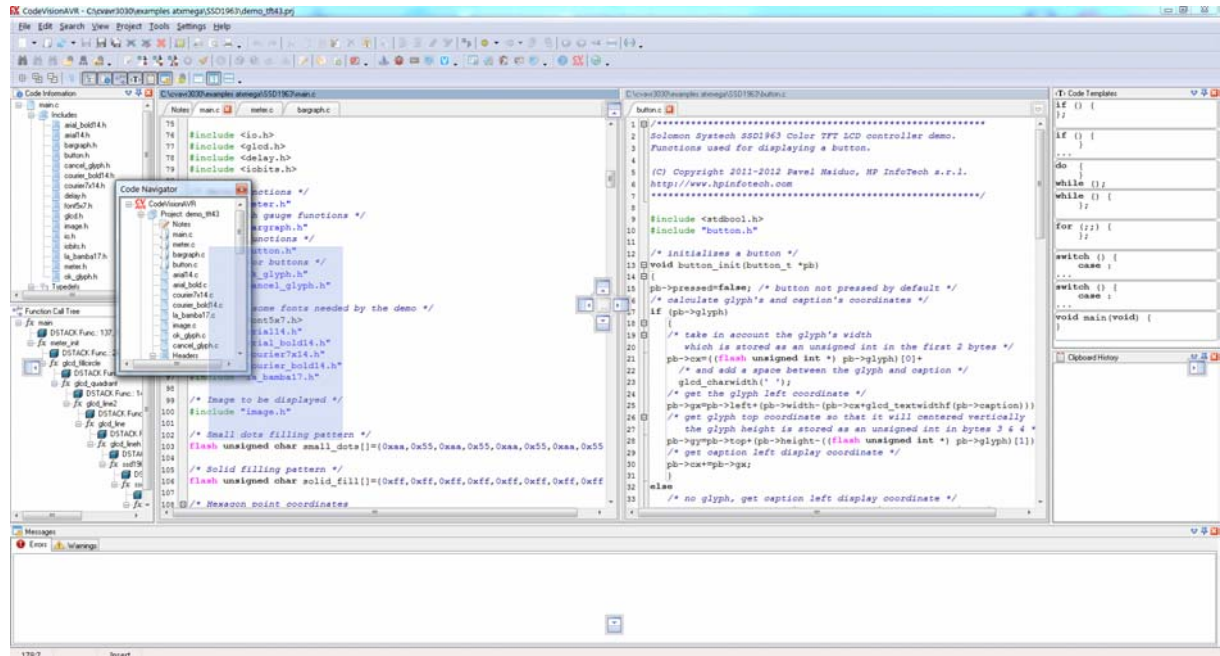
The window can be resized by dragging its margins and corners with the left mouse button pressed.

CodeVisionAVR

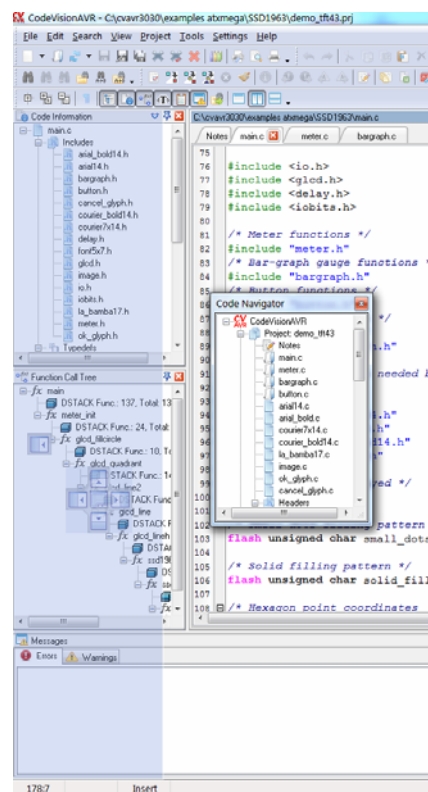
An undocked window can be docked to any position in the main application window or even to another docked window.

In order to dock the window, its top bar must be dragged, keeping the left mouse button pressed.

The possible dock locations of the window are outlined with special docking markers like in the picture below:



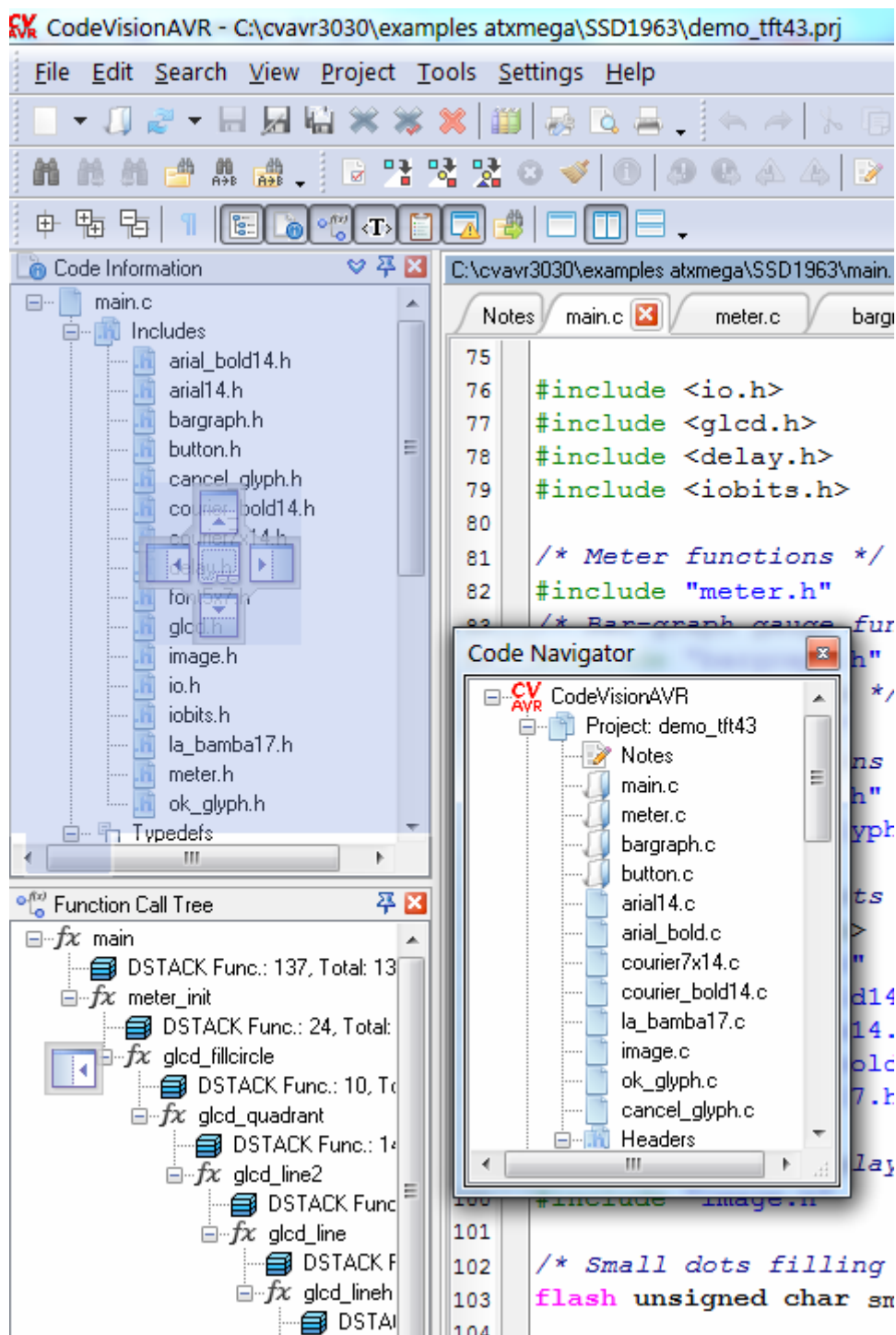
When the mouse cursor arrives on one of the docking markers, the future docking position will be outlined:



After the mouse button will be released, the window will become docked.

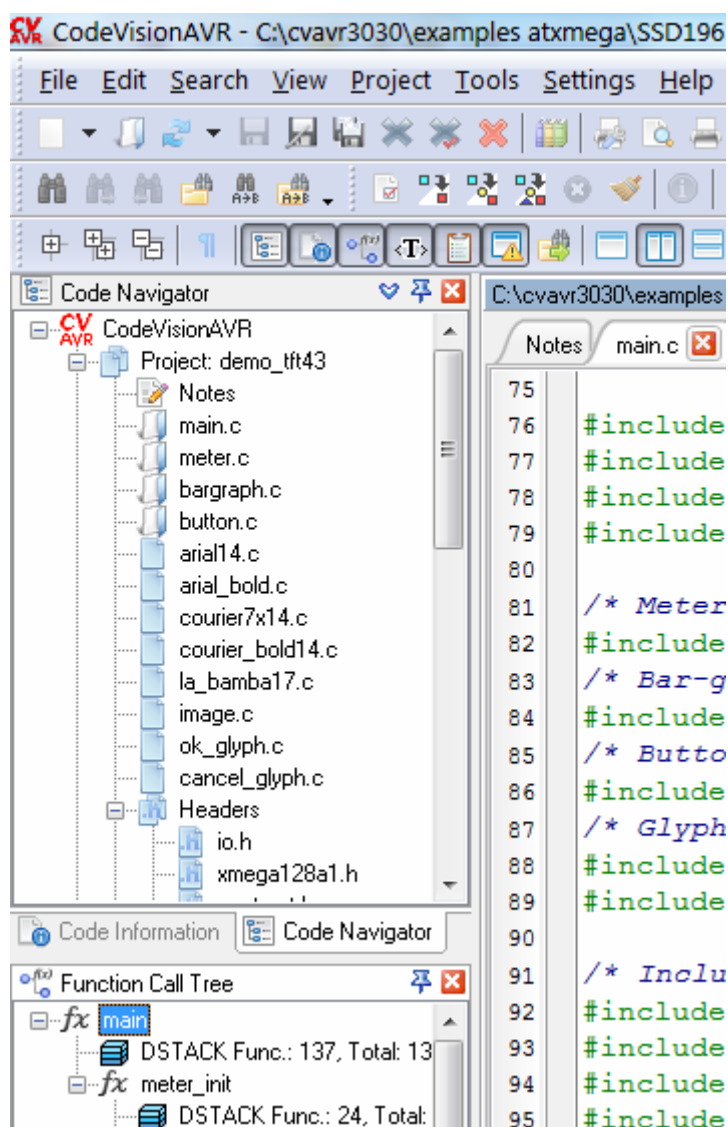
CodeVisionAVR

If the window is desired to be docked to another docked window, the future position of the window will be that of a tabbed page, like in the picture below:



CodeVisionAVR

Once docked, the window will become a tabbed page:



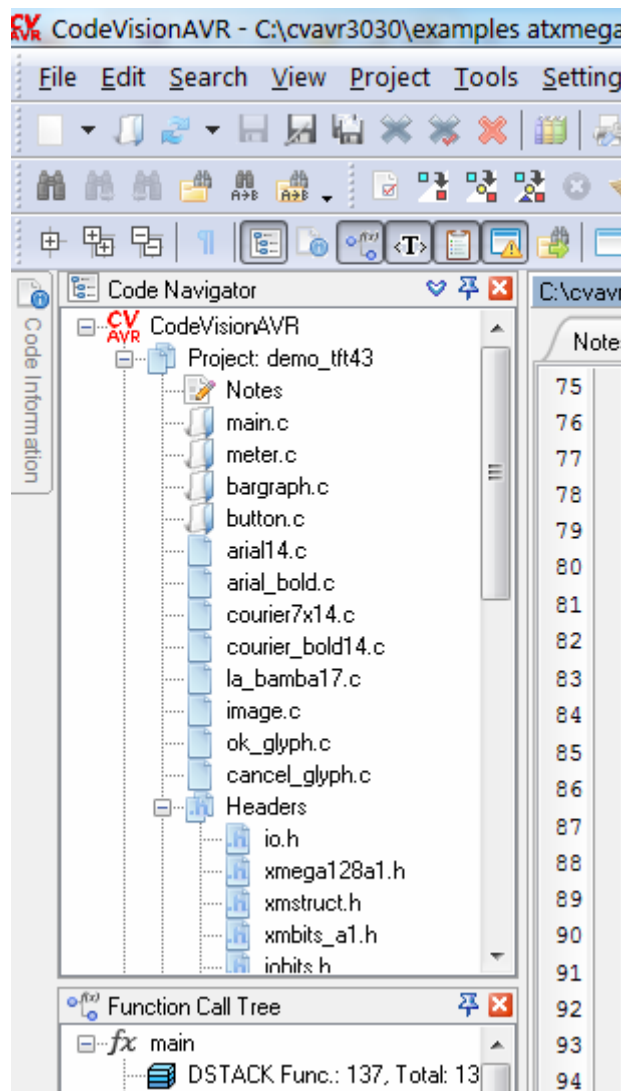
To undock a single tabbed page, the bottom tab must be dragged with the mouse.

CodeVisionAVR

A workspace window can be hidden by left clicking on its  icon, by pressing its corresponding button on the **View** toolbar or by using the **View** menu.

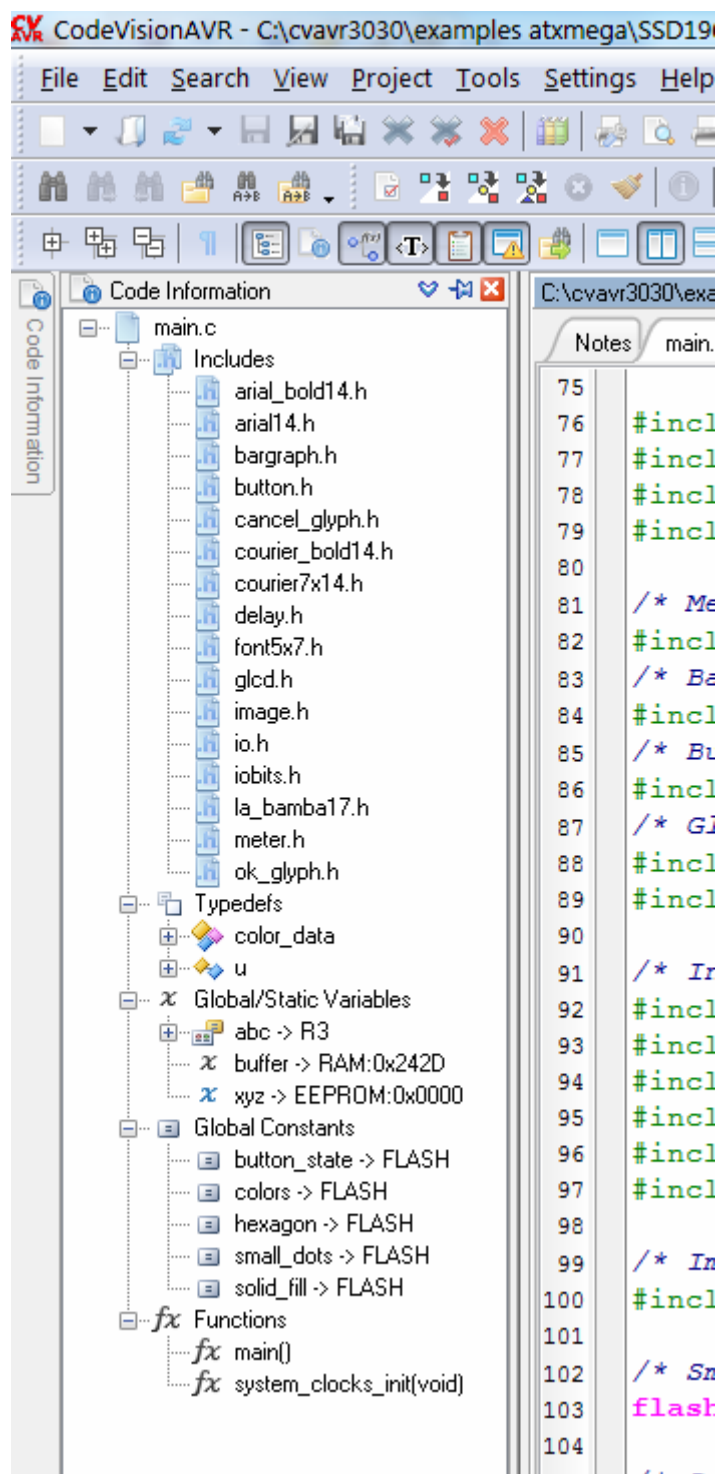
A window's corresponding button on the **View** toolbar must be pressed or the **View** menu must be used in order to make a hidden window visible again.

Clicking on the  icon will make the docked window temporarily hidden, its position will be displayed by a vertical bar located on the left or right of the docking site:



CodeVisionAVR

If the user will place the mouse cursor on the vertical bar, the hidden window will be displayed for a short amount of time

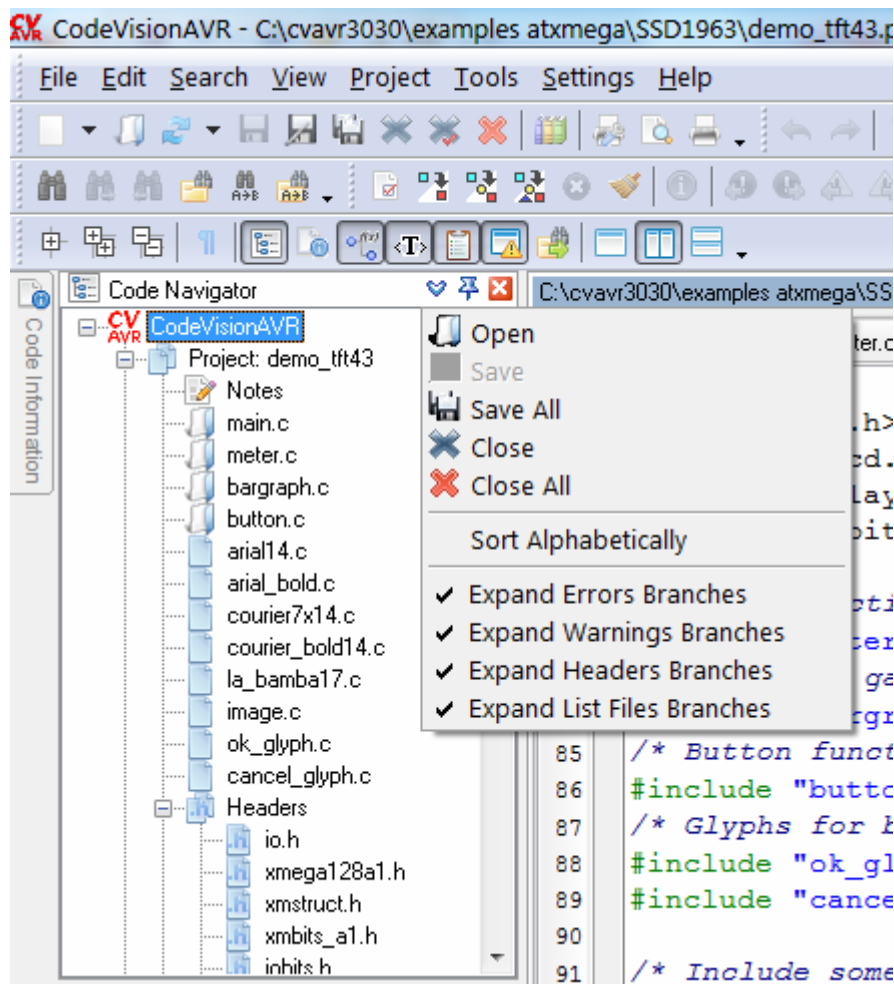


and then will become hidden again.

In order to lock the temporarily displayed window in position, the user must click on the  icon.

CodeVisionAVR

Clicking with the mouse on the  window icon will open a specific drop down menu:

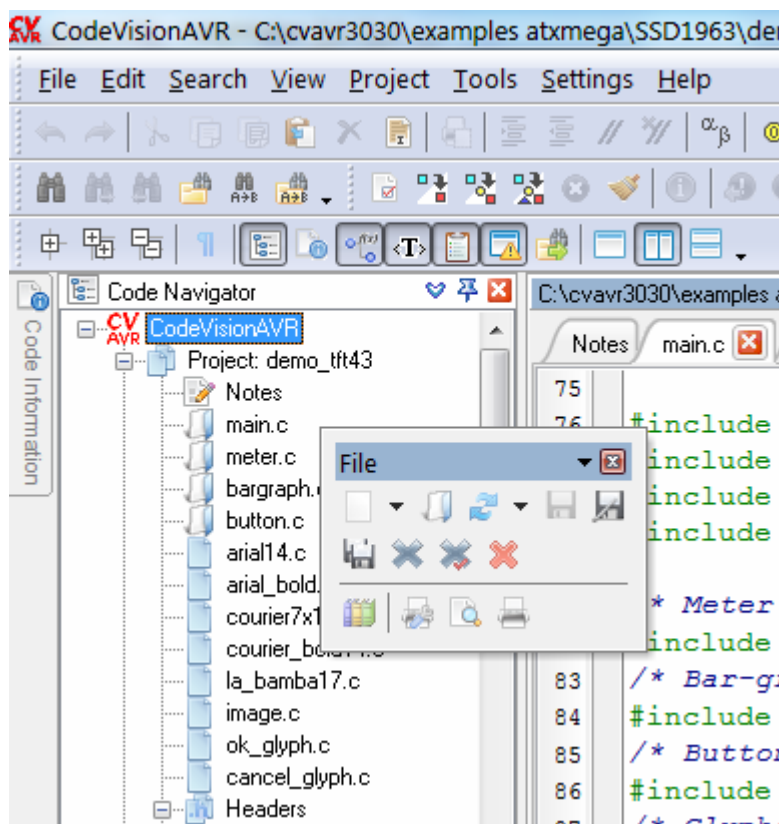


Alternatively this menu can be also invoked by right clicking with the mouse inside the window.

CodeVisionAVR

The menu toolbars can be placed to any position, by clicking with the left mouse button on the handle and dragging it, while keeping the button pressed.

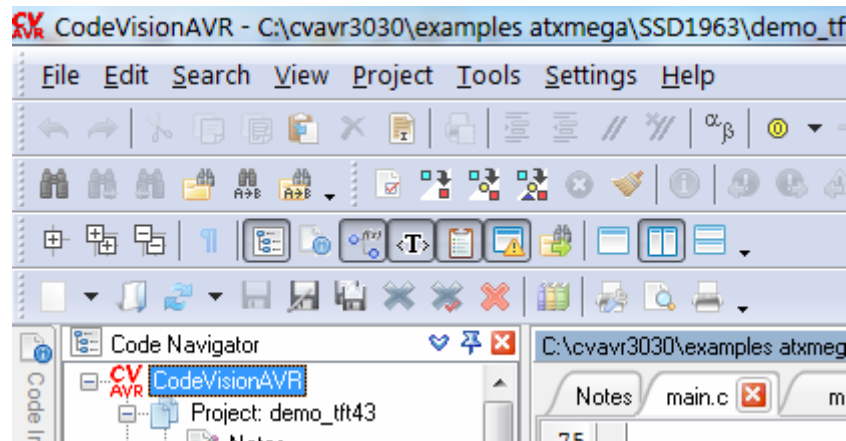
If the toolbar is moved outside the menu, it will become floating, like in the following picture:



and can be placed anywhere on the desktop.

CodeVisionAVR

The toolbar can be docked to a new position:

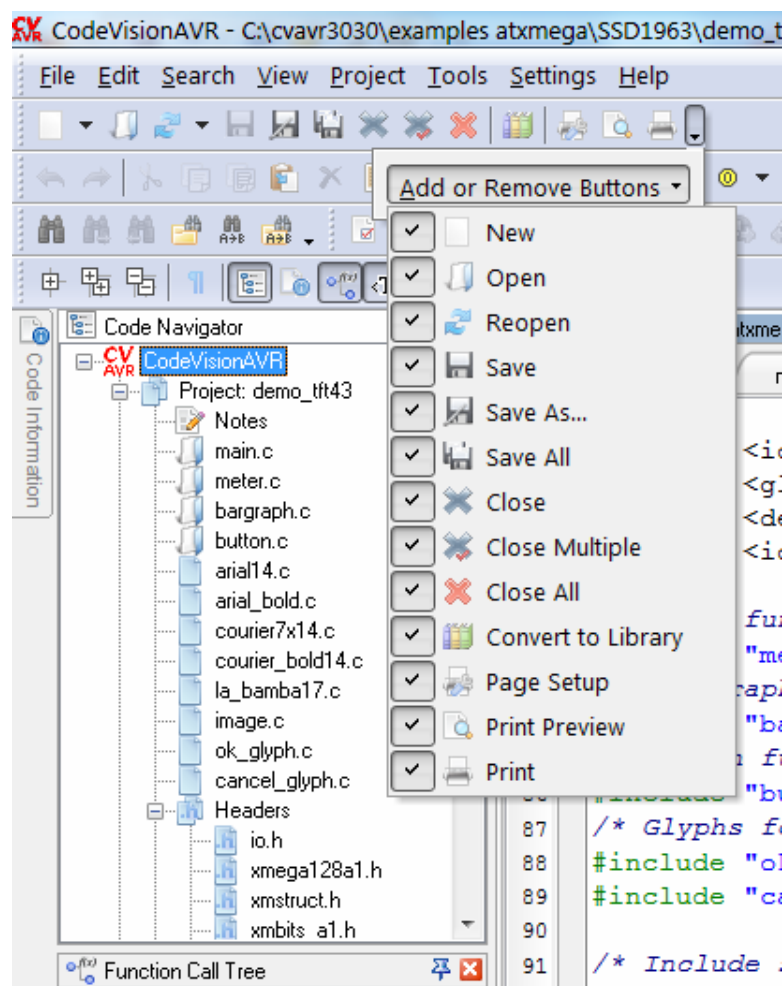


An undocked toolbar can be hidden by clicking on its  icon.

Alternatively the toolbars' visible state can be changed by using the **View|Toolbars** menu.

The buttons on a toolbar can be individually enabled or disabled by left clicking with the mouse on the  button.

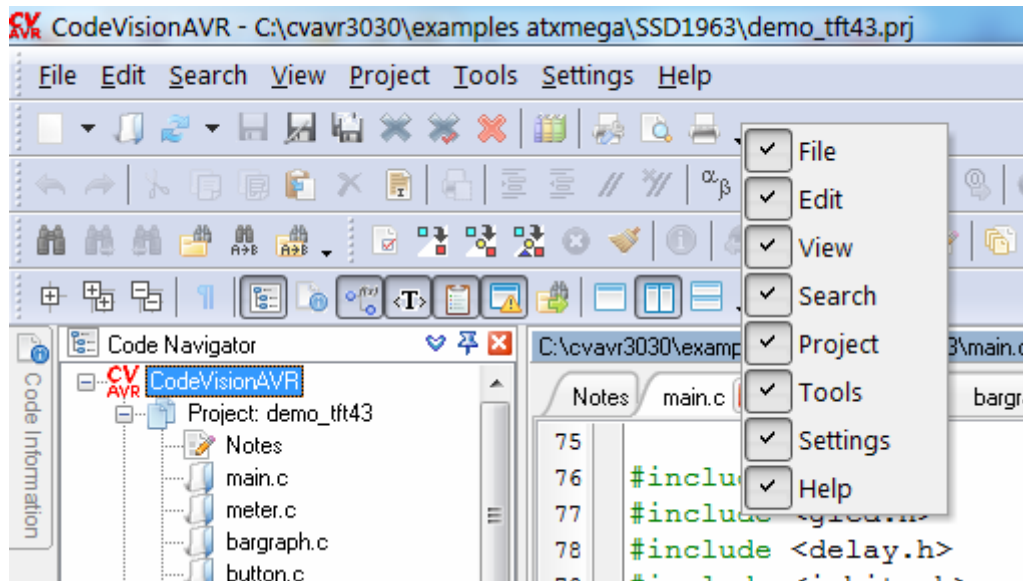
A drop-down menu will open for this purpose:



CodeVisionAVR

The visibility state of the toolbars can be also individually modified by right clicking with the mouse on the  button.

A drop-down menu will open for this purpose:



All the workspace layout will be automatically saved at program exit and restored back on the next launch.

The Editor uses a tabbed multiple window interface.

The following key shortcuts are available:

- Ctrl+TAB - switch to the next editor tabbed window
- Ctrl+Shift+TAB - switch to the previous editor tabbed window
- Ctrl+W - close the current editor tabbed window.

The current editor tabbed window can be also closed by clicking on the  icon located on the top right of the tabbed control.

Tabbed editor windows can be also undocked, dragged and then docked in any desired position, like it was exemplified above, allowing to create a fully customized workspace layout, that suits the user's specific needs.

3.2 Working with Files

Using the CodeVisionAVR IDE you can view and edit any text file used or produced by the C compiler or assembler.

3.2.1 Creating a New File

You can create a new source file using the **File|New|Source File** menu command, by pressing the **Ctrl+N** keys or the  and  buttons on the toolbar.

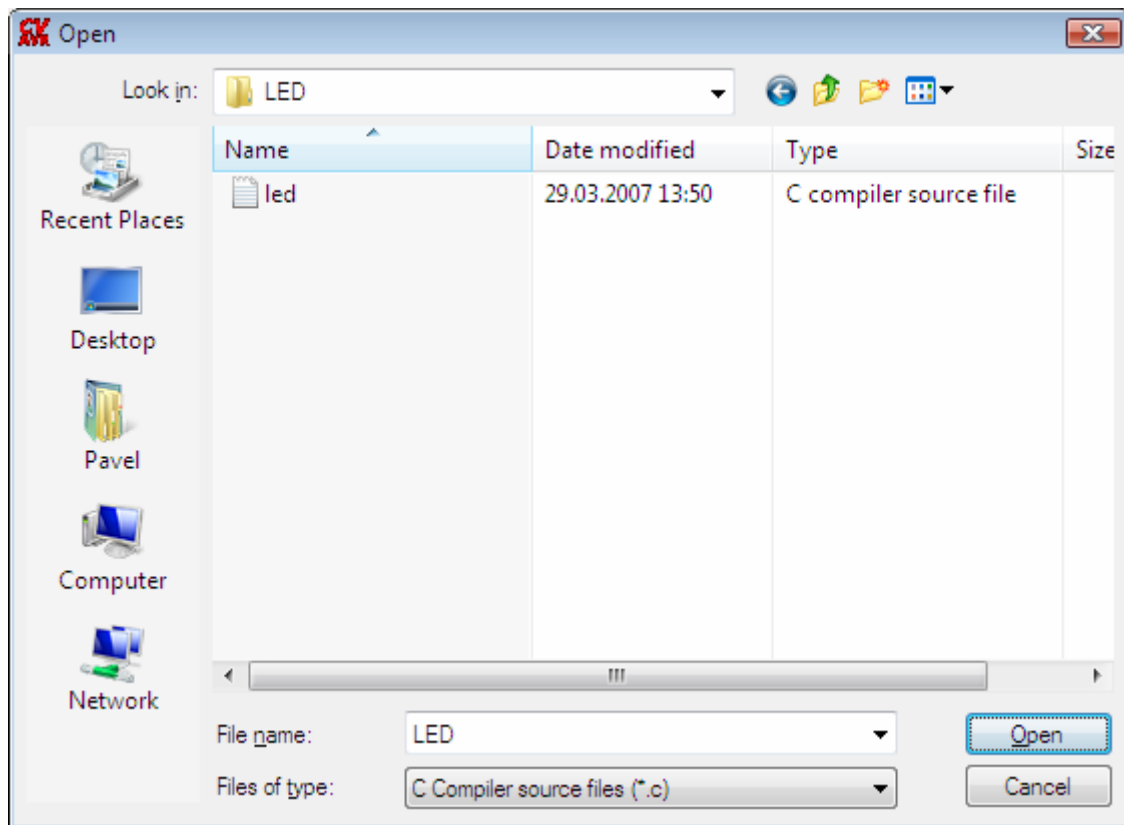
A new editor window appears for the newly created file.

The new file has the name **untitled.c**. You can save this file under a new name using the **File|Save As** menu command or the  toolbar button.

3.2.2 Opening an Existing File

You can open an existing file using the **File|Open** menu command, by pressing the **Ctrl+O** keys or the  button on the toolbar.

An **Open** dialog window appears.



You must select the name and type of file you wish to open.
By pressing the **Open** button you will open the file in a new editor window.

3.2.3 Files History

The CodeVisionAVR IDE keeps a history of the opened files.
The most recent eight files that were used can be reopened using the **File|Reopen** menu command or the  toolbar button.

3.2.4 Editing a File

A previously opened or a newly created file can be edited in the editor window by using the **Tab**, **Arrows**, **Backspace** and **Delete** keys.

Pressing the **Home** key moves the cursor to the start of the current text line.

Pressing the **End** key moves the cursor to the end of the current text line.

Pressing the **Ctrl+Home** keys moves the cursor to the start of the file.

Pressing the **Ctrl+End** keys moves the cursor to the end of the file.

Portions of text can be selected by dragging with the mouse.

You can copy the selected text to the clipboard by using the **Edit|Copy** menu command, by pressing the **Ctrl+C** keys or by pressing the  button on the toolbar.

By using the **Edit|Cut** menu command, by pressing the **Ctrl+X** keys or by pressing the  button on the toolbar, you can copy the selected text to the clipboard and then delete it from the file.

Text previously saved in the clipboard can be placed at the current cursor position by using the **Edit|Paste** menu command, by pressing the **Ctrl+V** keys or pressing the  button on the toolbar.

Clicking in the left margin of the editor window allows selection of a whole line of text.

Selected text can be deleted using the **Edit|Delete** menu command, by pressing the **Ctrl+Delete** keys or the  toolbar button.

Dragging and dropping with the mouse can move portions of text.

Pressing the **Ctrl+Y** keys deletes the text line where the cursor is currently positioned.

Changes in the edited text can be undone, respectively redone, by using the **Edit|Undo**, respectively **Edit|Redo**, menu commands, by pressing the **Ctrl+Z**, respectively **Shift+Ctrl+Z** keys, or by pressing the , respectively  buttons on the toolbar.

Clicking with the mouse right button in the Editor window, opens a pop-up menu that gives access to the above mentioned functions.

3.2.4.1 Searching/Replacing Text

You can find, respectively replace, portions of text in the edited file by using the **Search|Find**, respectively **Search|Replace**, menu commands, by pressing the **Ctrl+F**, respectively **Ctrl+R** keys, or by pressing the , respectively  buttons on the toolbar.

The **Search|Find Next**, respectively **Search|Find Previous**, functions can be used to find the next, respectively previous, occurrences of the search text.

The same can be achieved using the **F3**, respectively **Ctrl+F3** keys or the , respectively the , toolbar buttons.

Searching, respectively replacing, portions of text in files can be performed using the **Search|Find in Files**, respectively **Search|Replace in Files**, menu commands, by pressing the **Ctrl+Shift+F**, respectively **Ctrl+Shift+H** keys, or by pressing the , respectively  buttons on the toolbar.

These functions are also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.2 Setting Bookmarks

Bookmarks can be inserted or removed, at the line where the cursor is positioned, by using the **Edit|Toggle Bookmark** menu command, by pressing the **Shift+Ctrl+0...9** keys or the  toolbar button.

The **Edit|Jump to Bookmark** menu command, the **Ctrl+0...9** keys or the  toolbar button will position the cursor at the start of the corresponding bookmarked text line.

Jumping to the next bookmark can be achieved by using the **Edit|Jump to Next Bookmark** menu command, by pressing the **F2** key or by using the  toolbar button.

Jumping to the previous bookmark can be achieved by using the **Edit|Jump to Previous Bookmark** menu command, by pressing the **Shift+F2** keys or by using the  toolbar button.

After a jump to a bookmark was performed, the **Edit|Go Back** menu command or the  toolbar button allow to return to the previous position in the file.

The **Edit|Go Forward** menu command or the  toolbar button allow to return to the file position before the **Edit|Go Back** menu command or the  toolbar button were used.

These functions are also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.3 Jumping to a Symbol Definition or Declaration

When the editor cursor is located on a symbol name and the **Edit|Go to Definition/Declaration** menu command is performed, the **F12** key or the  toolbar button are pressed, a jump will be performed to the symbol definition or declaration located in any of the project's source files.

After a jump to the definition or declaration was performed, the **Edit|Go Back** menu command or the  toolbar button allow to return to the previous position in the edited file.

The **Edit|Go Forward** menu command or the  toolbar button allow to return to the file position before the **Edit|Go Back** menu command or the  toolbar button were used.

These functions are also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.4 Jumping to a Specific Line Number in the Edited File

You can go to a specific line number in the edited file, by using the **Edit|Go to Line** menu command, by pressing the **Ctrl+G** keys or the  toolbar button.

After a jump to a specific line was performed, the **Edit|Go Back** menu command or the  toolbar button allow to return to the previous position in the edited file.

The **Edit|Go Forward** menu command or the  toolbar button allow to return to the file position before the **Edit|Go Back** menu command or the  toolbar button were used.

These functions are also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.5 Printing a Text Selection

Portions of text can be selected by dragging with the mouse.

The **Edit|Print Selection** menu command or the  toolbar button allows the printing of the selected text.

This function is also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.6 Indenting/Unindenting a Text Selection

Portions of text can be selected by dragging with the mouse.

Selected portions of text can be indented, respectively unindented, using the **Edit|Indent Selection**, respectively **Edit|Unindent Selection**, menu commands, by pressing the **Ctrl+I**, respectively **Ctrl+U** keys or the , respectively , toolbar buttons.

These functions are also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.7 Commenting/Uncommenting a Text Selection

Portions of text can be selected by dragging with the mouse.

Selected portions of text can be commented, respectively uncommented, using the **Edit|Comment Selection**, respectively **Edit|Unindent Selection**, menu commands, by pressing the **Ctrl+[**,

respectively **Ctrl+]** keys or the , respectively , toolbar buttons.

These functions are also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

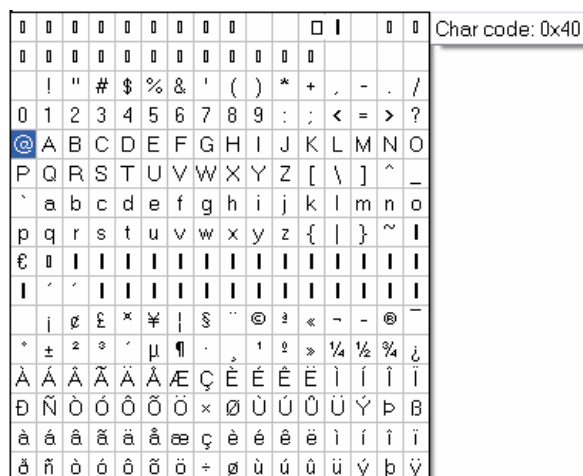
3.2.4.8 Match Braces

If the cursor is positioned before an opening, respectively after a closing, brace then selecting the **Edit|Match Braces** menu command, pressing the **Ctrl+M** keys or the  toolbar button will position the cursor after, respectively before, the corresponding matching closing, respectively opening brace. This function is also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.9 Inserting Special Characters in the Text

Special characters can be inserted in the edited text, at the cursor is position, by using the **Edit|Insert Special Characters** menu command, by pressing the **Ctrl+.** keys or the  toolbar button.

A pop-up window containing a character map grid will be displayed, allowing the user to select the appropriate character to be inserted:



This function is also available in the pop-up menu, invoked by mouse right clicking in the Editor window.

3.2.4.10 Using the Auto Complete Functions

The CodeVisionAVR Editor has the possibility to display pop-up hint windows for function parameters, structure or union members, C keywords, library functions, data types and macros.

These functions can be enabled and configured using the **Settings|Editor|Auto Complete** menu.

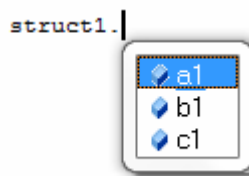
Function parameter auto complete is automatically invoked when the user types the name of a function defined in the currently edited file, followed by a '(' auto completion triggering character. A pop-up hint with parameter list will show like in the example below:



The parameter to be specified is highlighted with bold text.

Structure or union members auto complete is invoked after the user writes the name of a structure/union or pointer to structure/union followed by the '.' or '->' auto completion triggering characters.

A pop-up hint with the members list will show like in the example below:

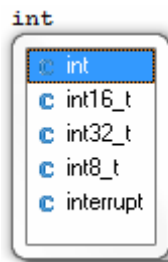


The user can select the member to be inserted in the text at the cursor position, by using the up/down arrow keys, respectively the mouse, and then pressing Enter or Space keys, respectively the left mouse button.

Pressing the Esc key will close the pop-up hint window, without inserting the member.

The structure or union members auto completion works only for global structures/unions defined in the currently edited source file and after a **Project|Compile** or **Project|Build** was performed.

C code auto complete displays a pop-up hint window with C keywords, library functions, data types, predefined macros, based on the first characters of a word typed in the Editor:



The user can select the auto completed word to be inserted in the text at the cursor position, by using the up/down arrow keys, respectively the mouse, and then pressing Enter or Space keys, respectively the left mouse button.

Pressing the Esc key will close the pop-up hint window, without inserting the auto completed word.

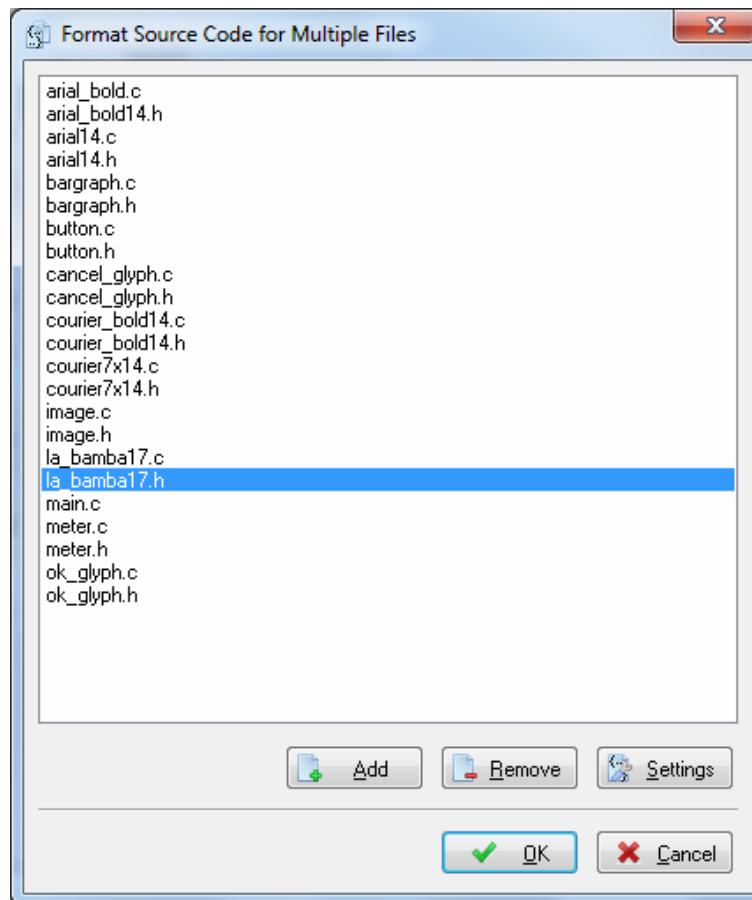
3.2.4.11 Formatting the C Source Code

The C source code of the currently edited file can be formatted to a particular style using the **Edit|Format Source Code** menu command or by pressing the  button on the Edit toolbar.

The style formatting can be applied to a selected portion of text using the **Edit|Format Source Code in Selection** menu command or by pressing the  button on the Edit toolbar.

The menu commands mentioned above, are also accessible in the pop-up menu invoked by right clicking in the editor text.

C source code formatting can be also applied to several files at the same time using the **Edit|Format Source Code for Multiple Files** menu command or by pressing the  button on the Edit toolbar. A file selection window will be displayed:



Initially the file list will contain all the .C and .H files of the currently opened project.

More files can be added by pressing the **Add** button.

By clicking in the file list, one or more files can be selected.

Note: Multiple files can be selected by holding the **Ctrl** key and clicking on the corresponding files in the list. Alternatively a range of files can be selected by pressing the **Shift** key and clicking on the first file, then pressing **Shift** and clicking on the last file.

Pressing the **Remove** button will remove the selected file(s) from the list.

The C source file formatting style can be customized by pressing the **Settings** button (see chapter 3.5.4 for a detailed description).

Pressing the **OK** button will apply the formatting to all the files in the list.

Pressing the **Cancel** button will exit, without applying source code formatting.

3.2.4.12 Using Code Folding

The CodeVisionAVR Editor has the possibility of displaying staples on the left side of code blocks delimited by the `{ }` characters.

For each code block there will be also displayed collapse  or expansion  marks on the gutter located on the left side of the Editor window. Clicking on these marks allow to individually fold or unfold blocks of code.

The **View|Toggle Fold** menu and the  toolbar button allow to collapse/expand the block of code where the cursor is located.

The **View|Expand All Folds** menu and the  toolbar button allow to expand all folded blocks of code.

The **View|Collapse All Folds** menu and the  toolbar button allow to collapse all blocks of code delimited by the `{ }` characters.

These commands are also available in the pop-up menu that is invoked by right clicking with the mouse in the Editor window.

If the **Settings|Editor|General|Visual Aids|Save Folded Lines** option is enabled, the folded/unfolded state of the code blocks is saved when the file is closed and it will be restored back, when the file is opened again.

3.2.5 Saving a File

The currently edited file can be saved by using the **File|Save** menu command, by pressing the **Ctrl+S** keys or by pressing the  button on the toolbar.

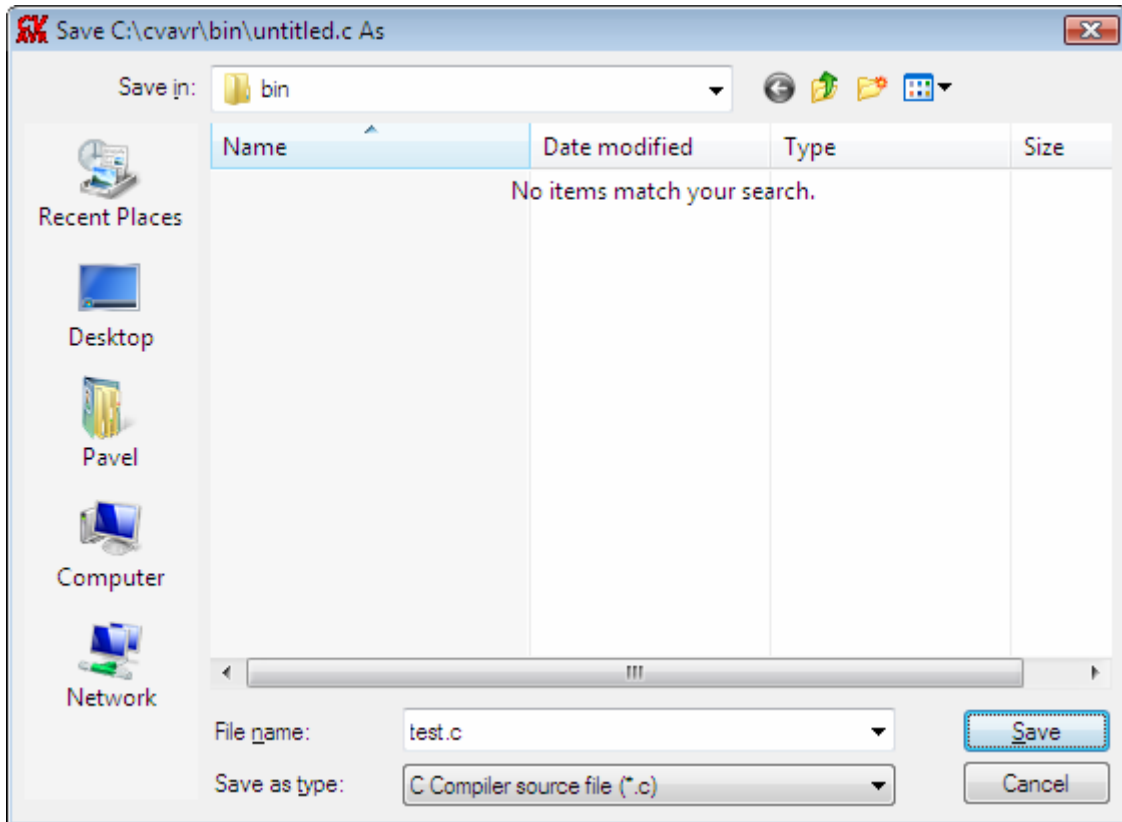
When saving, the Editor will create a backup file with a `~` character appended to the extension.

All currently opened files can be saved using the **File|Save All** menu command, by pressing the **Ctrl+Shift+S** keys or the  toolbar button.

3.2.6 Renaming a File

The currently edited file can be saved under a new name by using the **File|Save As** menu command or the  toolbar button.

A **Save As** dialog window will open.



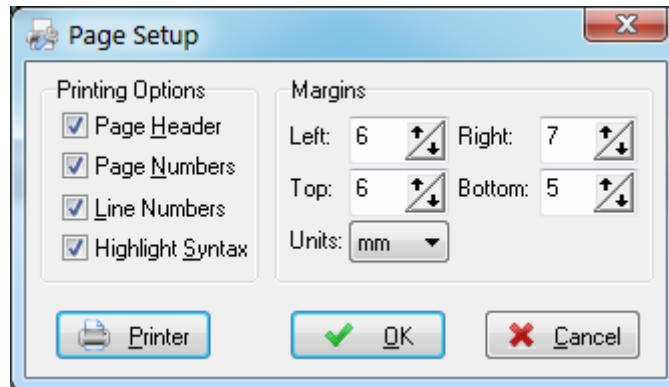
You will have the possibility to specify the new name and type of the file, and eventually its new location.

3.2.7 Printing a File

You can print the current file using the **File|Print** menu command or by pressing the  button on the toolbar.

The contents of the file will be printed to the Windows default printer.

The paper margins used when printing can be set using the **File|Page Setup** menu command or the  toolbar button, which opens the **Page Setup** dialog window.



The units used when setting the paper margins are specified using the **Units** list box.

The printer can be configured by pressing the **Printer** button in this dialog window.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

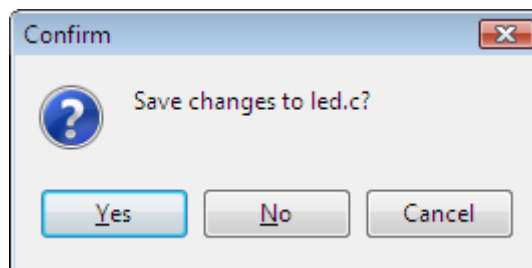
The print result can be previewed using the **File|Print Preview** menu command or by pressing the  toolbar button.

3.2.8 Closing a File

You can quit editing the current file by using the **File|Close** menu command, the **Ctrl+F4** shortcut or the  toolbar button.

The current editor tabbed window can be also closed by clicking on the  icon located on the top right of the tabbed control.

If the file was modified, and wasn't saved yet, you will be prompted if you want to do that.



Pressing **Yes** will save changes and close the file.

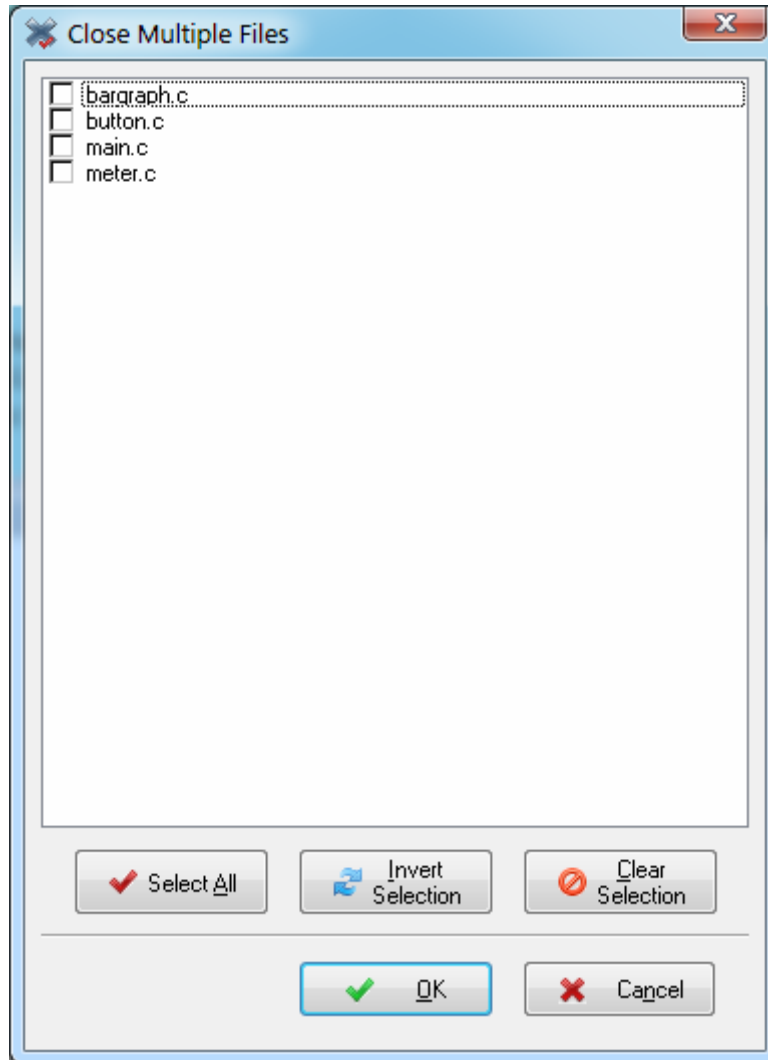
Pressing **No** will close the file without saving the changes.

Pressing **Cancel** will disable the file closing process.

3.2.9 Closing Multiple Files

Closing several files can be performed using the **File|Close Multiple** menu command or the  toolbar button.

A dialog window, which lists all the opened files, will open for this purpose:



Files to be closed can be selected by checking the appropriate check boxes.

All the listed files can be selected using the **Select All** button.

The state of the check boxes can be reversed using the **Invert Selection** button.

The **Clear Selection** button can be used to un-check all the check boxes.

Pressing the **OK** button will close all the selected files from the list.

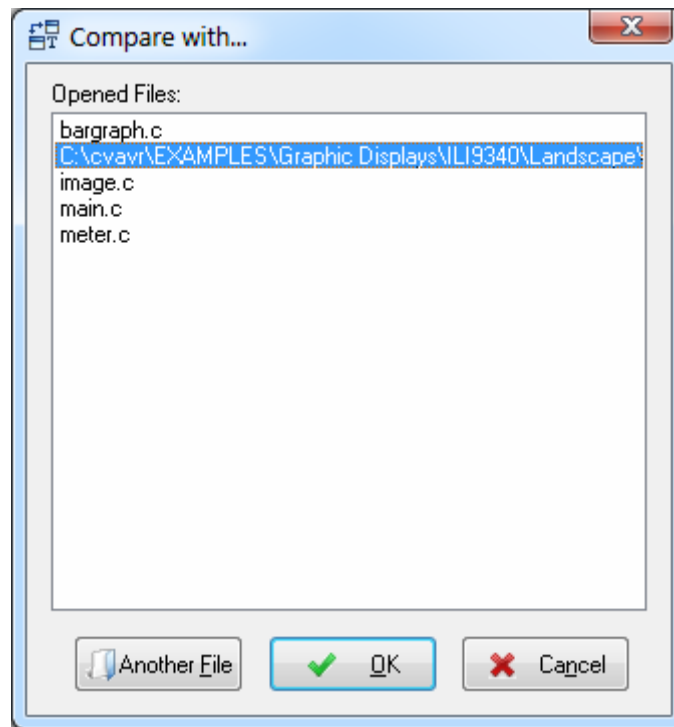
Pressing the **Cancel** button will close the dialog window, without closing any file.

3.2.10 Comparing Files

The contents of two text files, opened in the Editor, can be compared by executing the **Edit|Compare Files** menu command or by pressing the  toolbar button on the toolbar.

This function can be also invoked by right clicking in the Editor window of the currently edited file and selecting the **Compare Files** option in the pop-up menu.

A dialog window will open, allowing the user to select the second file to be compared with:



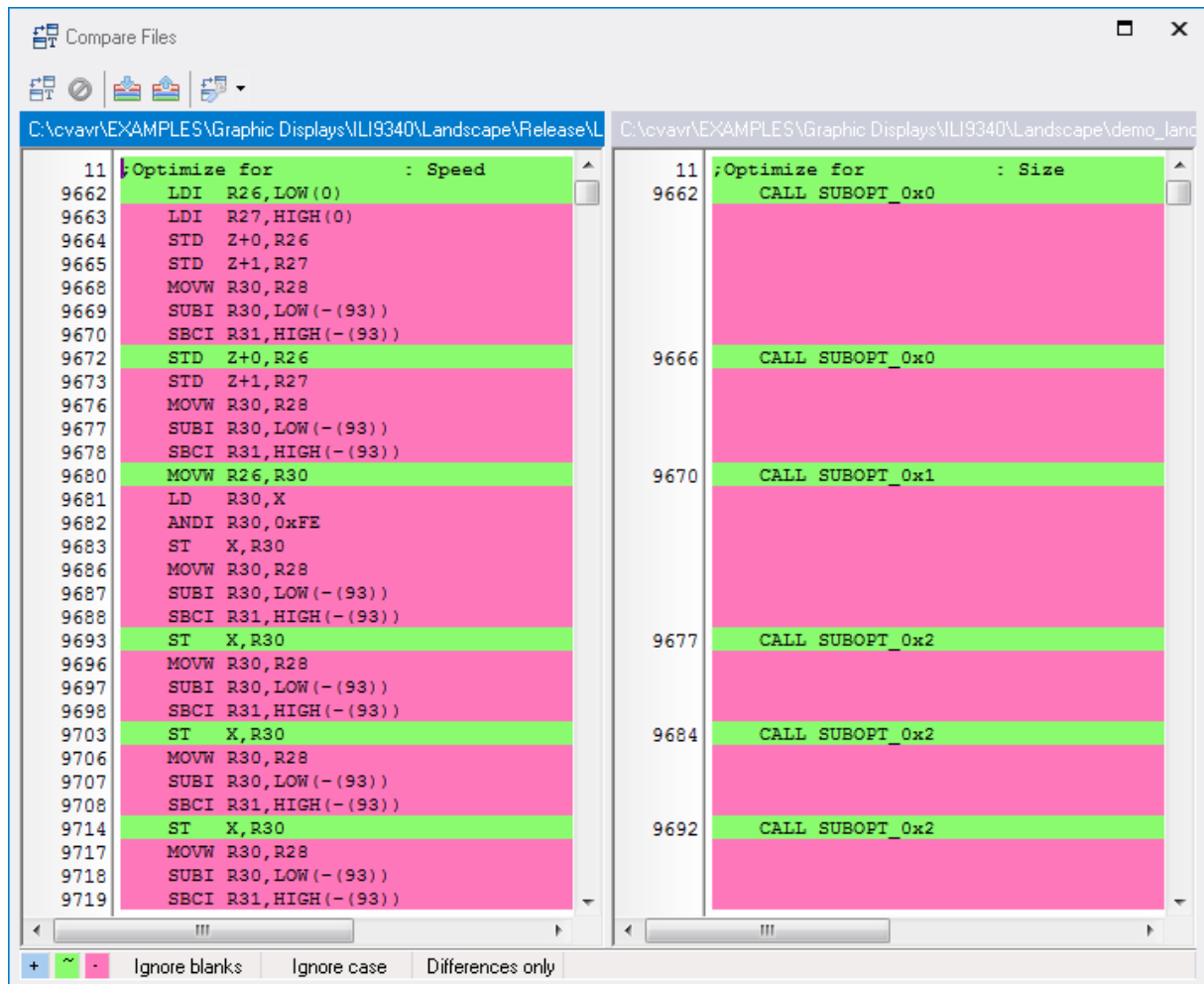
The second file can be one of the already opened in the Editor or the user has the option to open a file by pressing the **Another File** button.

The file selection must be confirmed by pressing the **Ok** button.

The comparison action can be canceled by clicking on the **Cancel** button.

CodeVisionAVR

Once the two files to be compared were selected, their contents is displayed in a new window, the differences being highlighted with special colors.



If a file is changed in the editor, a * character is appended to its path, displayed in the **Compare Files** window.

The user has then the possibility to repeat the comparison process by pressing the  button.

This process can be always aborted by pressing the  button.

Pressing the ,  respectively, toolbar buttons allows to position the cursor to the next, respectively previous, text difference.

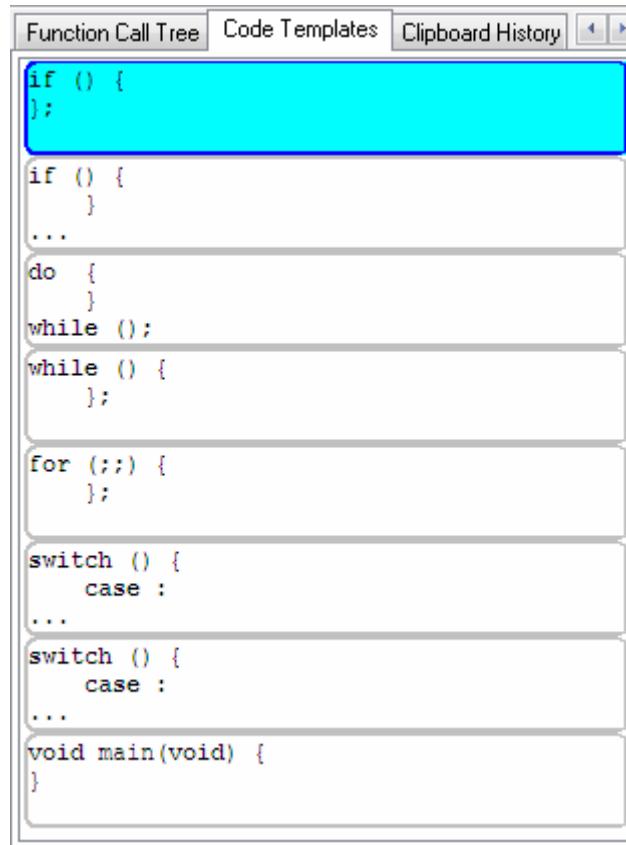
Text comparison options can be specified by pressing the  toolbar button:

- **Ignore Blanks**
- **Ignore Case**
- **Show Differences Only.**

The  toolbar button also allows to select the colors used for highlighting the text differences.

3.2.11 Using the Code Templates

The **Code Templates** window allows easy adding most often used code sequences to the currently edited file.



This is achieved by clicking on the desired code sequence in the **Code Templates** window and then dragging and dropping it to the appropriate position in the Editor window.

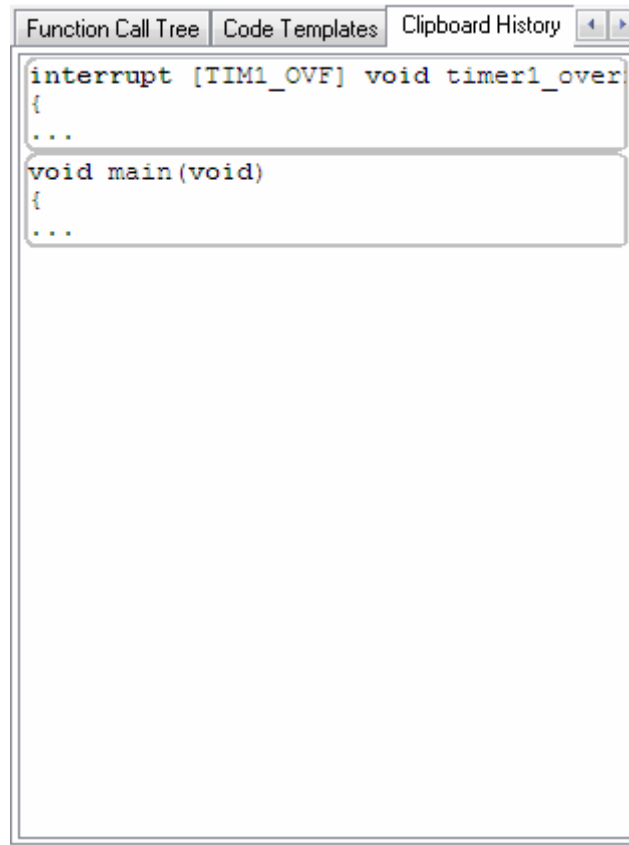
New code templates can be added to the list by dragging and dropping a text selection from the Editor window to the **Code Templates** window.

By right clicking in the **Code Templates** window you can open a pop-up menu with the following choices:

- **Copy to the Edit Window** the currently selected code template
- **Paste** a text fragment from the clipboard to the **Code Templates** window
- **Move Up** in the list the currently selected code template
- **Move Down** in the list the currently selected code template
- **Delete** the currently selected code template from the list.

3.2.12 Using the Clipboard History

The **Clipboard History** window allows viewing and accessing text fragments that were recently copied to the clipboard.



By right clicking in the **Clipboard History** window you can open a pop-up menu with the following choices:

- **Copy to the Edit Window** the currently selected text fragment from the **Clipboard History** window
- **Delete** the currently selected text fragment from the list
- **Delete All** the text fragments from the list.

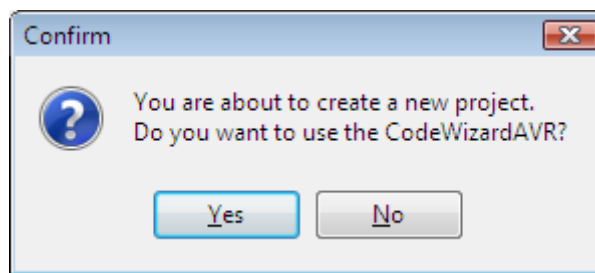
3.3 Working with Projects

The Project groups the source file(s) and compiler settings that you use for building a particular program.

3.3.1 Creating a New Project

You can create a new project file using the **File|New|Project** menu command, by pressing the  and  buttons on the toolbar.

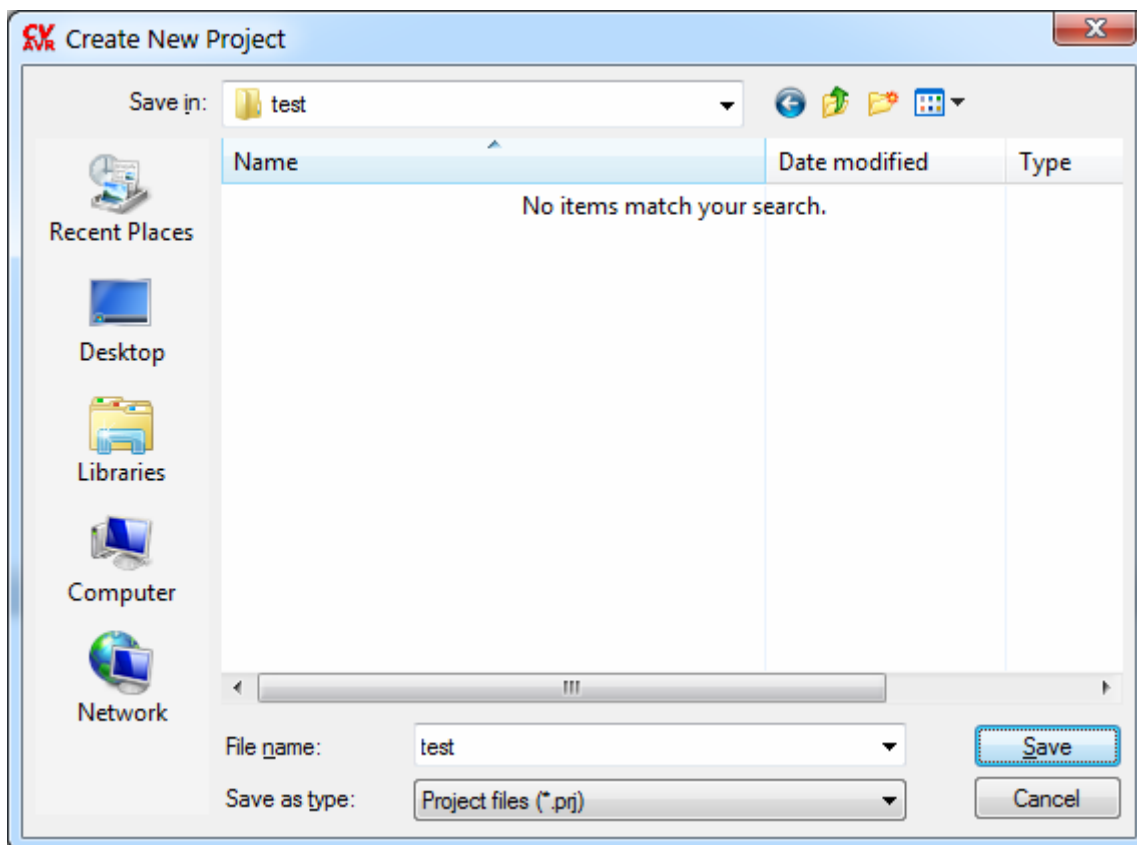
A dialog will open asking you to confirm if you would like to use the CodeWizardAVR to create the new project.



If you select **No** then the **Create New Project** dialog window will open.

CodeVisionAVR

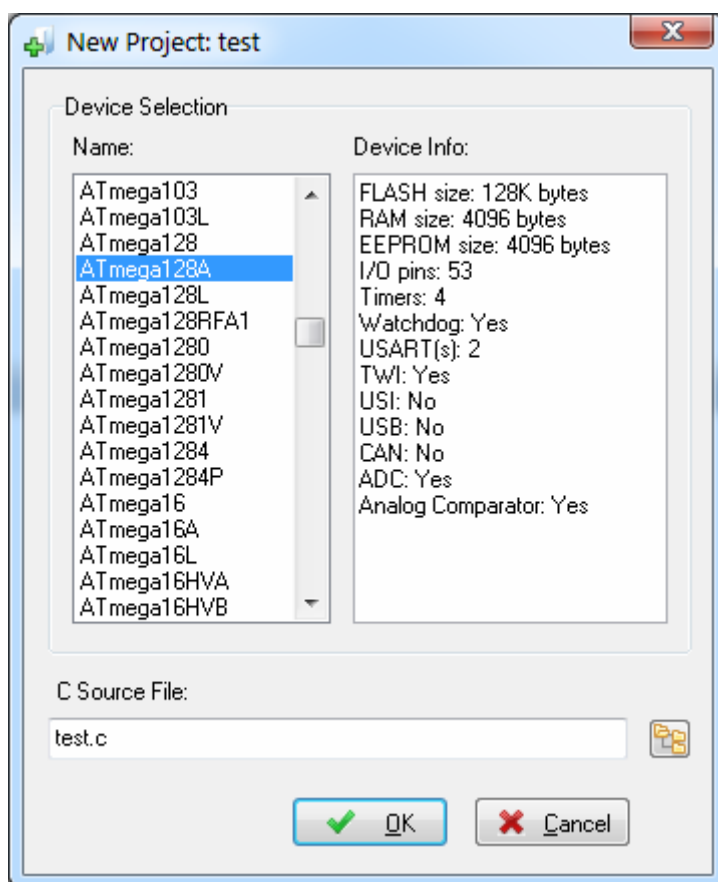
You must specify the new Project file name and its location.



The Project file will have the .prj extension.

CodeVisionAVR

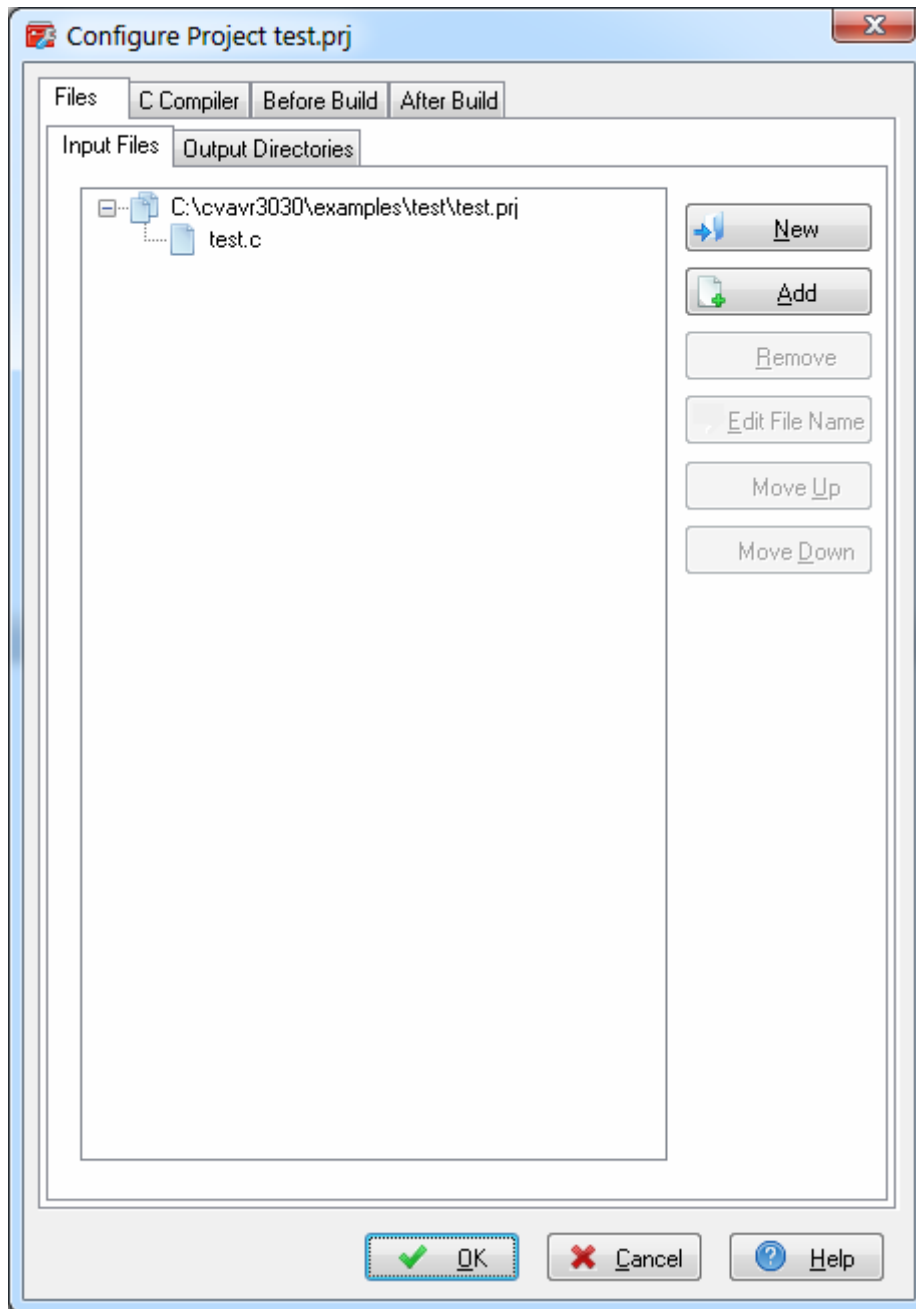
After the name and location of the project file was specified, a device selection dialog will open:



The dialog also allows to specify the name of the first C source file of the project.

CodeVisionAVR

Once the OK button is pressed the project and the C source file are created and the project configuration window is displayed:



The Project configuration can be later modified by using the **Project|Configure** menu command or by pressing the  toolbar button.

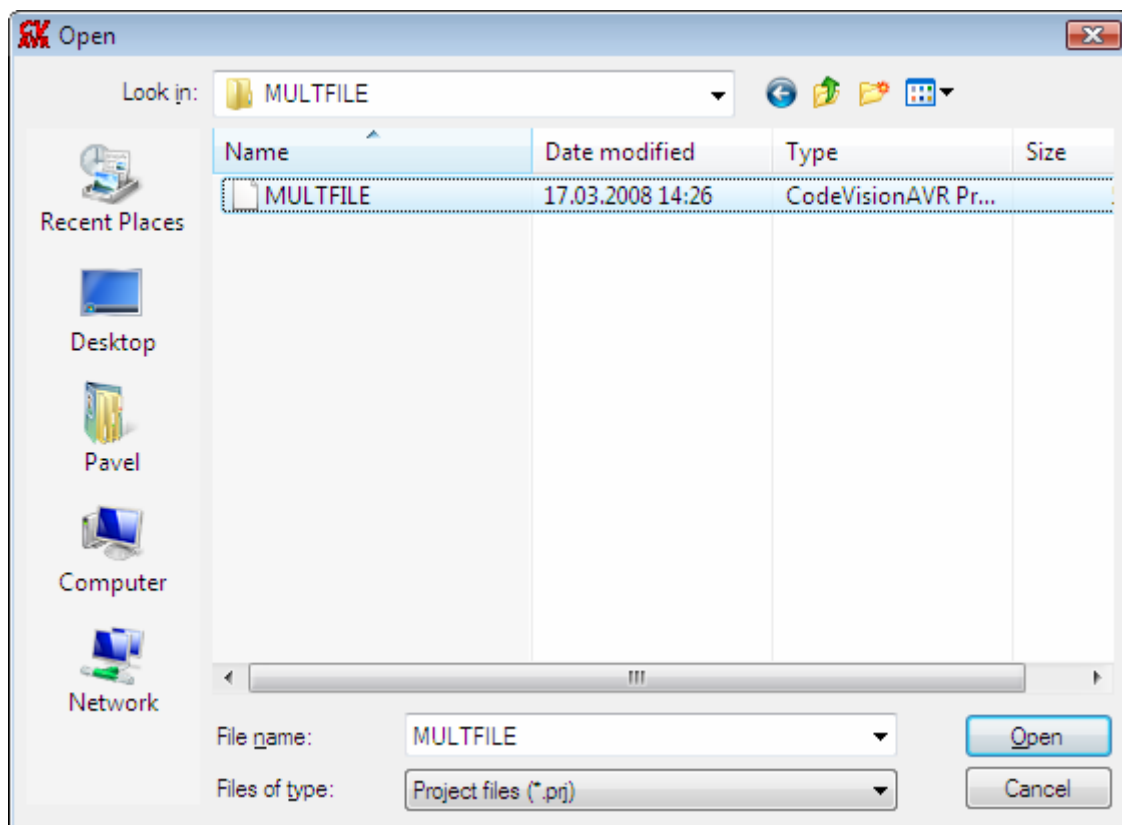
Note: When a **.prj** project for the CodeVisionAVR IDE is created, a corresponding **.cproj** project file for Atmel Studio will be created too.

This allows editing/compiling the same project in both Atmel Studio and CodeVisionAVR IDE.

3.3.2 Opening an Existing Project

An existing Project file can be opened using the **File|Open** menu command or by pressing the  button on the toolbar.

An **Open** dialog window appears.



You must select the file name of the Project you wish to open.

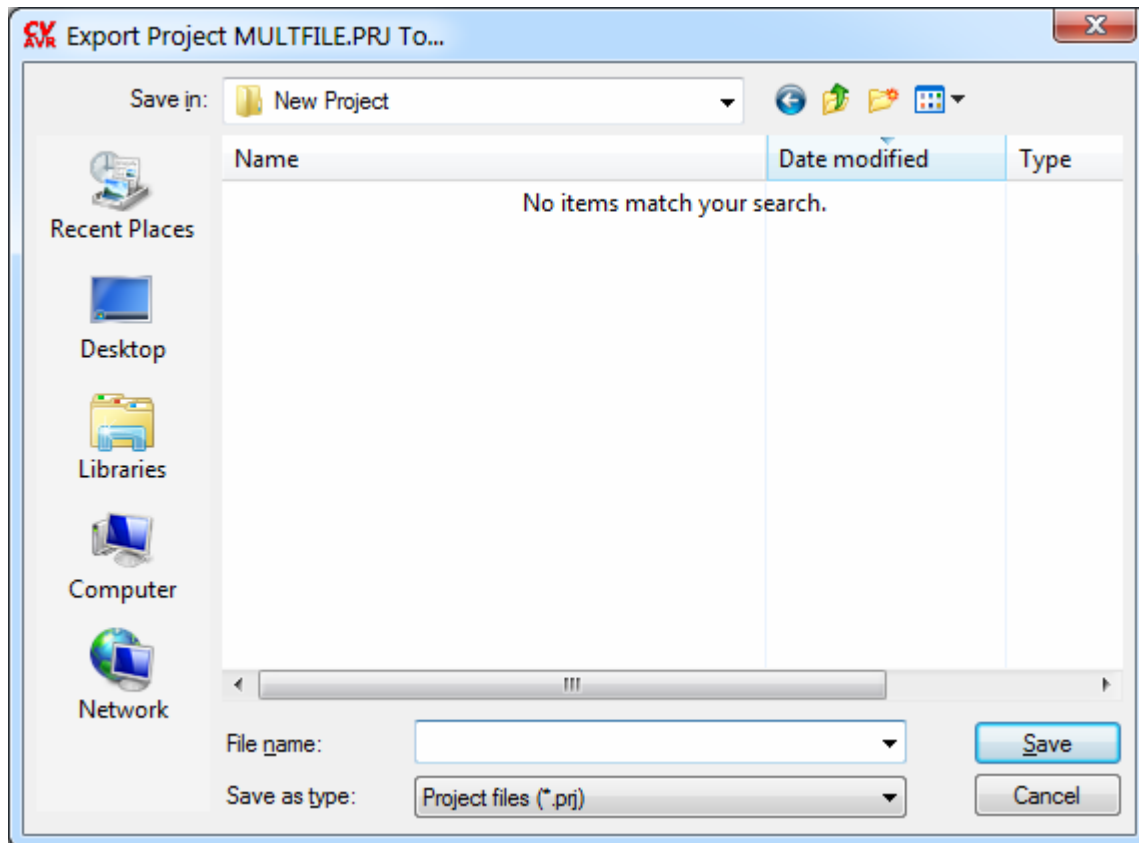
By pressing the **Open** button you will open the Project file and its source file(s).

You can later configure the Project by using the **Project|Configure** menu command or by pressing the  toolbar button.

3.3.3 Exporting a Project

The settings of the currently opened project can be exported to a new one by using the **Project|Export to a New CodeVisionAVR Project** menu command or the  toolbar button.

Upon execution of this command a Project Export dialog window will open:



allowing to specify the name of the new project to which all the settings of the current project will be exported.

3.3.4 Exporting a Project to the CodeVisionAVR Extension for Atmel Studio

The currently opened project can be exported to a project file for Atmel Studio 6.2 or 7.0, by using the **Project|Export to a CodeVisionAVR Extension for Atmel Studio** menu command or the  toolbar button.

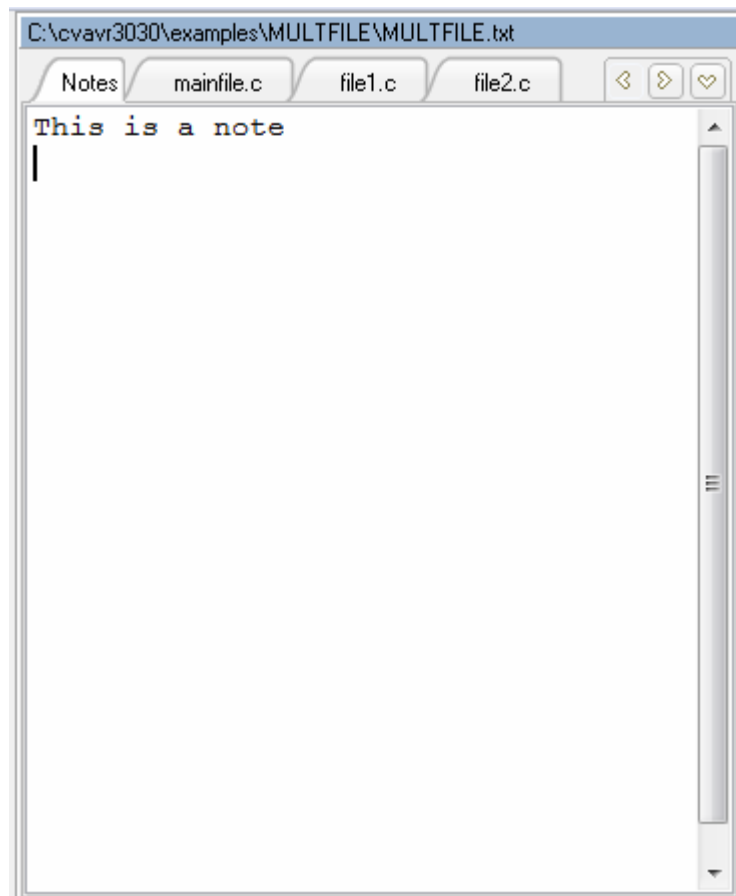
Upon execution of this command, an Atmel Studio *.cproj* project file, associated with the CodeVisionAVR project, will be created in the same directory.

Once this file is opened in Atmel Studio, it will allow the project to be built using the CodeVisionAVR extension.

3.3.5 Adding Notes or Comments to the Project

With every Project the CodeVisionAVR IDE creates an associated text file where you can place notes and comments.

You can access this file using the **Project|Notes** menu command or the  toolbar button.



This file can be edited using the standard Editor commands.

The file is automatically saved when you **Close** the Project or **Quit** the CodeVisionAVR program.

3.3.6 Configuring the Project

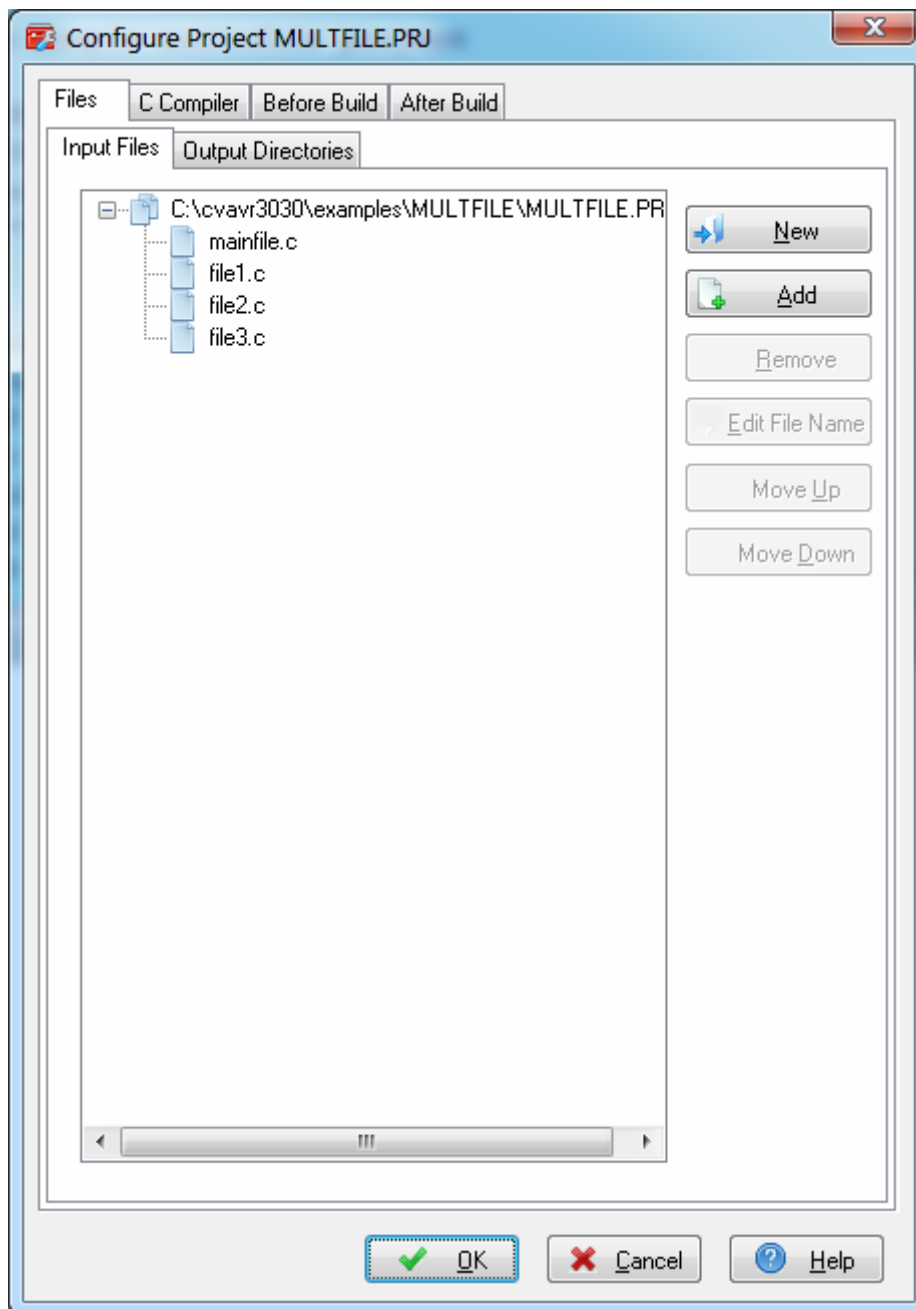
The Project can be configured using the **Project|Configure** menu command or the  toolbar button.

3.3.6.1 Adding or Removing a File from the Project

To add or remove a file from the currently opened project you must use the **Project|Configure** menu command or the  toolbar button.

A **Configure Project** tabbed dialog window will open.

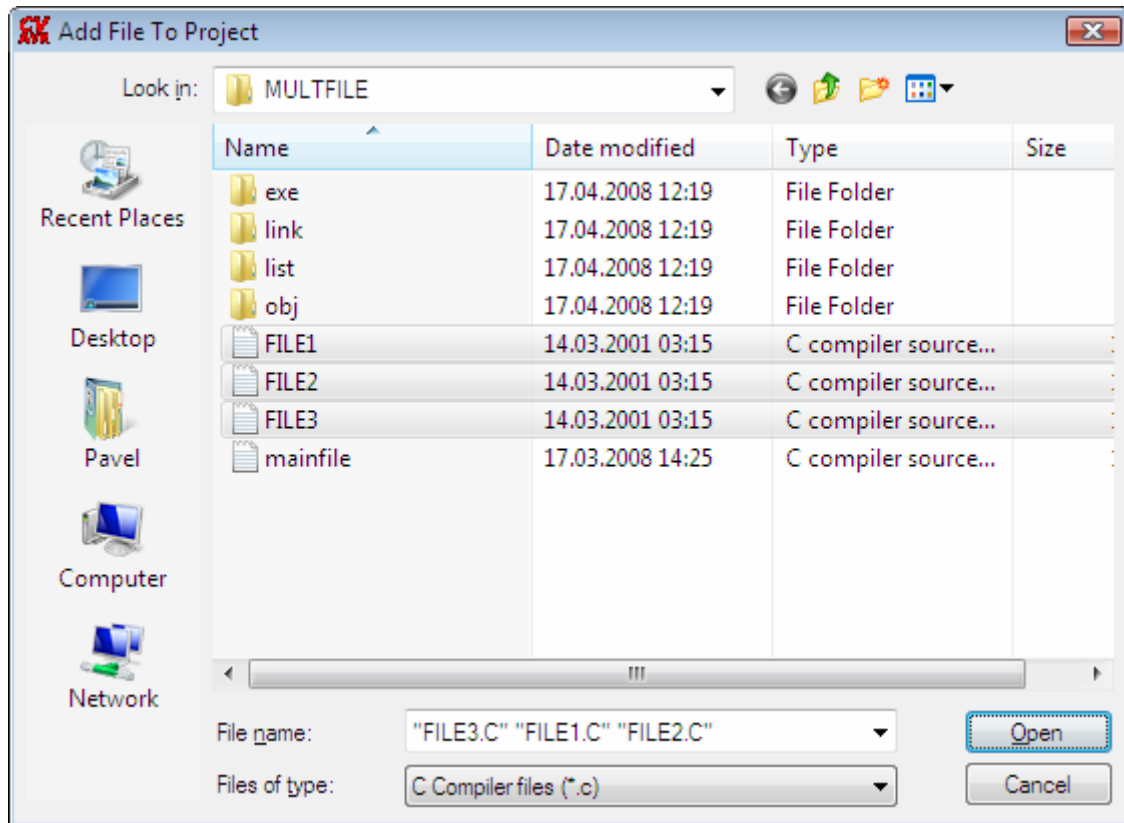
You must select the **Files** and **Input Files** tabs.



By pressing the **New** button you can create a new .c source file and add it to the project.
The **Add** button allows adding an existing source file to the project.

CodeVisionAVR

Multiple files can be added by holding the Ctrl key when selecting in the **Add File to Project** dialog.



When the project is **Open**-ed all project files will be opened in the editor.

By clicking on a file, and then pressing the **Remove** button, you will remove this file from the project.

The project's file compilation order can be changed by clicking on a file and moving it up, respectively down, using the **Move Up**, respectively **Move Down**, buttons.

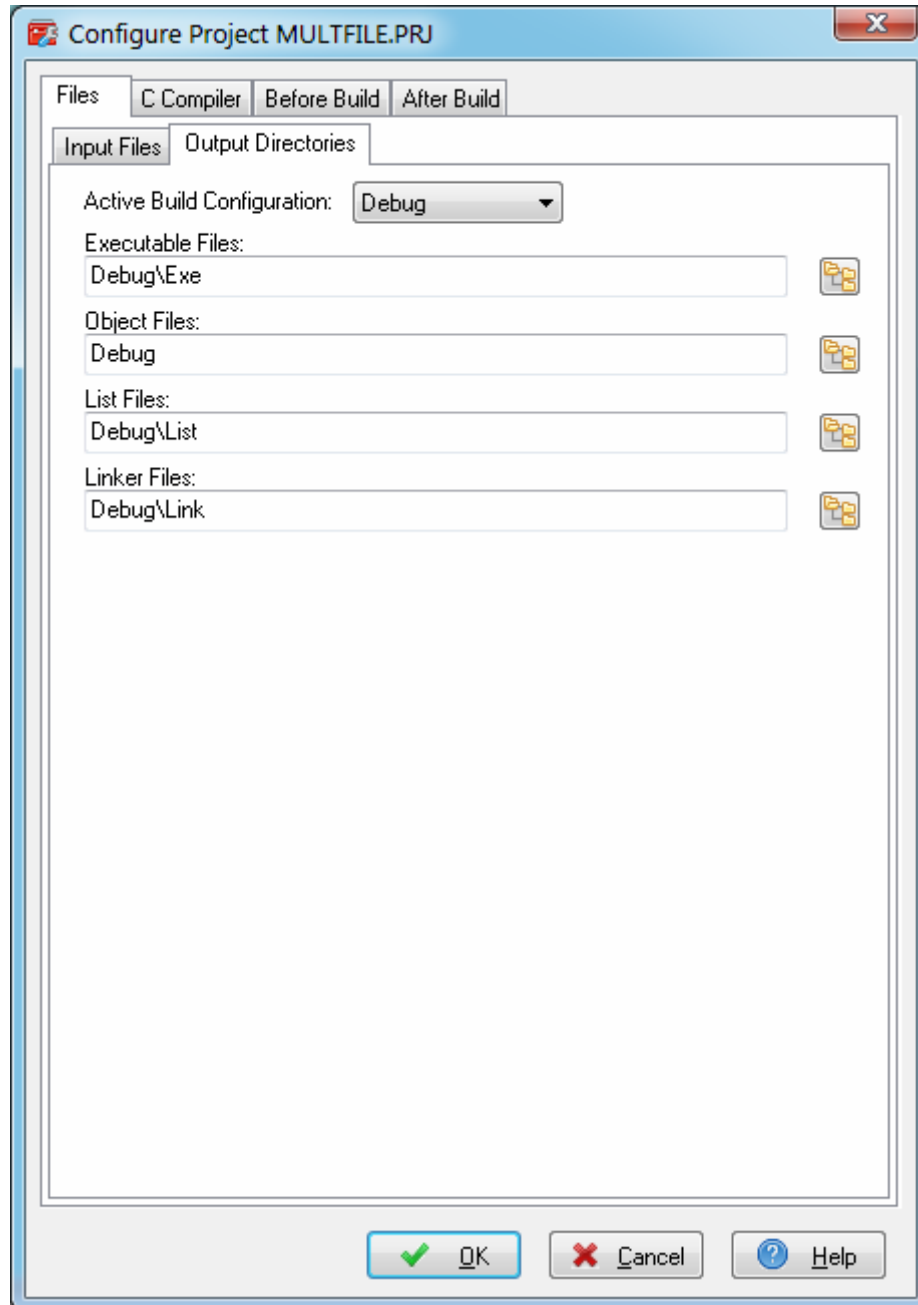
Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

When creating a project with multiple files the following rules must be preserved:

- only .C files must be added to the project's Files list
- there's no need to `#include` the .C files from the Files list as they will be automatically linked
- data type definitions and function declarations must be placed in header .H files, that will be `#include -d` as necessary in the .C files
- global variables declarations must be placed in the .C files where necessary
- there's no need to declare global variables, that are not static, in header .H files, because if these files will be `#include -d` more than once, the compiler will issue errors about variable redeclarations.

3.3.6.2 Setting the Project Output Directories

Selecting the **Output Directories** tab allows the user to specify distinct directories where will be placed the files resulted after the compilation and linking.



Pressing the  button allows to select an existing directory.

The **.rom**, **.hex** and **.EEP** files resulted after the **Build** process will be placed in the **Executable Files** directory.

The object files resulted after the **Compile** process will be placed in the **Object Files** directory.

The **.cof** COFF object file that results after the **Build** process will be also placed in the **Object Files** directory.

The **.asm**, **.lst** and **.map** files created during the **Build** process will be placed in the **List Files** directory.

Various files created by the linker during the **Build** process will be placed in the **Linker Files** directory.

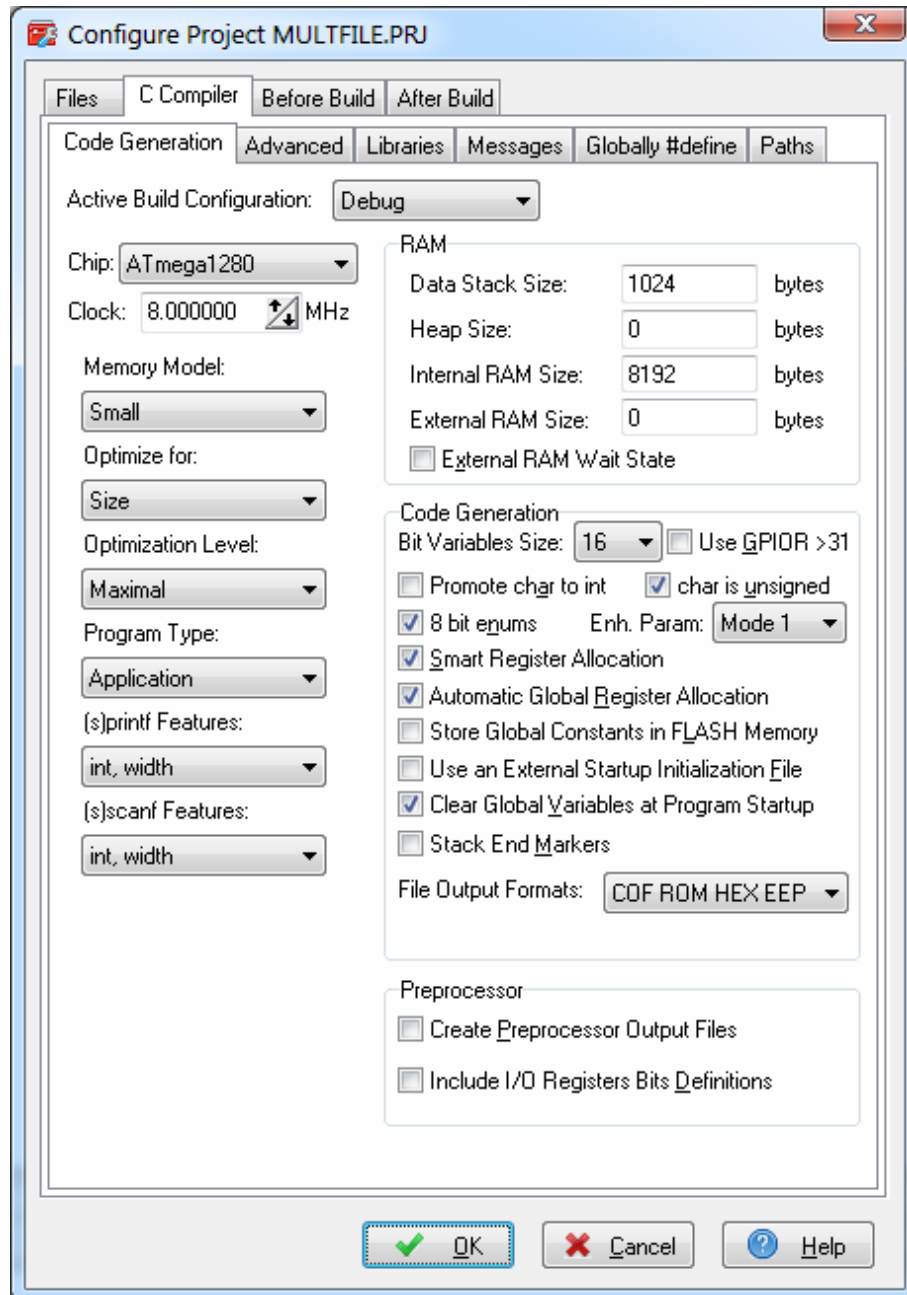
3.3.6.3 Setting the C Compiler Options

To set the C compiler options for the currently opened project you must use the **Project|Configure** menu command or the  toolbar button.

A **Configure Project** tabbed dialog window will open. You must select the **C Compiler** and **Code Generation** tabs.

CodeVisionAVR allows to specify two separate Build Configurations: **Debug** and **Release**, with different **Code Generation**, **Warning Messages** and **Globally #define** options.

The **Active Build Configuration** selects which one of the above options will be used when a **Project|Build** or **Project|Build All** will be performed.



You can select the target AVR microcontroller chip by using the **Chip** combo box.

You must also specify the CPU **Clock** frequency in MHz, which is needed by the Delay Functions, 1 Wire Protocol Functions and Maxim DS1820/DS18S20/DS18B20 Temperature Sensors Functions.

CodeVisionAVR

The required memory model can be selected by using the **Memory Model** list box.

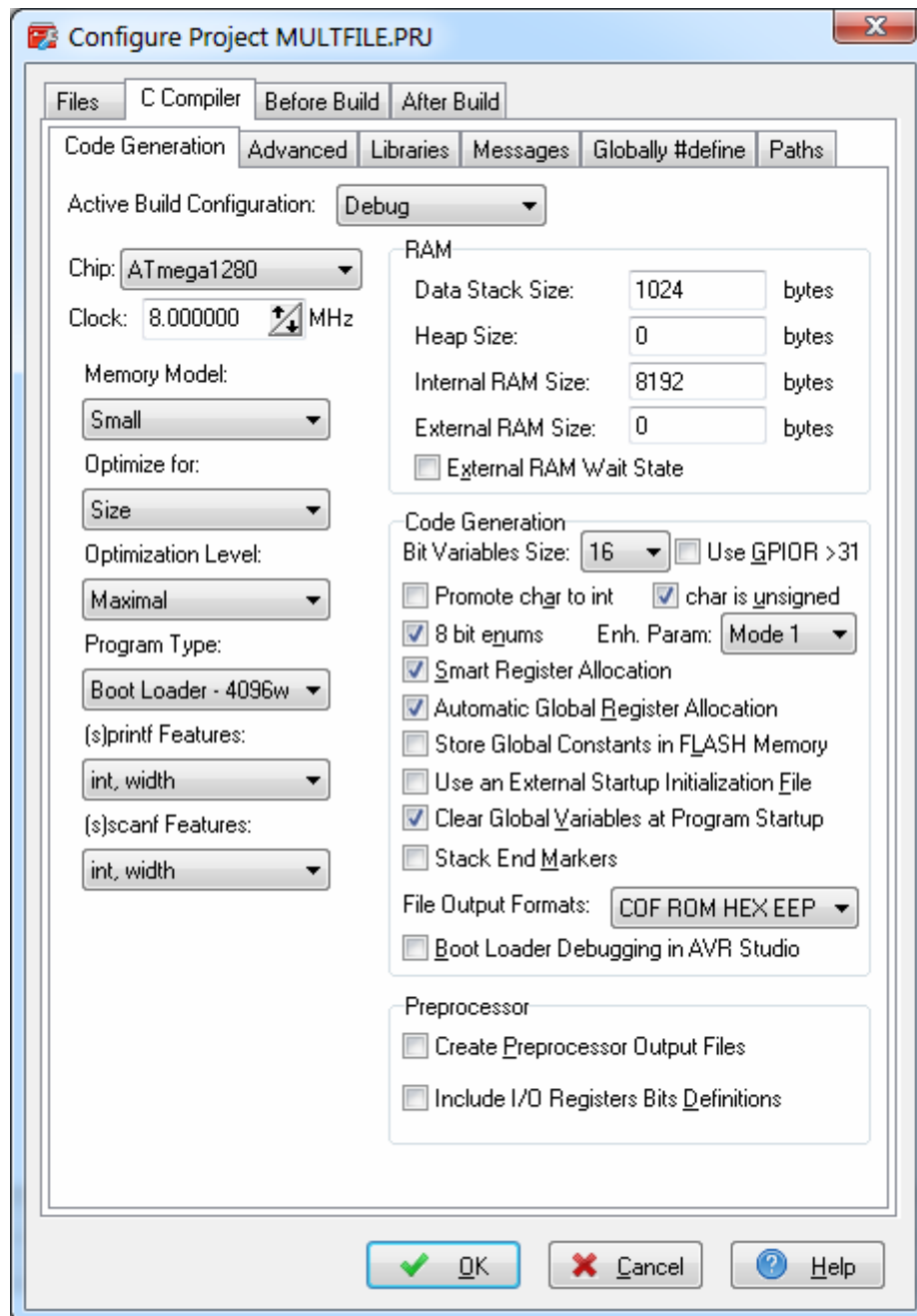
The compiled program can be optimized for minimum size, respectively maximum execution speed, using the **Optimize for|Size**, respectively **Optimize for|Speed**, settings.

The amount of code optimization can be specified using the **Optimization Level** setting. The *Maximal* optimization level may make difficult the code debugging with AVR Studio.

For devices that allow self-programming the **Program Type** can be selected as:

- **Application**
- **Boot Loader**

If the **Boot Loader** program type was selected, a supplementary **Boot Loader Debugging in AVR Studio** option is available.



If this option is enabled, the compiler will generate supplementary code that allows the Boot Loader to be source level debugged in the AVR Studio simulator/emulator.

When programming the chip with the final Boot Loader code, the Boot Loader Debugging option must be disabled.

For reduced core chips like ATtiny10, there is an additional option: **Enable auto Var. Watch in AVR Studio.**

If this option is enabled, the compiler will generate additional code that allows local automatic variables, saved in the Data Stack, to be watched in AVR Studio 4.18 SP2 or later.

After finishing debugging the program, this option should be disabled and the project rebuild.

This will allow to reduce the size of the program and increase its execution speed.

The **(s)printf features** option allows to select which versions of the printf and sprintf **Standard C Input/Output Functions** will be linked in your project:

- **int** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', no width or precision specifiers are supported, only the '+' and '-' flags are supported, no input size modifiers are supported
- **int, width** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', the width specifier is supported, the precision specifier is not supported, only the '+', '-', '0' and '-' flags are supported, no input size modifiers are supported
- **long, width** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', the width specifier is supported, the precision specifier is not supported, only the '+', '-', '0' and '-' flags are supported, only the 'l' input size modifier is supported
- **long, width, precision** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', the width and precision specifiers are supported, only the '+', '-', '0' and '-' flags are supported, only the 'l' input size modifier is supported
- **float, width, precision** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'e', 'E', 'f', 'x', 'X', '%', the width and precision specifiers are supported, only the '+', '-', '0' and '-' flags are supported, only the 'l' input size modifier is supported.

The more features are selected, the larger is the code size generated for the printf and sprintf functions.

The **(s)scanf features** option allows to select which versions of the scanf and sscanf **Standard C Input/Output Functions** will be linked in your project:

- **int, width** - the following conversion type characters are supported: 'c', 's', 'i', 'd', 'u', 'x', '%', the width specifier is supported, no input size modifiers are supported
- **long, width** - the following conversion type characters are supported: 'c', 's', 'i', 'd', 'u', 'x', '%', the width specifier is supported, only the 'l' input size modifier is supported
- **long, float, width** - the following conversion type characters are supported: 'c', 's', 'i', 'd', 'u', 'x', 'f', 'e', 'E', 'g', 'G', '%', the width specifier is supported, the 'l' input size modifier is supported only for integer types.

The more features are selected, the larger is the code size generated for the scanf and sscanf functions.

The **Data Stack Size** must be also specified.

If the dynamic memory allocation functions from the Standard Library are to be used, the **Heap Size** must be also specified.

It can be calculated using the following formulae:

$$heap\_size = (n + 1) \cdot 4 + \sum_{i=1}^n block\_size_i$$

where: n is the number of memory blocks that will be allocated in the heap

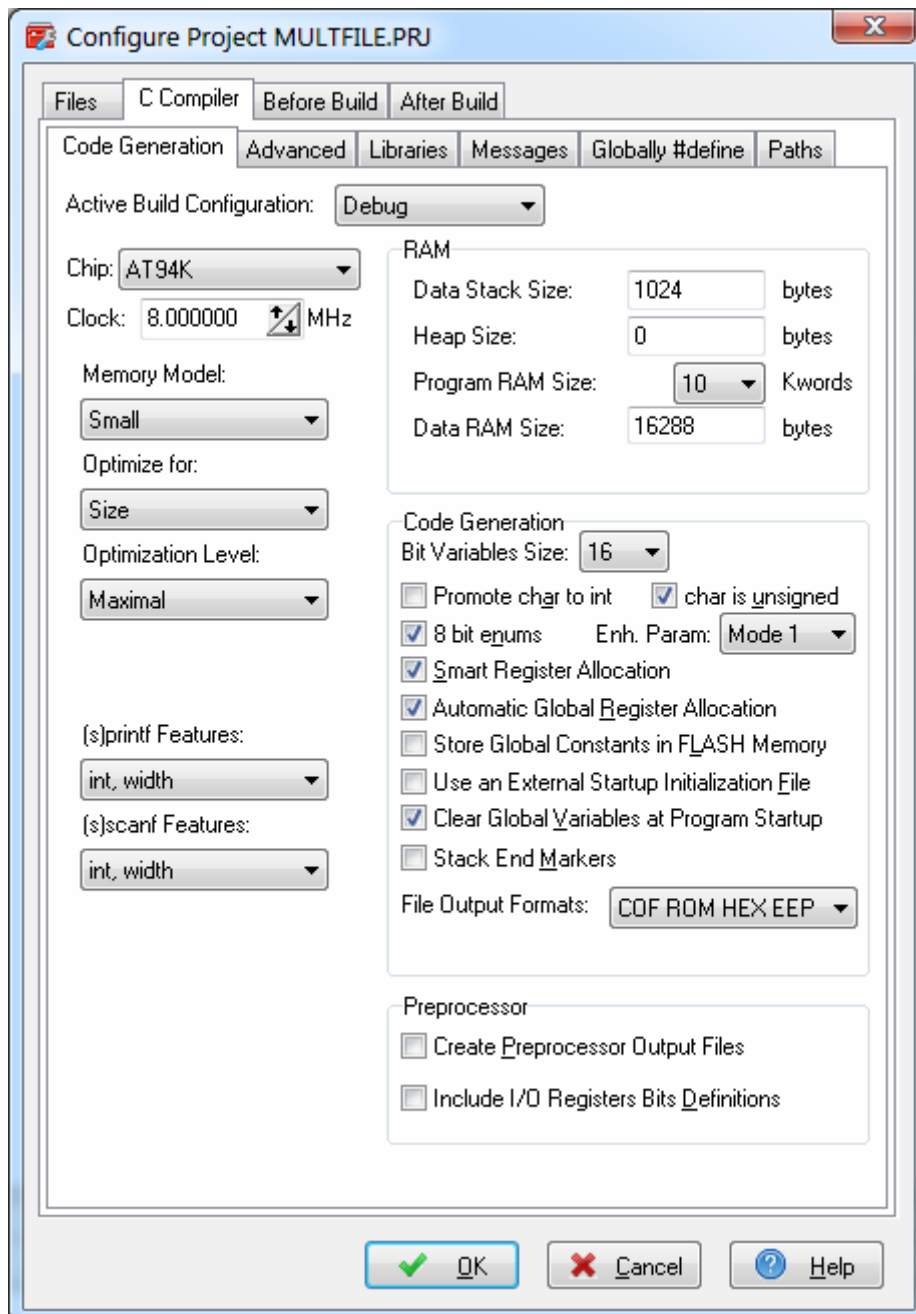
$block\_size_i$ is the size of the memory block i .

CodeVisionAVR

If the memory allocation functions will not be used, then the **Heap Size** must be specified as zero. Eventually you may also specify the **External RAM Size** (in case the microcontroller have external SRAM memory connected).

The **External RAM Wait State** option enables the insertion of wait states during access to the external RAM. This is useful when using slow memory devices.

If an Atmel AT94K05, AT94K10, AT94K20 or AT94K40 FPSLIC device will be used, than there will be the possibility to specify the **Program RAM Size** in Kwords.



The maximum size of the global bit variables, which are placed in the GPIOR (if present) and registers R2 to R14, can be specified using the **Bit Variables Size** list box.

The **Use GPIOR >31** option, when checked, allows using GPIOR located at addresses above 31 for global bit variables.

Note that bit variables located in GPIOR above address 31 are accessed using the IN, OUT, OR, AND instructions, which leads to larger and slower code than for bit variables located in GPIOR with the address range 0...31, which use the SBI, CBI instructions. Also the access to bit variables located in GPIOR above address 31 is not atomic.

Therefore it is recommended to leave the **Use GPIOR >31** option not checked if the number of global bit variables is small enough and no additional registers are needed for their storage.

Checking the **Promote char to int** check box enables the ANSI promotion of **char** operands to **int**.

This option can also be specified using the **#pragma promotechar** compiler directive.

Promoting **char** to **int** leads to increases code size and lowers speed for an 8 bit chip microcontroller like the AVR.

In order to assure code compatibility with other C compilers, the **Promote char to int** option is enabled by default for newly created projects.

If the **char is unsigned** check box is checked, the compiler treats by default the **char** data type as an unsigned 8 bit in the range 0...255.

If the check box is not checked the **char** data type is by default a signed 8 bit in the range -128...127.

This option can also be specified using the **#pragma uchar** compiler directive.

Treating **char** as unsigned leads to better code size and speed.

If the **8 bit enums** check box is checked, the compiler treats the enumerations as being of 8 bit **char** data type, leading to improved code size and execution speed of the compiled program. If the check box is not checked the enumerations are considered as 16 bit **int** data type as required by ANSI.

The following modes, specified in the **Project|Configure|C Compiler|Code Generation** menu, are used for function parameter passing and storage:

- **Enhanced Parameter: No** - all function parameters are passed using the **Data Stack** and accessed using the **LDD Rn, Y+d** and **STD Y+d,Rn** instructions
- **Enhanced Parameter: Mode 1** - all function parameters, except the last one, are passed using the **Data Stack**.

The last parameter is passed in registers R26 for 1 byte, R26, R27 for 2 byte and R26, R27, R24, R25 for 4 byte parameters.

However in the function prologue this last parameter is pushed in the **Data Stack** too.

So in this mode all function parameters are also accessed using the **LDD Rn, Y+d** and **STD Y+d,Rn** instructions.

Better code size is obtained, because register accessing instructions are used when passing the last function parameter during function call.

- **Enhanced Parameter: Mode 2** - all function parameters, except the last one, are passed using the **Data Stack**.

The last parameter is passed in registers R26 for 1 byte, R26, R27 for 2 byte and R26, R27, R24, R25 for 4 byte parameters.

In the function prologue the function parameters are copied from the **Data Stack** or registers R26, R27, R24, R25 to the registers R16..R21, that were not allocated for local variables.

In this mode function parameters that could be allocated/copied to registers R16..R21 are accessed using more efficient instructions.

The rest of the parameters are still accessed using the **LDD Rn, Y+d** and **STD Y+d,Rn** instructions.

Even better code size is obtained, because register accessing instructions are used when passing the last parameter and for accessing the parameters stored in registers inside the function.

Note: If this mode is used for programs which contain functions that use inline assembly code to access function parameters, then such functions must be enclosed between **#pragma dstack+** and **#pragma dstack-** like in the following example:

```
/* This will force passing the function parameters
   using the data stack */
#pragma dstack_par+

int sum_abc(int a, int b, unsigned char c) {
#asm
    ldd    r30,y+3 ;R30=LSB a
    ldd    r31,y+4 ;R31=MSB a
    ldd    r26,y+1 ;R26=LSB b
    ldd    r27,y+2 ;R27=MSB b
    add    r30,r26 ; (R31,R30)=a+b
    adc    r31,r27
    ld     r26,y    ;R26=c
    clr    r27      ;promote unsigned char c to int
    add    r30,r26 ; (R31,R30)=(R31,R30)+c
    adc    r31,r27
#endasm
}

/* Re-enable passing the function parameters using registers,
   if Enhanced Parameter Passing Mode 2 is set in the
   Project|Configure|C Compiler|Code Generation menu */
#pragma dstack_par-
```

The **Smart Register Allocation** check box enables allocation of registers R2 to R14 (not used for bit variables) and R16 to R21 in such a way that 16bit variables will be preferably located in even register pairs, thus favouring the usage of the enhanced core MOVW instruction for their access. This option is effective only if the **Enhanced Instructions** check box is also checked.

If **Smart Register Allocation** is not enabled, the registers will be allocated in the order of variable declaration.

The **Smart Register Allocation** option should be disabled if the program was developed using CodeVisionAVR prior to V1.25.3 and it contains inline assembly code that accesses the variables located in registers R2 to R14 and R16 to R21.

The registers in the range R2 to R14, not used for bit variables, can be automatically allocated to **char** and **int** global variables and global pointers by checking the **Automatic Global Register Allocation** check box.

If the **Store Global Constants in FLASH Memory** check box is checked, the compiler will treat the **const** type qualifier as equivalent to the **flash** memory attribute and will place the constants in FLASH memory. If the option is not checked, constants marked with the **const** type qualifier will be stored in RAM memory and the ones marked with the **flash** memory attribute will be stored in FLASH memory. The **Store Global Constants in FLASH Memory** option is, by default, not enabled for newly created projects.

In order to maintain compatibility with V1.xx projects, the **Store Global Constants in FLASH Memory** option must be checked.

An external startup.asm file can be used by checking the **Compilation|Use an External Startup File** check box.

The **Clear Global Variables at Program Startup** check box allows enabling or disabling the initialization with zero of global variables located in RAM and registers R2 to R14 at program startup after a chip reset. If an external startup.asm file is used, this option must signal to the compiler if the variable initialization with zero is performed in this file or not.

For debugging purposes you have the option **Stack End Markers**. If you select it, the compiler will place the strings **DSTACKEND**, respectively **HSTACKEND**, at the end of the **Data Stack**, respectively **Hardware Stack** areas.

When you debug the program with the AVR Studio debugger you may see if these strings are overwritten, and consequently modify the **Data Stack Size**.

When your program runs correctly you may disable the placement of these strings in order to reduce code size.

Using the **File Output Formats** list box you can select the following formats for the files generated by the compiler:

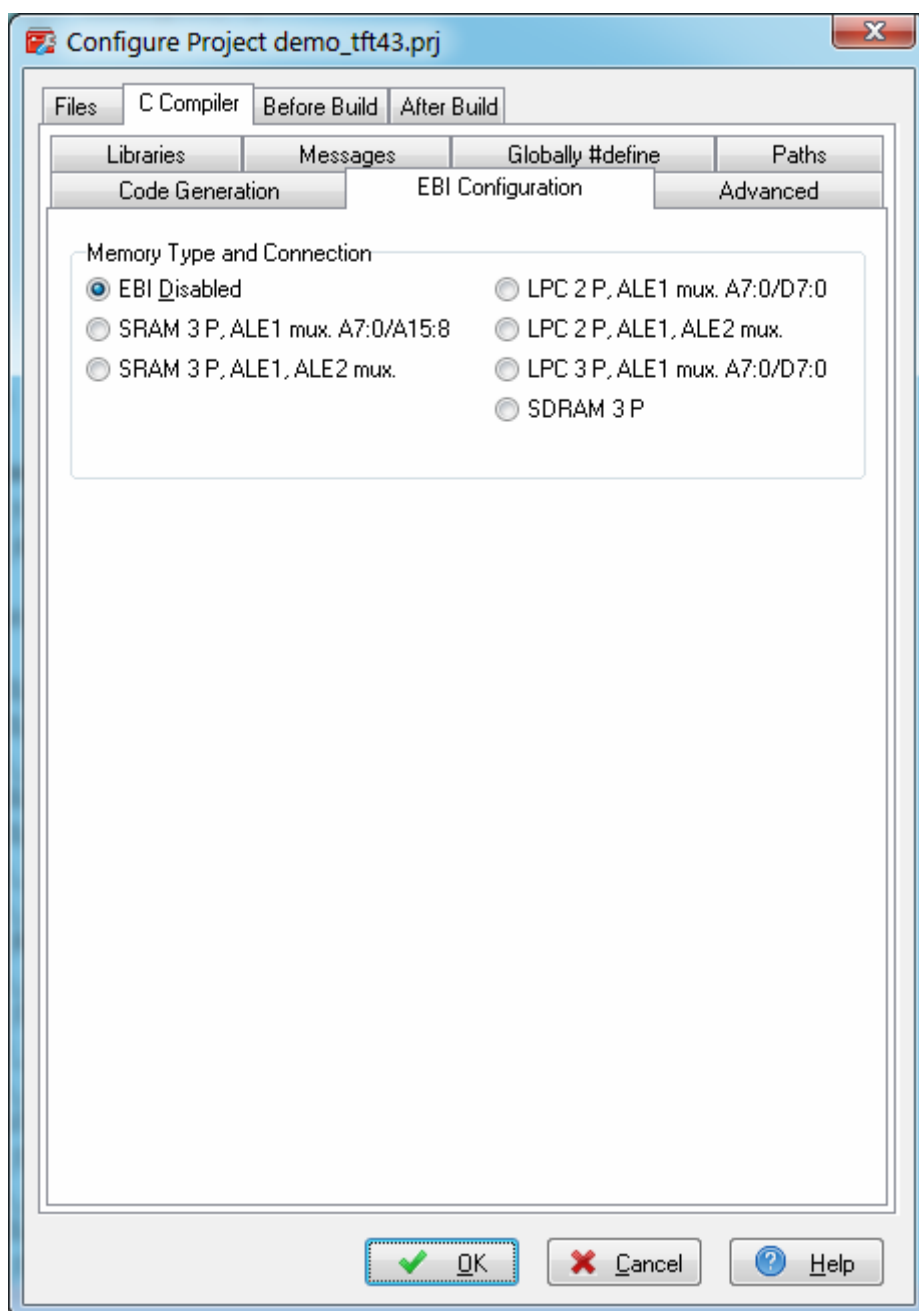
- COFF (required by the Atmel AVR Studio debugger), ROM, Intel HEX and EEP (required by the In-System Programmer) ;
- Atmel generic OBJ, ROM, Intel HEX and EEP (required by the In-System Programmer).

The following **Preprocessor** options can be set:

- **Create Preprocessor Output Files** - when enabled, an additional file with the .i extension will be created for each compiled source file. The preprocessor output files will contain the source files text with all the preprocessor macros expanded. Enabling this option will slow down the compilation process.
- **Include I/O Registers Bits Definitions** - will enable the I/O register bits definitions in the device header files.

CodeVisionAVR

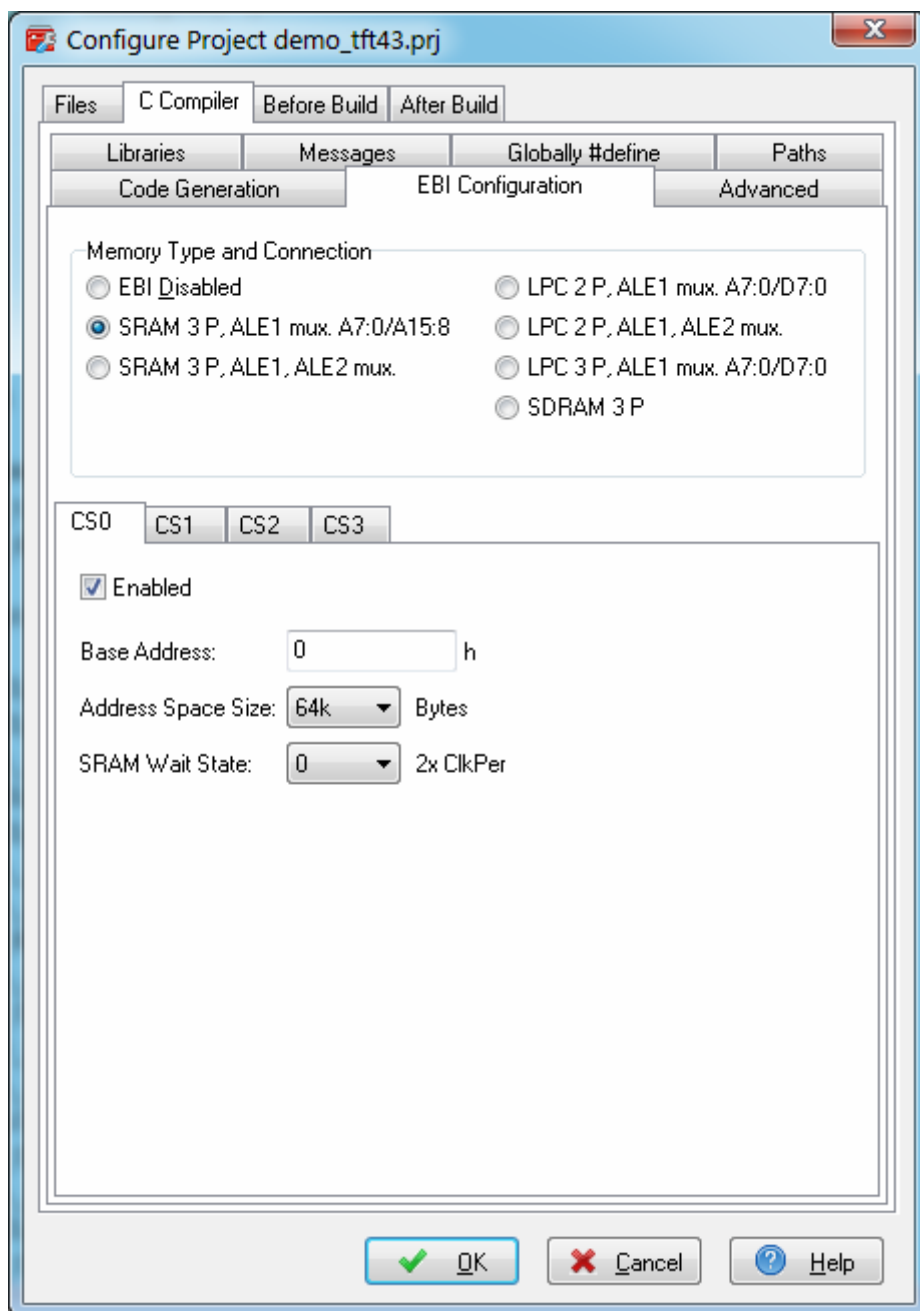
For the XMEGA chips that feature an **External Bus Interface (EBI)** an additional **EBI Configuration** tab is present:



The check boxes from the **Memory Type and Connection** group allow to specify the **EBI** operating mode and kind of external RAM connected to the chip.

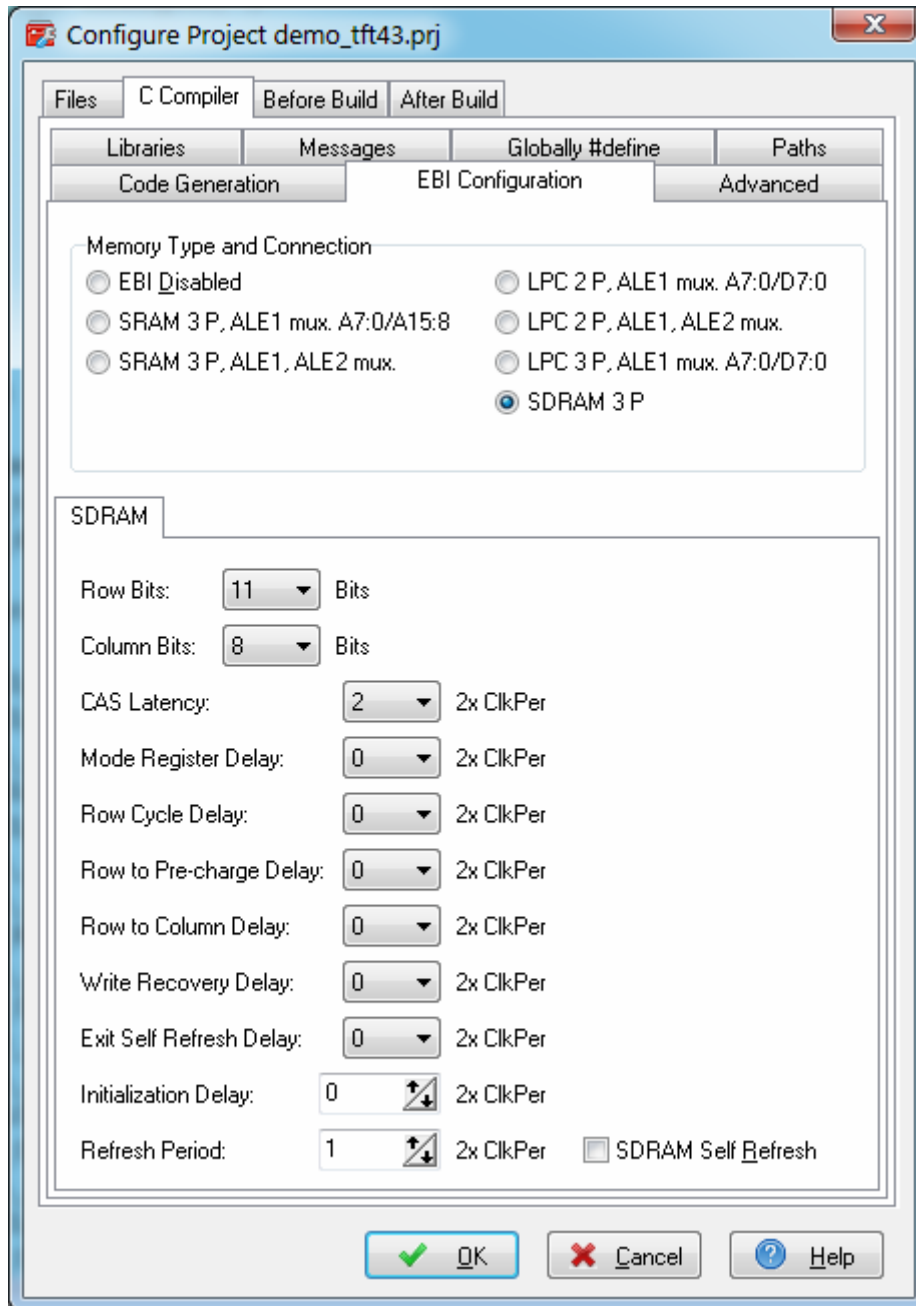
CodeVisionAVR

Depending on the **EBI** operating mode, additional tabs are displayed for the configuration of the **CS0...CS3** chip select signals:



The **Enable** check box activates the usage of the corresponding **CSn** chip select signal.
The **Base Address** represents the starting address, in hexadecimal, of the **Address Space** for which the chip select signal becomes active.
The **Address Space Size** list box allows to specify the address range size for which the chip select signal is active.
The **SRAM Wait State** list box allows inserting additional wait states when accessing slow external memory.

Specific options can be set if **SDRAM** chips are connected to the XMEGA chip:



These options are described in detail in Atmel's **XMEGA A Manual** in the **EBI - External Bus Interface** chapter.

Note: All the necessary code for **EBI** setup will be automatically added by the compiler in the startup initialization that is executed immediately after the chip reset. There is no need for the programmer to write his own code for this purpose.

When **SDRAM** is used as external memory and a different clock source is used instead of the internal 2MHz oscillator, it is necessary to execute the function that configures the system clocks **before** the **EBI** setup sequence, which will ensure that correct timing is used for later **SDRAM** access by the startup code.

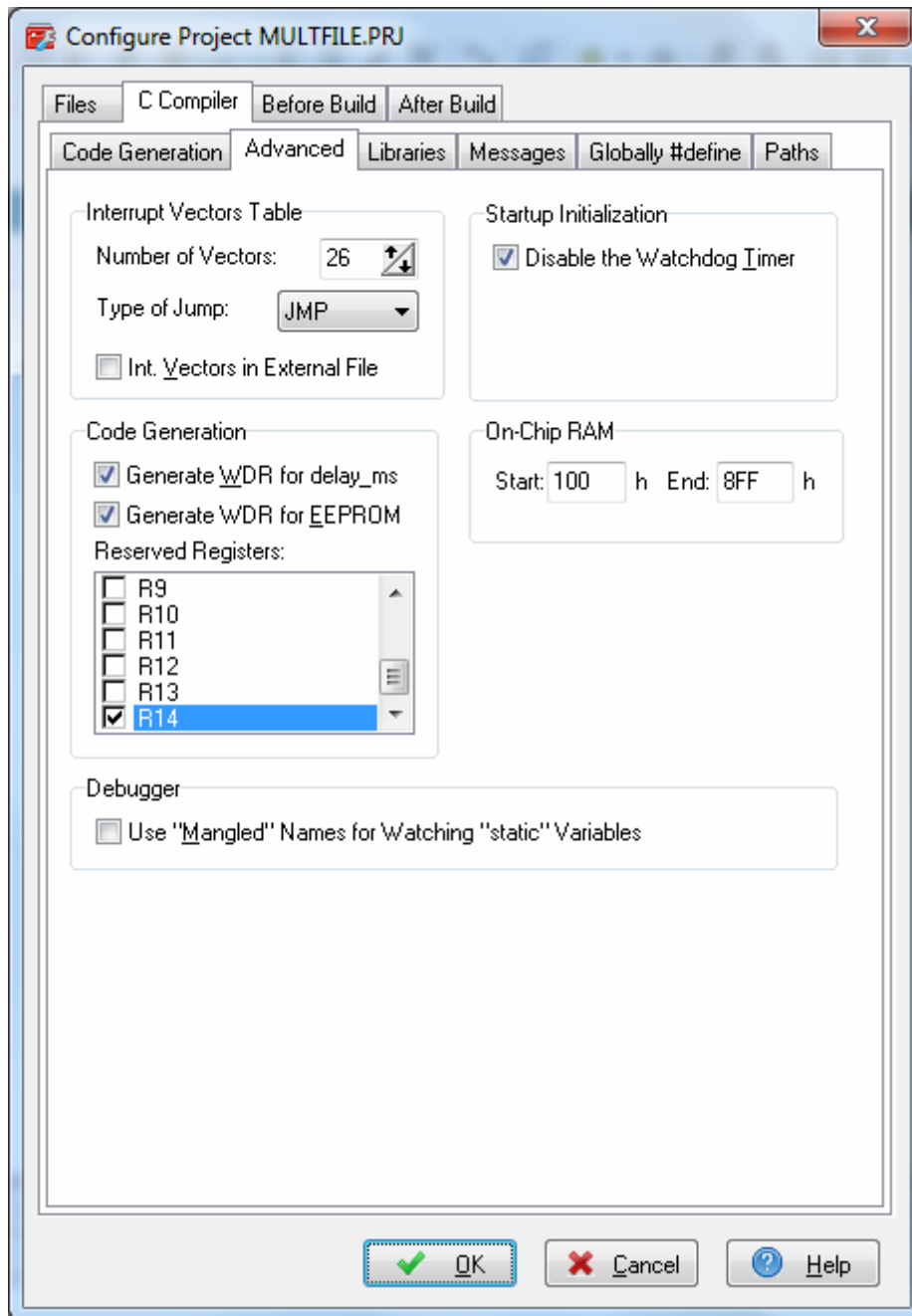
CodeVisionAVR

This can be achieved by using the `__reset` attribute applied to the clock initialization function:

```
__reset void system_clocks_init(void)
{
// Initialization code ...
}
```

The code generated by the CodeWizardAVR for XMEGA chips, automatically handles such situations.

The **Advanced** tab, which is present only in the Advanced version of the compiler, enables more detailed custom configuration like the number and jump type of the interrupt vectors and memory usage:



The **Int. Vectors in External File** option enables or disables placing the interrupt vectors in an external `vectors.asm` file created by the user. If this option is enabled the compiler will not generate any interrupt vectors by itself as the vectors will be present in the `vectors.asm` file.

The **On-Chip RAM Start** and **End** fields allow to specify the RAM area to be used by the compiler.

Checking the **Startup Initialization - Disable the Watchdog Timer** option allows generation of code that ensures that the watchdog timer is disabled after a software reset.

The following advanced **Code Generation** options are available:

- **Generate WDR for delay_ms** - when enabled, the WDR (Watch Dog Reset) instruction is executed in every 1 ms cycle of the `delay_ms` function
- **Generate WDR for EEPROM** - enables the generation of the WDR instruction during access to on-chip EEPROM.

The **Reserved Registers** option allows to prevent the automatic allocation of some of the registers R2 to R14 to global variables, if the **Automatic Global Registers Allocation** option is enabled in the **Project|Configure|C Compiler|Code Generation** menu.

The reserved registers can in this case be used for inline assembly code or be allocated manually for a specific global variable.

Example:

```
register unsigned char abc @14; /* the global variable abc is allocated
                                to the reserved register R14 */
register unsigned char abc=123; /* the variable abc, allocated to R14,
                                is also initialized with the value 123
                                during definition */
```

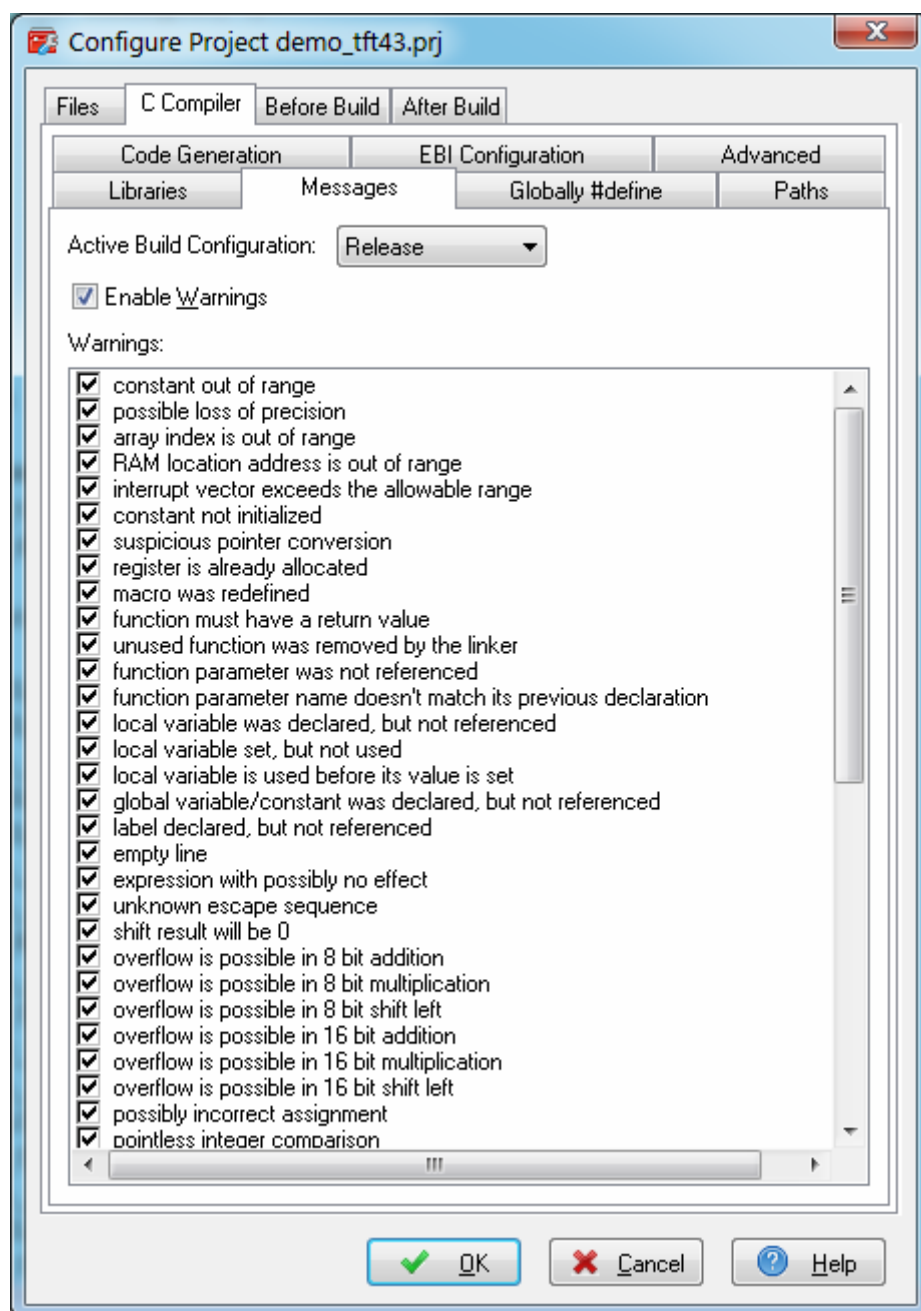
The option **Use "Mangled" Names for Watching "static" Variables** in the debugger, is useful when several static global variables with the same name were declared in different C program modules.

It allows to distinguish between them in the debugger's watch window.

If it's enabled, the `.map` file will display the mangled name of the static variable, which must be used with the debugger.

CodeVisionAVR

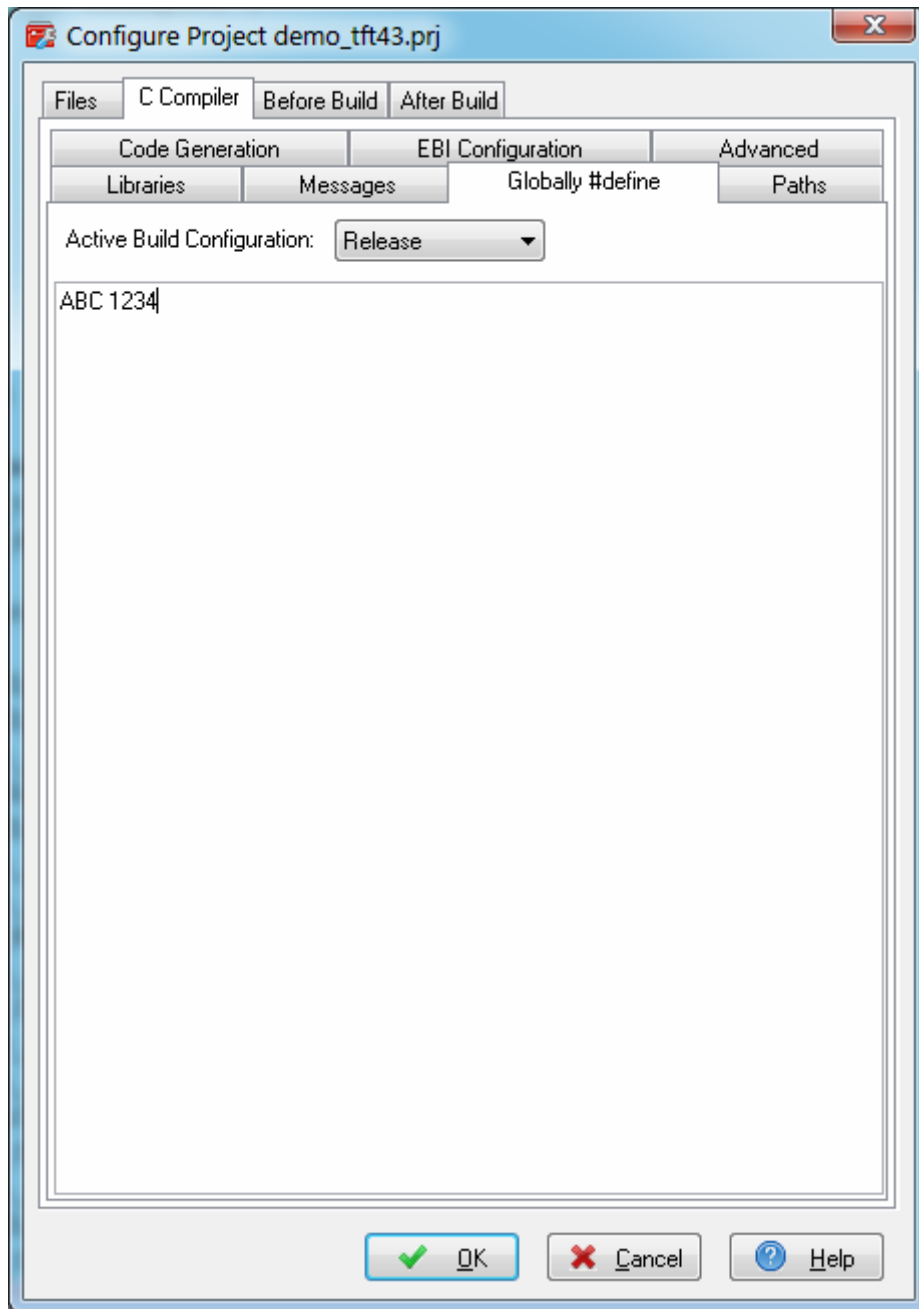
The **Messages** tab allows to individually enable or disable various compiler and linker warnings:



The generation of warning messages during compilation can be globally enabled or disabled by using the **Enable Warnings** check box.

CodeVisionAVR

The **Globally #define** tab allows to #define macros that will be visible in all the project files.
For example:



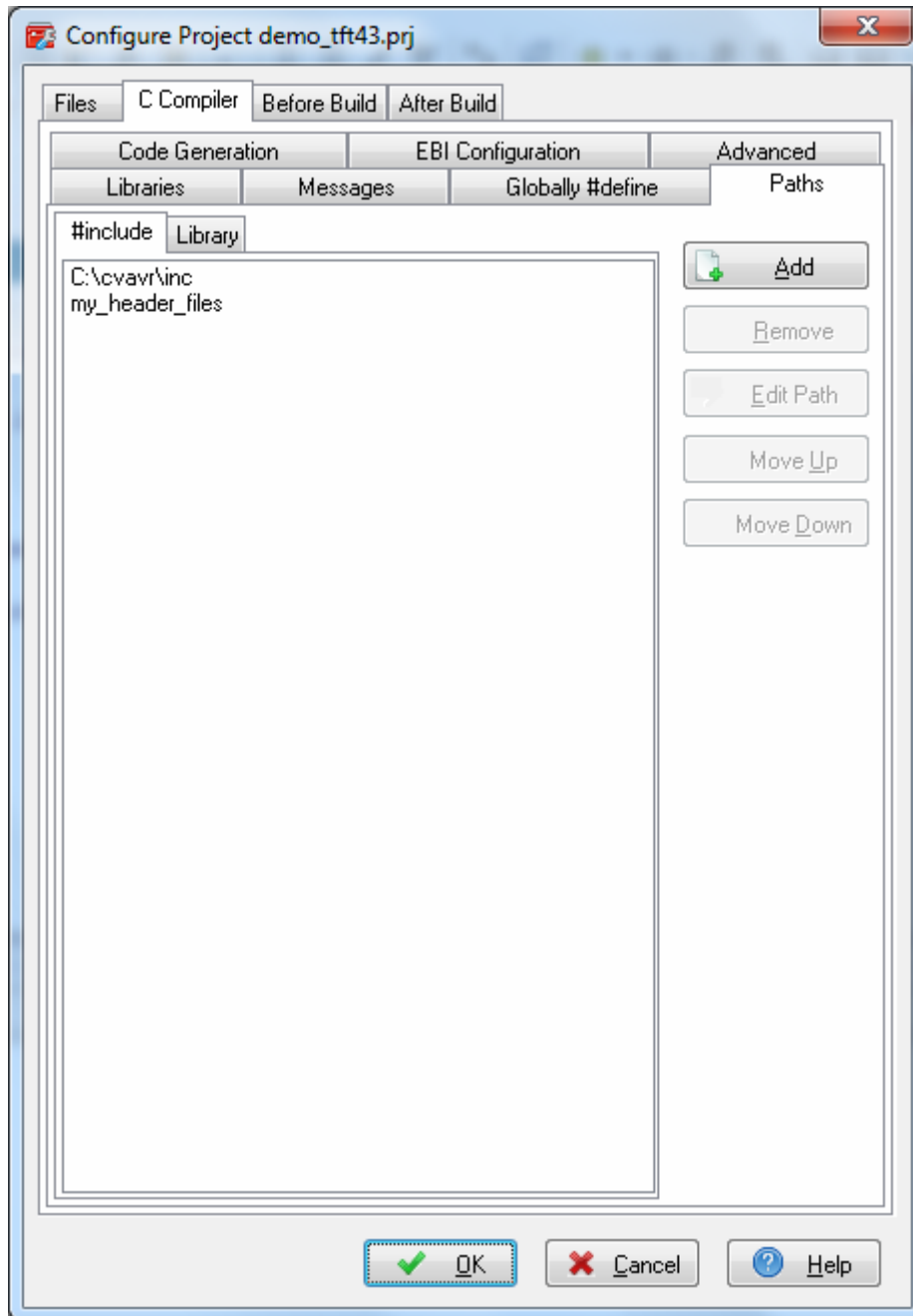
will be equivalent with placing the macro definition:

```
#define ABC 1234
```

in each project's program module.

CodeVisionAVR

The **Paths** tab allows to specify additional search paths for **#include** and **Library** files.



The path lists can be modified by clicking on the following buttons:

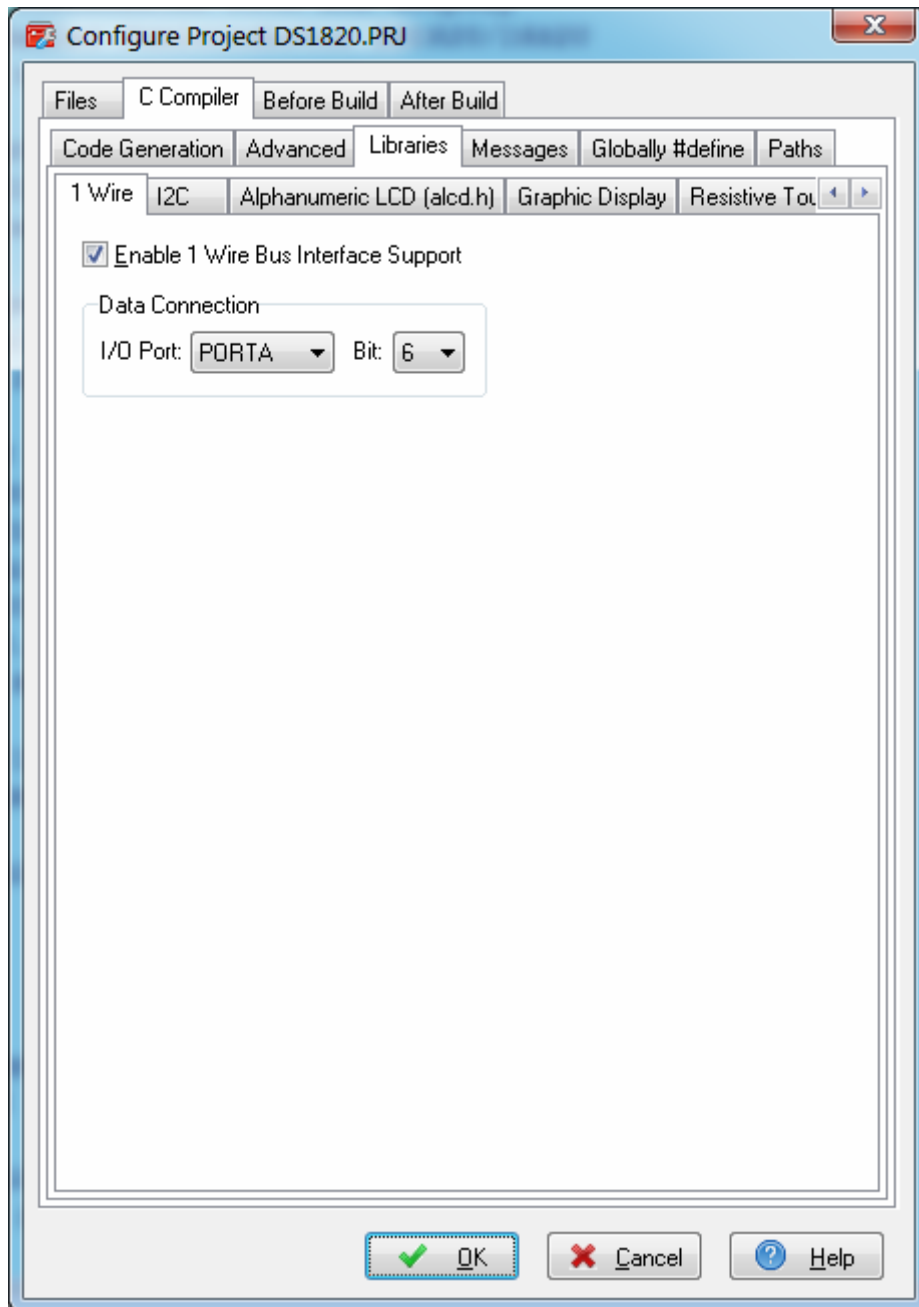
- **Add** - adds a path to the list
- **Remove** - removes the currently selected path from the list
- **Edit** - allows editing the currently selected path from the list
- **Move Up** - increases the search priority, by moving up the currently selected path in the list
- **Move Down** - decreases the search priority, by moving down the currently selected path in the list.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

3.3.6.4 Setting the 1 Wire Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **1 Wire** tab is used for configuring the I/O port allocation for the 1 Wire Protocol Functions.



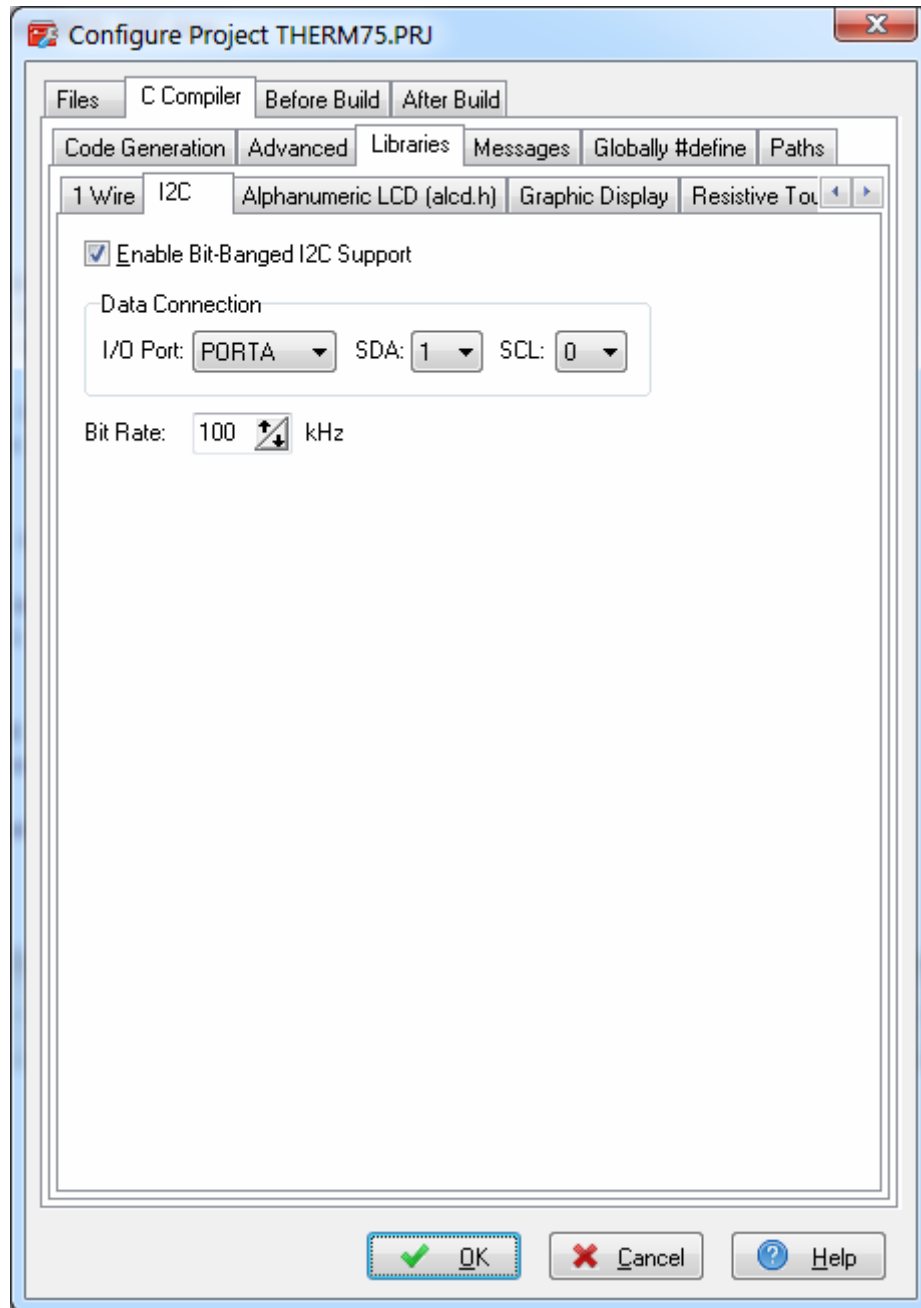
The following settings are available:

- **Enable 1 Wire Bus Interface Support** allows the activation of the 1 Wire Protocol Functions
- **I/O Port** and **Bit** specify in **Data Connection**, the port and bit used for 1 Wire bus communication.

3.3.6.5 Setting the Bit-Banged I²C Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **I²C** tab is used for configuring the I/O port allocation and bit rate of the software bit-banged I²C Bus Functions.



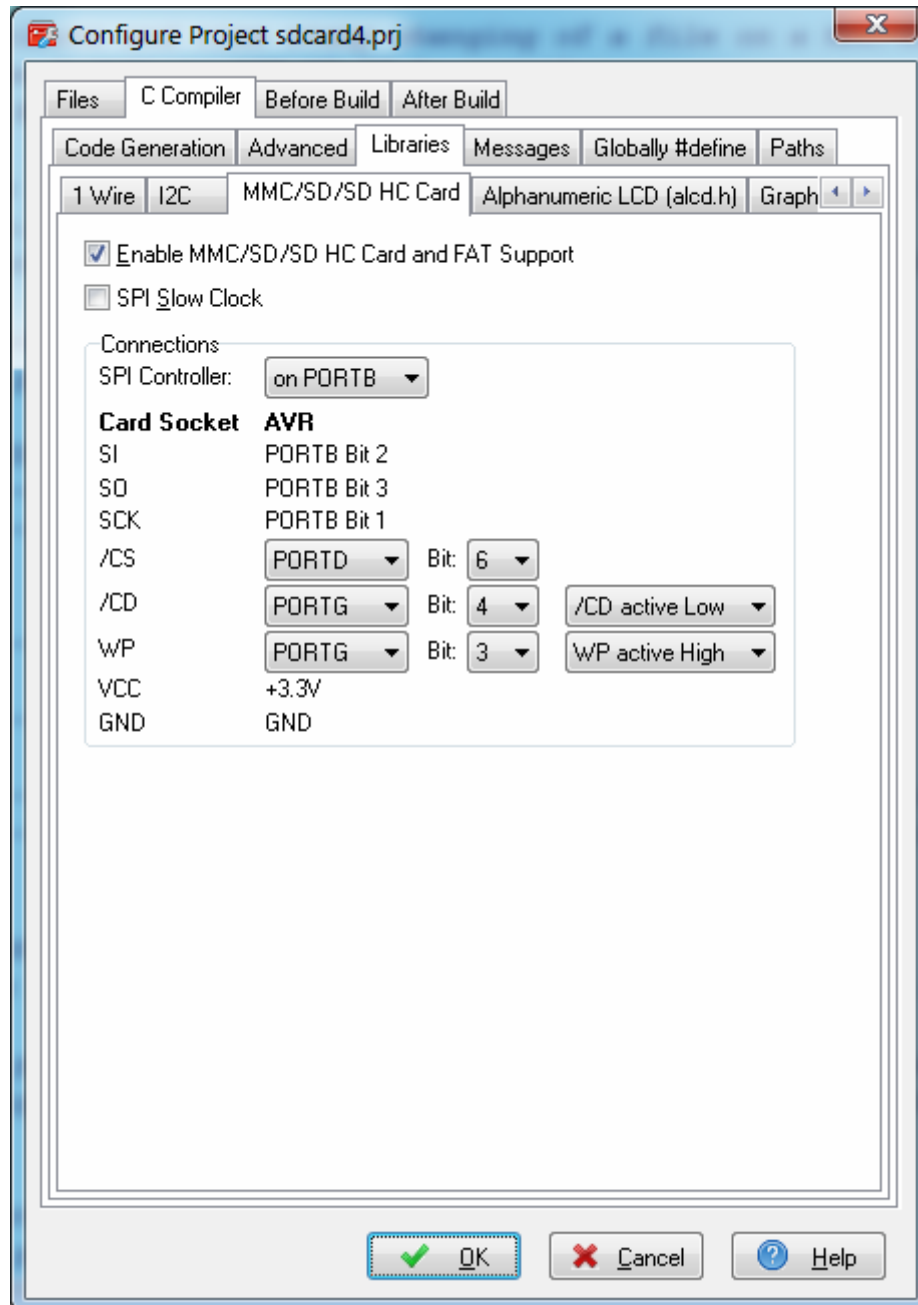
The following settings are available:

- **Enable Bit-Banged I2C Support** allows the activation of the **I²C Bus Functions** library.
- **I/O Port**, **SDA** and **SCL** specify in **Data Connection**, the port and bits used for I²C bus communication
- **Bit Rate** specifies the frequency of the clock pulses on the **SCL** line.

3.3.6.6 Setting the MMC/SD/SD HC Card Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **MMC/SD/SD HC Card** tab is used for configuring the I/O port allocation for the MMC/SD/SD HC FLASH Memory Card Driver Functions.



The **Enable MMC/SD/SD HC Card and FAT Support** check box activates the appropriate **MMC/SD/SD HC FLASH Memory Card Driver** and **FAT Access Functions** libraries.

The **SPI Slow Clock** options allows to use a two times slower data rate when communicating with the MMC/SD/SD HC Card in order to provide better compatibility with some hardware designs.

The user has the possibility to specify the polarity of the **CD (Card Detect)** signal as active **Low** or **High**, and even to disable it's usage.

In this situation, no I/O port signal is allocated for this purpose and the presence of the card must be detected by calling the **sdcard_present** function from the **MMC/SD/SD HC FLASH Memory Card Driver** library.

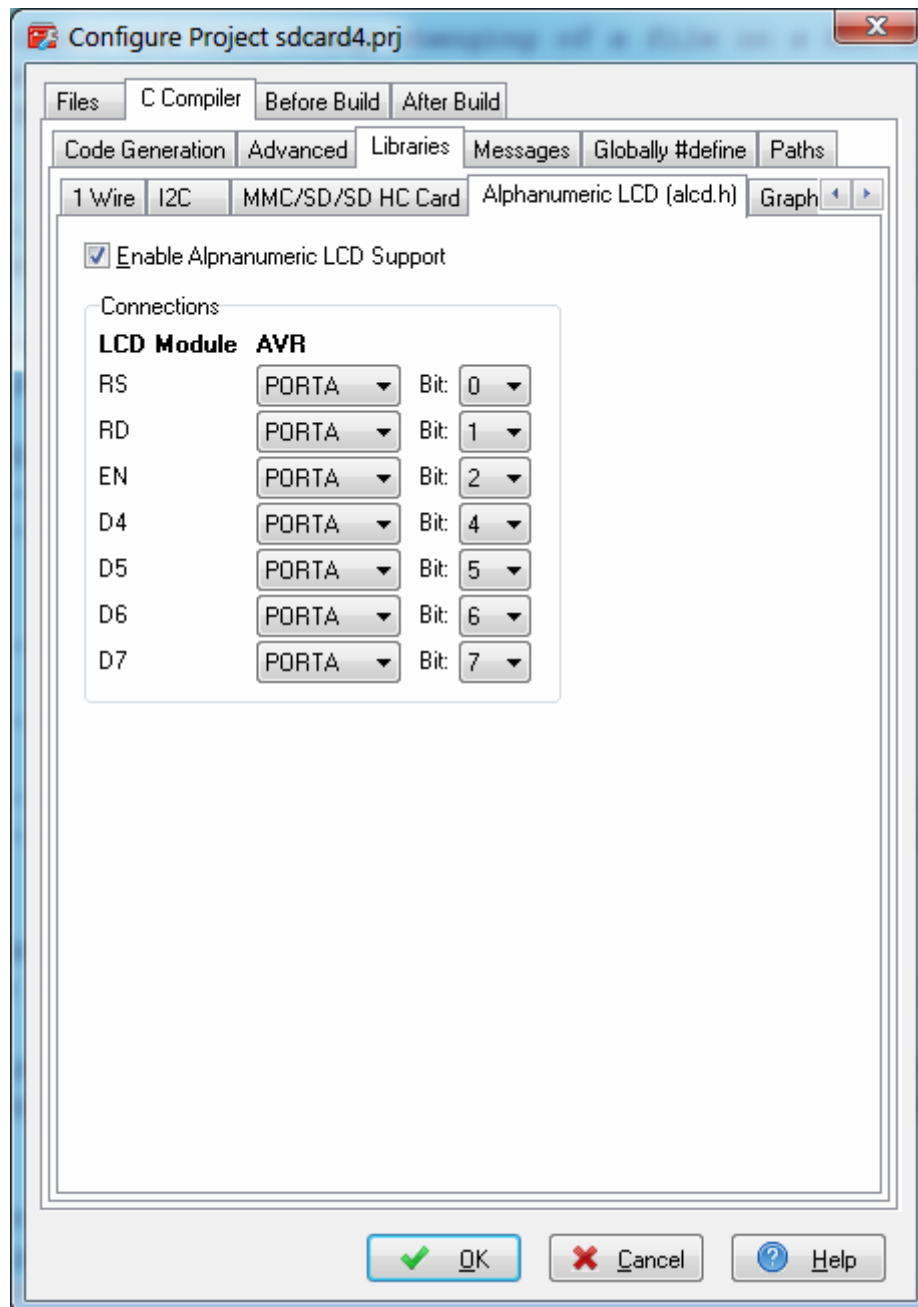
The polarity of the **WP (Write Protect)** signal can also be specified as active **Low** or **High**, or it's usage can be totally disabled.

In this later case, no I/O port signal will be allocated for it.

3.3.6.7 Setting the Alphanumeric LCD Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **Alphanumeric LCD** tab is used for configuring the I/O port allocation for the **LCD Functions** for displays with up to 2x40 characters.



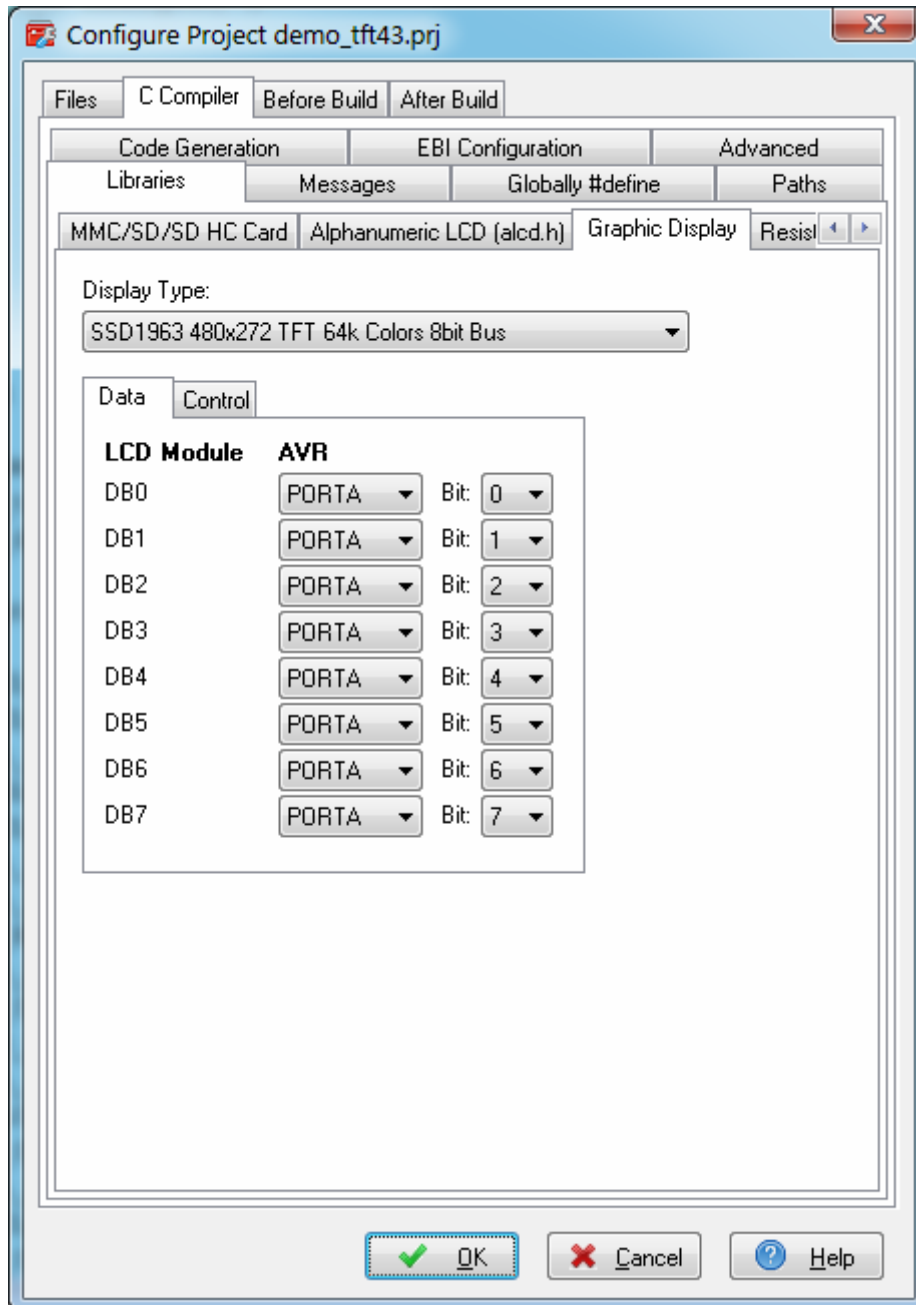
The **Enable Alphanumeric LCD Support** check box activates the configuration specified for the *alcd.h* library functions.

The connections between the LCD module and the AVR I/O ports can be specified individually for each signal in the **Connections** group box.

3.3.6.8 Setting the Graphic Display Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **Graphic Display** tab is used for configuring the I/O port allocation for the **Graphic Display Functions**.



The **Display Type** list box allows to select the graphic controller type and LCD resolution.

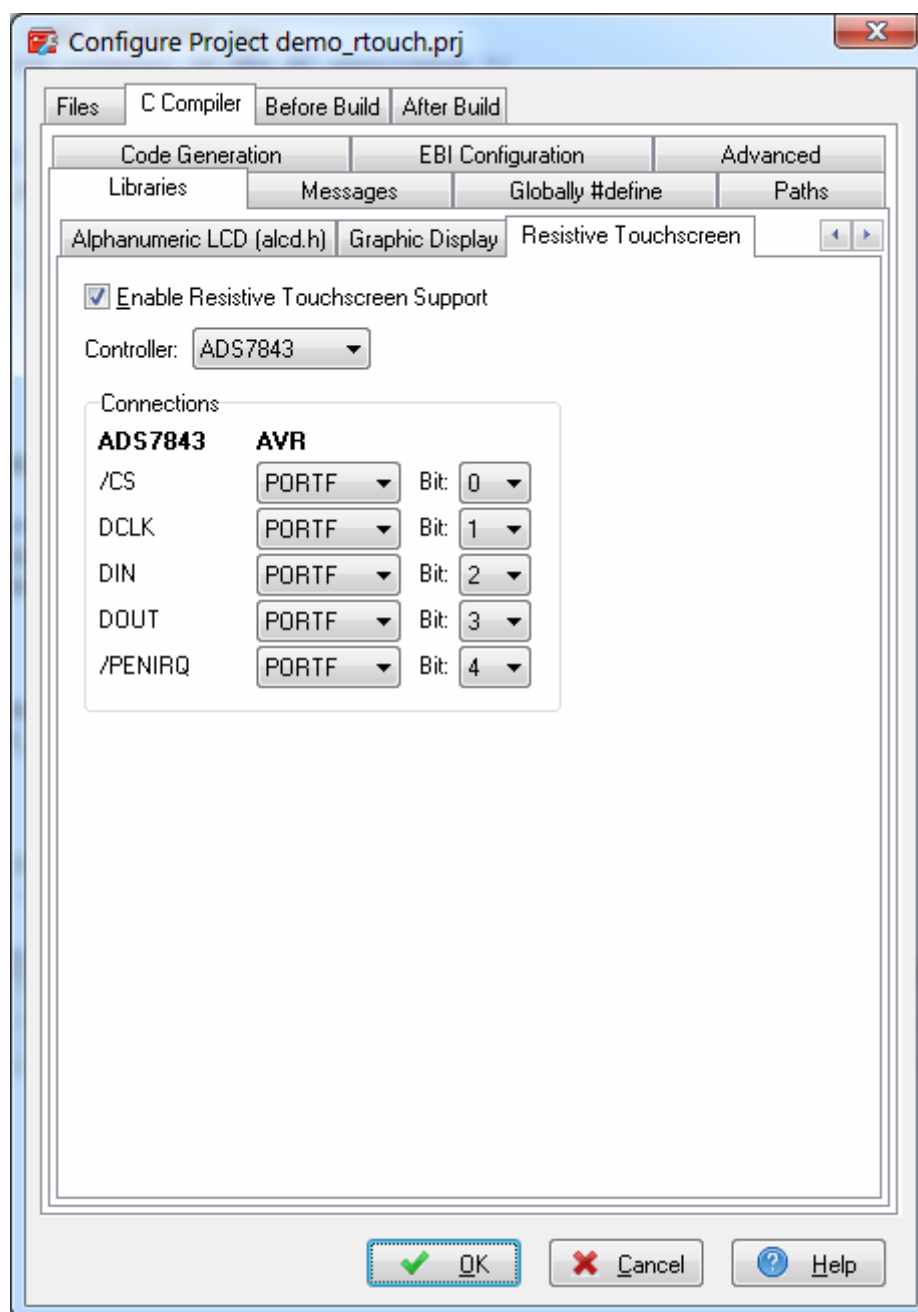
The connections between the graphic display module and the AVR I/O ports can be specified individually for each signal in the **Connections** group box.

Note: In order to obtain maximum performance, it is advised to set the display controller's **data bus** bits to match the bits with the same numbers of the same AVR I/O port.

3.3.6.9 Setting the Resistive Touchscreen Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **Resistive Touchscreen** tab is used for configuring the I/O port allocation for the **Resistive Touchscreen Functions**.



The **Enable Resistive Touchscreen Support** option must be checked in order to enable the usage of the touchscreen library.

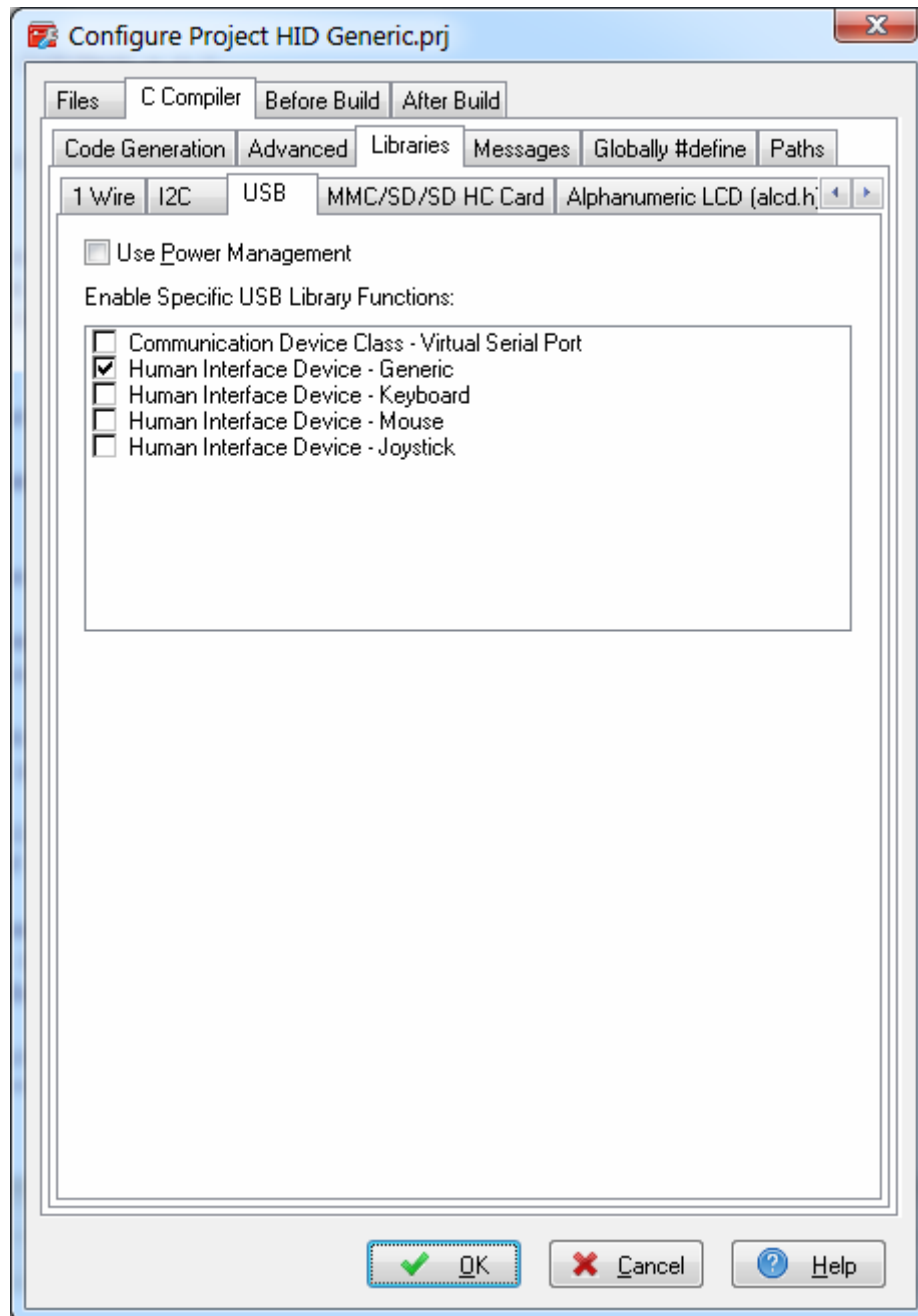
The **Controller** list box allows selecting the resistive touchscreen controller type.

The connections between the touchscreen controller and the AVR I/O ports can be specified individually for each signal in the **Connections** group box.

3.3.6.10 Setting the USB Library Options

The **Libraries** tab is used for configuring specific driver libraries used by the compiler.

The **USB** tab is used for configuring specific features of the CodeVisionAVR USB library.



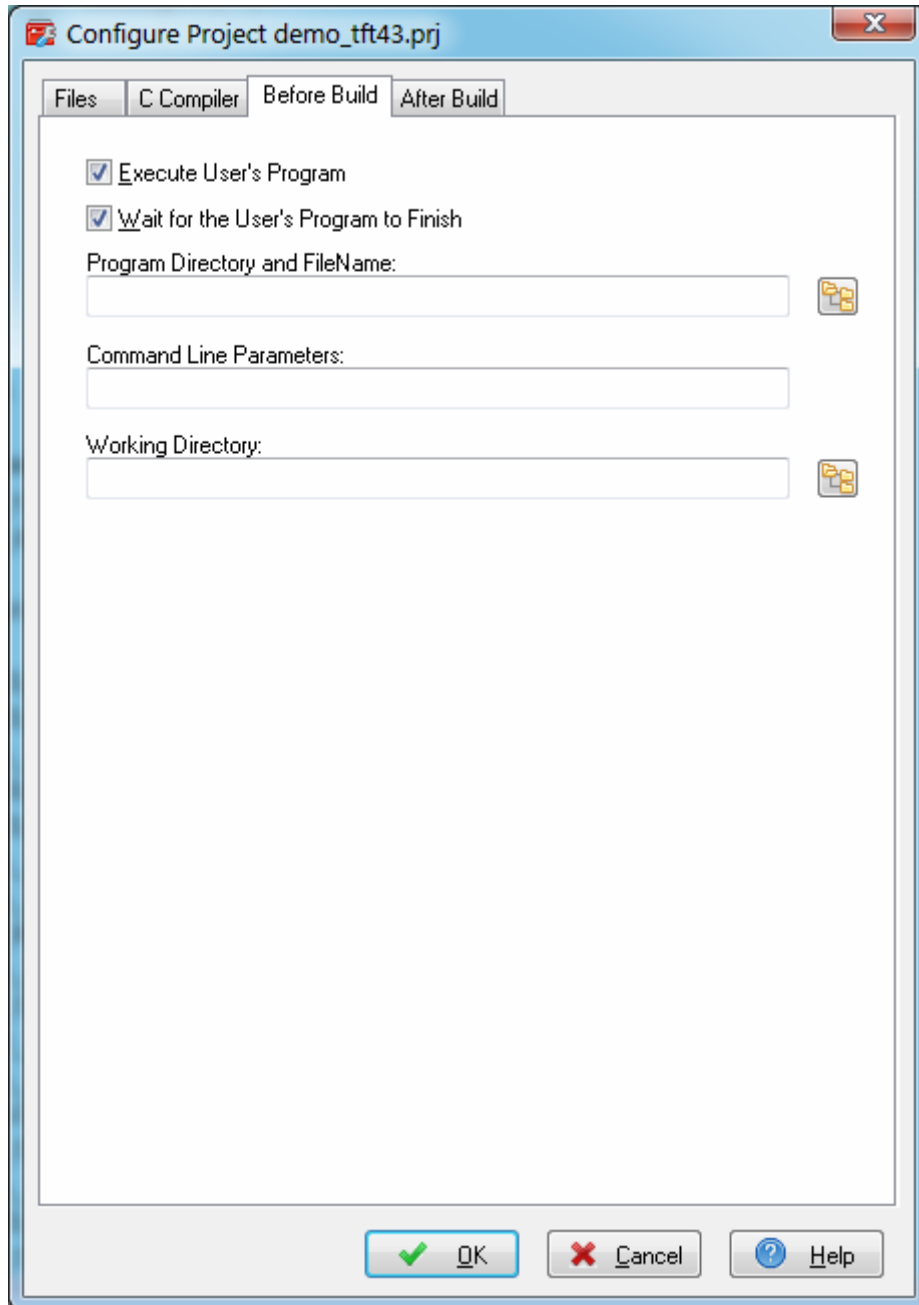
The **Use Power Management** option allows reducing the power consumption, when the USB bus is in the suspended state, by stopping the clock of the PLL used by the USB controller. Enabling this option however increases the program's code size.

Some of the USB library functions require specific features to be enabled in order to support certain USB device classes.

This is accomplished by checking the corresponding option in the **Enable Specific USB Library Functions** list.

3.3.6.11 Executing an User Specified Program before Build

This option is available if you select the **Before Build** tab in the Configure Project window. If you check the **Execute User's Program** option, then a program, that you have previously specified, will be executed before the compilation/assembly process.



The following parameters can be specified for the program to be executed:

- Program Directory and File Name
- Program Command Line Parameters
- Program Working Directory.

There is also the option to wait for the user's program to finish its execution before starting the Build process.

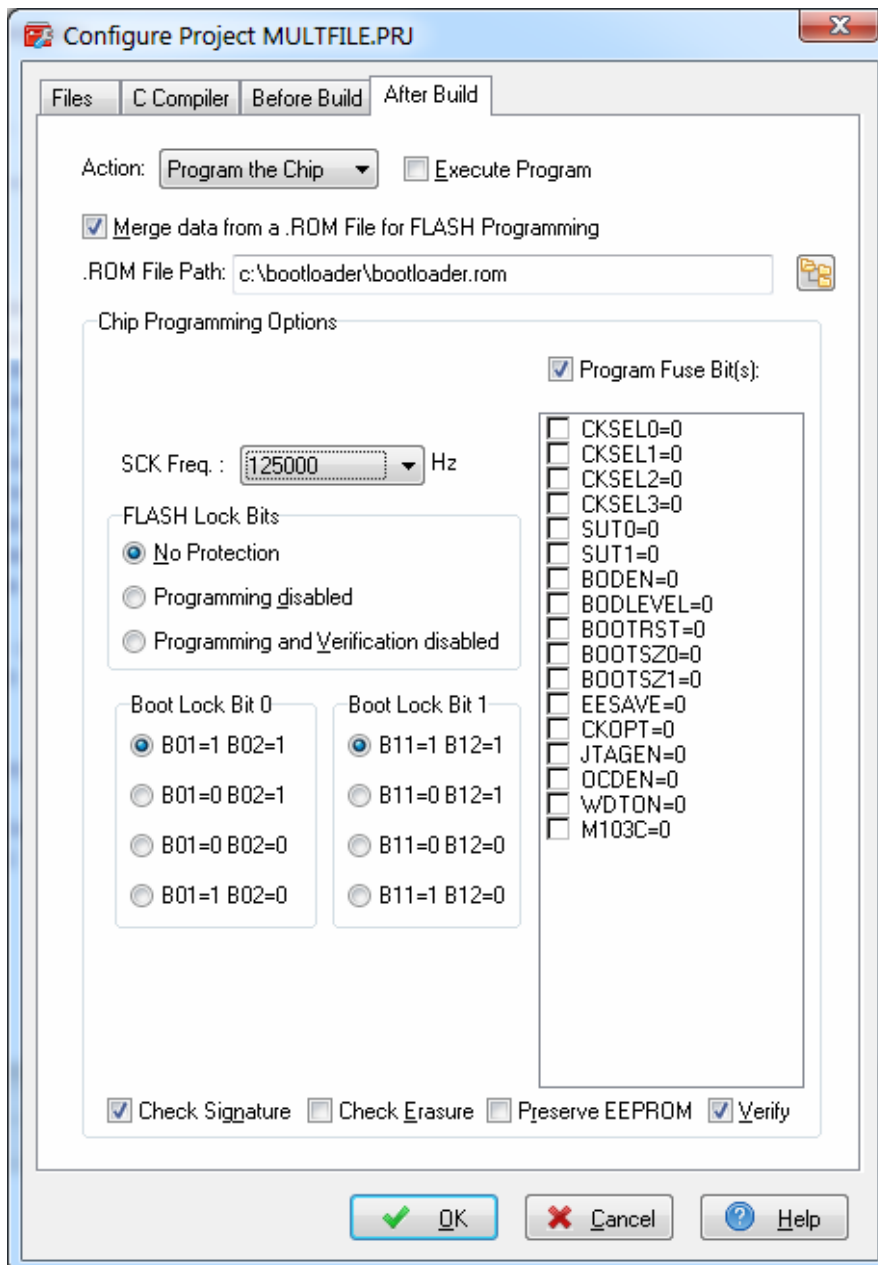
Pressing the  button allows to select a directory and file.

The command line can accept the following parameters:

- %bc substitutes the Active Build Configuration: DEBUG or RELEASE
- %P substitutes the full project path
- %p substitutes the project name without path
- %h substitutes the name of the .hex file created by the compiler
- %e substitutes the name of the .eep file created by the compiler
- %f<project_file_number> substitutes the project's source file name without path
- %F<project_file_number> substitutes the project's source file name with full path.

3.3.6.12 Transferring the Compiled Program to the AVR Chip after Build

This option is available if you select the **After Build** tab in the Configure Project window.



If the **Action|Program the Chip** option is selected, then after successful compilation/assembly your program will be automatically transferred to the AVR chip using the built-in Programmer software.

The following steps are executed automatically:

- Chip erasure
- FLASH and EEPROM blank check
- FLASH programming and verification
- EEPROM programming and verification
- Fuse and Lock Bits programming

The **Merge data from a .ROM File for FLASH Programming** option, if checked, will merge in the FLASH programming buffer the contents of the .ROM file, created by the compiler after Make, with the data from the .ROM file specified in **.ROM File Path**.

This is useful, for example, when adding a boot loader executable compiled in another project, to an application program that will be programmed in the FLASH memory.

You can select the type of the chip you wish to program using the **Chip** combo box.

The SCK clock frequency used for In-System Programming with the STK500, AVRISP or AVRISP MkII can be specified using the **SCK Freq.** listbox. This frequency must not exceed $\frac{1}{4}$ of the chip's clock frequency.

If the chip you have selected has Fuse Bit(s) that may be programmed, then a supplementary **Program Fuse Bit(s)** check box will appear.

If it is checked, then the chip's Fuse Bit(s) will be programmed after **Build**.

The Fuse Bit(s) can set various chip options, which are described in the Atmel data sheets.

If a Fuse Bit(s) check box is checked, then the corresponding fuse bit will be set to 0, the fuse being considered as programmed (as per the convention from the Atmel data sheets).

If a Fuse Bits(s) check box is not checked, then the corresponding fuse bit will be set to 1, the fuse being considered as not programmed.

If you wish to protect your program from copying, you must select the corresponding option using the **FLASH Lock Bits** radio box.

If you wish to check the chip's signature before programming you must use the **Check Signature** option.

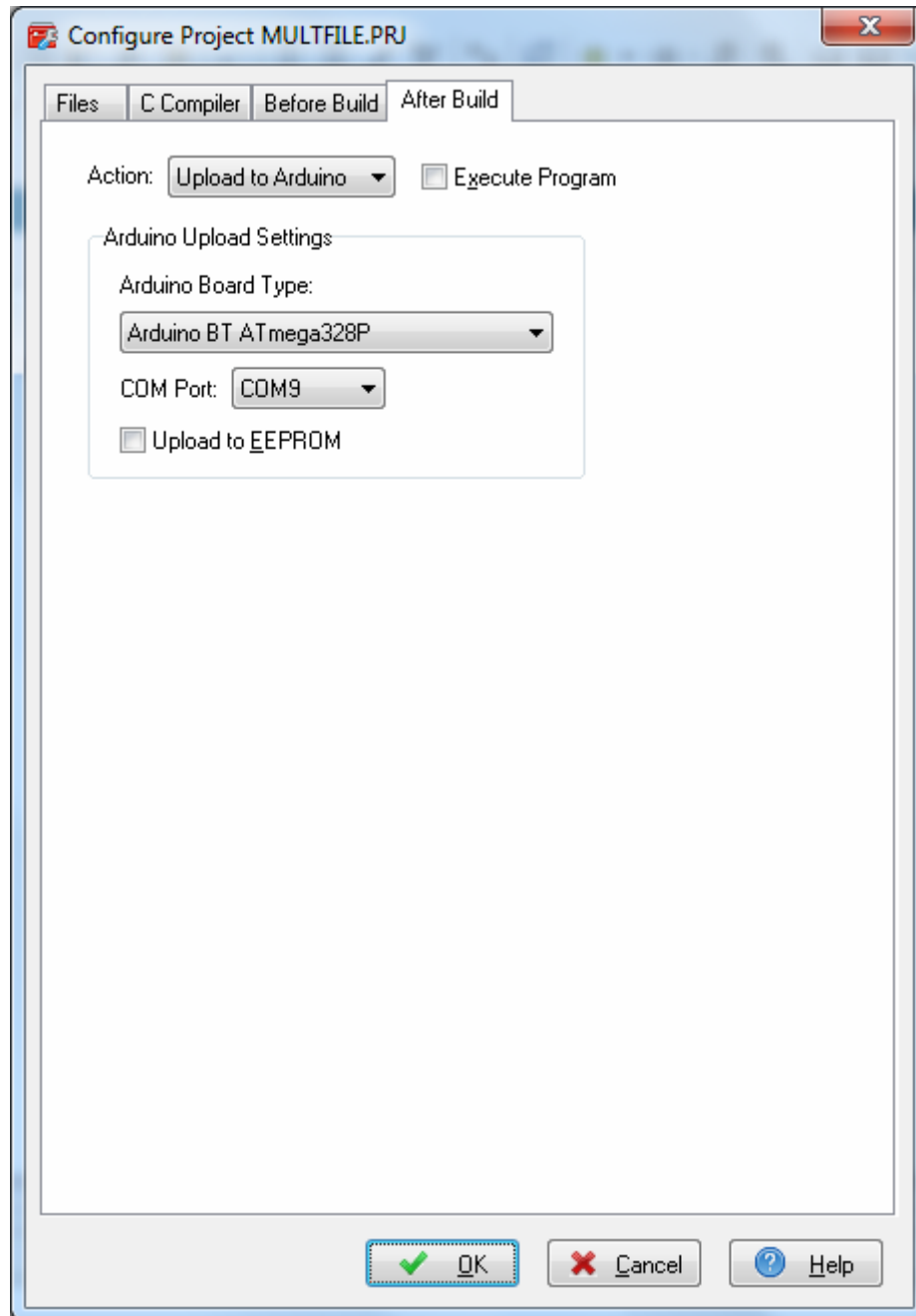
To speed up the programming process you can uncheck the **Check Erasure** check box. In this case there will be no verification of the correctness of the FLASH erasure.

The **Preserve EEPROM** checkbox allows preserving the contents of the EEPROM during chip erasure.

To speed up the programming process you can uncheck the **Verify** check box. In this case there will be no verification of the correctness of the FLASH and EEPROM programming.

CodeVisionAVR

If the project's target chip type is an ATmega8, ATmega168, ATmega328, ATmega1280 or ATmega2560, then there's also the possibility to upload the .hex FLASH contents, respectively .eep EEPROM contents, files to an Arduino compatible development board. This option is selected using **Action|Upload to Arduino**.



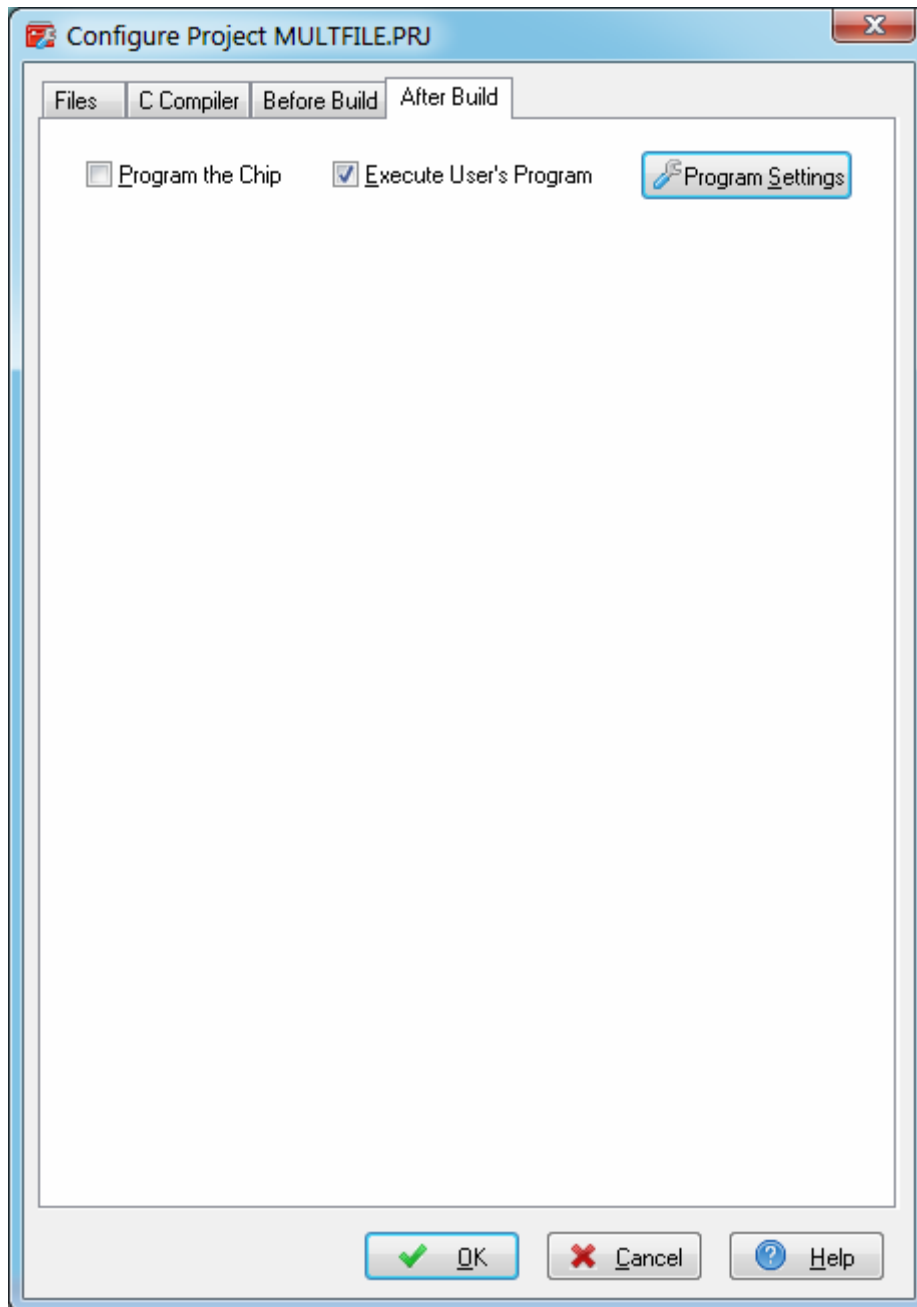
The above dialog window allows selecting the **Arduino Board Type** and the serial **COM Port** used for communication with the development board.

The **Upload to EEPROM** checkbox allows to enable or disable automatic programming of the chip's EEPROM, if the compiler has generated an .EEP file during project build.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

3.3.6.13 Executing an User Specified Program after Build

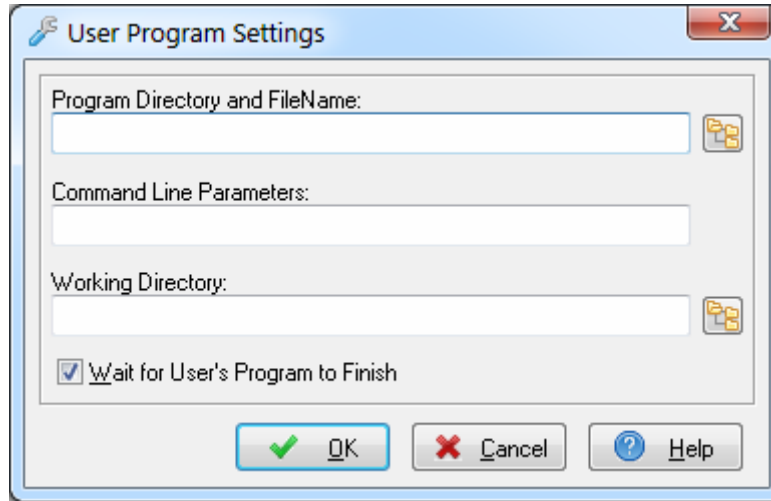
This option is available if you select the **After Build** tab in the Configure Project window. If you check the **Execute User's Program** option, then a program, that you have previously specified, will be executed after the compilation/assembly process.



CodeVisionAVR

Using the **Program Settings** button you can modify the:

- Program Directory and File Name
- Program Command Line Parameters
- Program Working Directory



Pressing the  button allows to select a directory and file.

If the **Wait for User's Program to Finish** option is enabled, any eventual chip programming after build will be performed only after the program will finish execution.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

The command line can accept the following parameters:

- %bc substitutes the Active Build Configuration: DEBUG or RELEASE
- %P substitutes the full project path
- %p substitutes the project name without path
- %h substitutes the name of the **.hex** file created by the compiler
- %e substitutes the name of the **.eep** file created by the compiler
- %l substitutes the name of the **.elf** production file created by the compiler
- %c substitutes the name of the target chip type for which the project is built
- %f<project_file_number> substitutes the project's source file name without path
- %F<project_file_number> substitutes the project's source file name with full path.

3.3.7 Obtaining an Executable Program

Obtaining an executable program requires the following steps:

1. Compiling the Project's C program modules, using the CodeVisionAVR C Compiler, and obtaining object files needed by the linker
2. Linking the object files created during compilation and obtaining a single assembler source file
3. Assembling the assembler source file, using the Atmel AVR assembler AVRASM2.

Compiling, executes step 1.

Building, executes step 1, 2 and 3.

Compilation is performed only for the program modules that were modified since the previous similar process.

This leads to significant project build reduction times, compared with the old CodeVisionAVR V1.xx, where all the program modules were compiled even if they were not changed.

The resulting **.rom**, **.hex**, **.eep** and **.elf** files will be placed in the **Executable Files** directory.

If the **Project|Configure|After Build|Action:Program the Chip** option is enabled, then the **.elf** production file will also contain, besides the FLASH and EEPROM data, the settings for programming the lock and fuse bits.

Alternatively the lock, respectively fuse bits, can be specified in the program source using the **#pragma lock_bits**, respectively **#pragma fuses** compiler directives.

The object files, including the **.cof** COFF object file used for debugging, will be placed in the **Object Files** directory.

The **.asm**, **.lst** and **.map** files will be placed in the **List Files** directory.

Various files created by the linker during the **Build** process will be placed in the **Linker Files** directory.

The **Executable Files**, **Object Files**, **List Files** and **Linker Files** directories are specified in the **Project|Configure|Files|Output** menu.

3.3.7.1 Checking Syntax

Checking the currently edited source file for syntax errors can be performed by using the

Project|Check Syntax menu or by pressing the  toolbar button.

This function is useful because it's faster than **Project|Compile** menu command, which compiles all the modified files in a project.

It can also be executed by selecting **Check Syntax** in the pop-up menu, which is invoked by right clicking with the mouse in the editor window.

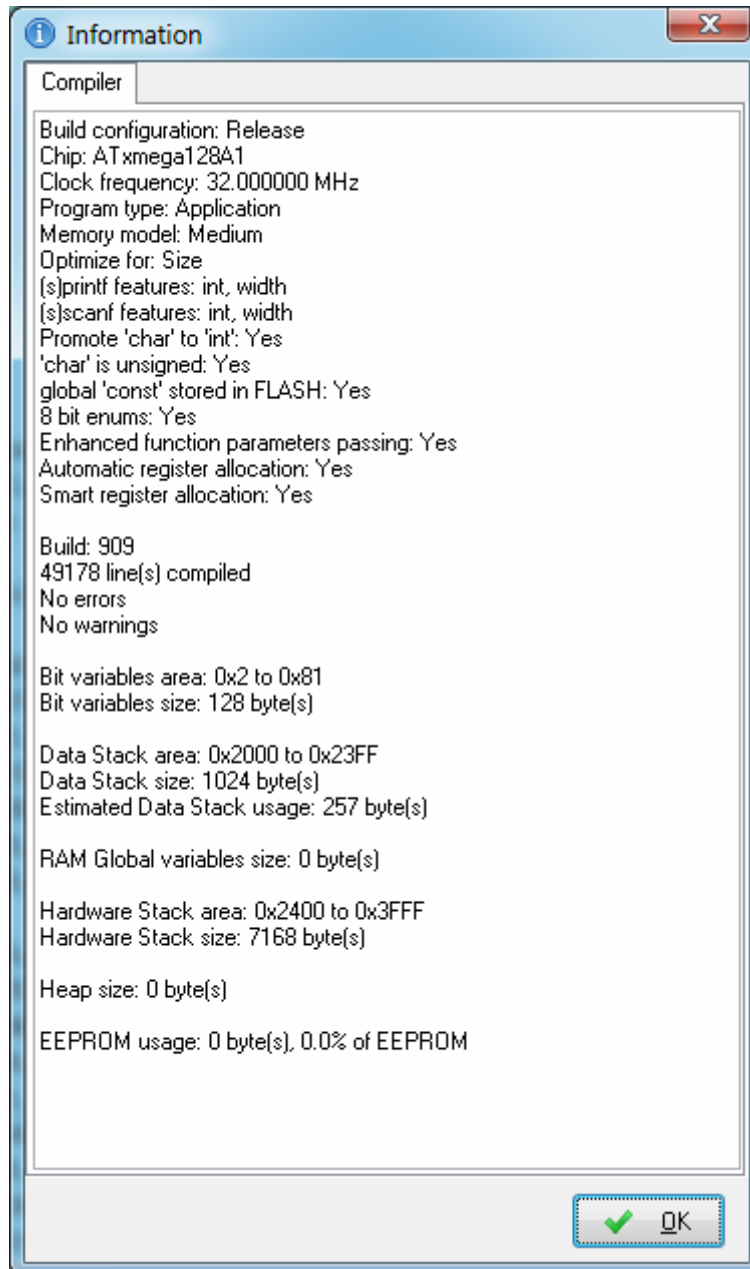
3.3.7.2 Compiling the Project

To compile the Project you must use the **Project|Compile** menu command, press the **F9** key or the  button of the toolbar. The CodeVisionAVR C Compiler will be executed, producing the object files needed by the linker.

Compilation will be performed only for the program modules that were modified since the previous similar process.

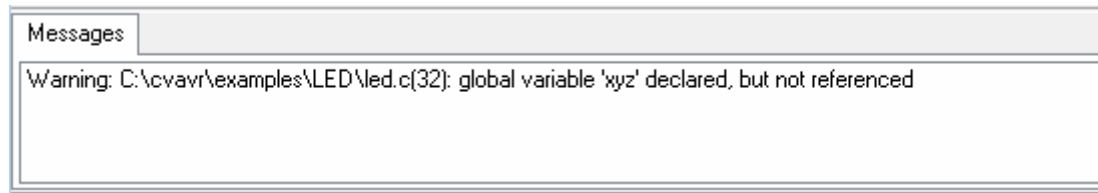
The compilation process can be stopped using the **Project|Stop Compilation** menu command or by pressing the  button on the toolbar.

After the compilation is complete, an **Information** window will open, showing the compilation results.

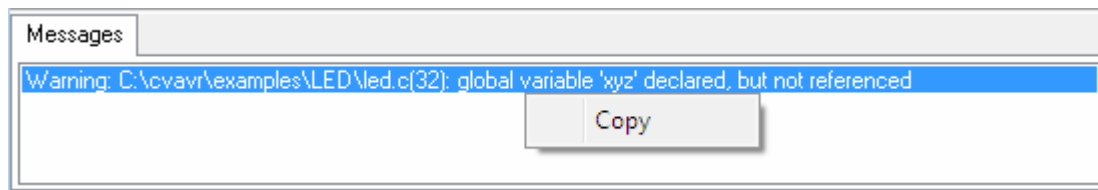


CodeVisionAVR

Eventual compilation errors and/or warnings will be listed in the **Message** window located under the **Editor** window, or in the **Code Navigator** window.



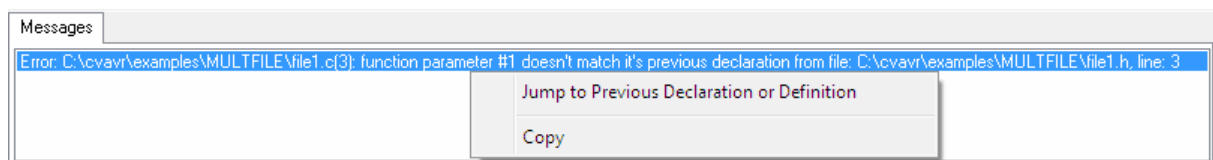
By left clicking with the mouse on the error or warning message, the source line with the problem will be highlighted.
Right clicking with mouse opens a pop-up menu that contains the option to **Copy** the error message to the clipboard:



The **Project|Go to Next Error**, respectively **Project|Go to Previous Error** menu commands, the **F8**, respectively **Ctrl+F8** keys or the , respectively  toolbar buttons, allow moving to the next, respectively previous error message.

The **Project|Go to Next Warning**, respectively **Project|Go to Previous Warning** menu commands, the **F4**, respectively **Ctrl+F4** keys or the , respectively  toolbar buttons, allow moving to the next, respectively previous warning message.

If the message refers also to a previous declaration or definition from a file that is different than the one where the error was signaled, right clicking with the mouse opens a pop-up menu with the **Jump to Previous Declaration or Definition** option:



Selecting this option will highlight the source line where the previous declaration or definition was made.

The size of the **Message** window can be modified using the horizontal slider bar placed between it and the **Editor** window.

3.3.7.3 Building the Project

To build the Project you must use the **Project|Build** menu command, press the **Shift+F9** keys or the  button of the toolbar. The CodeVisionAVR C Compiler will be executed, producing the object files needed by the linker.

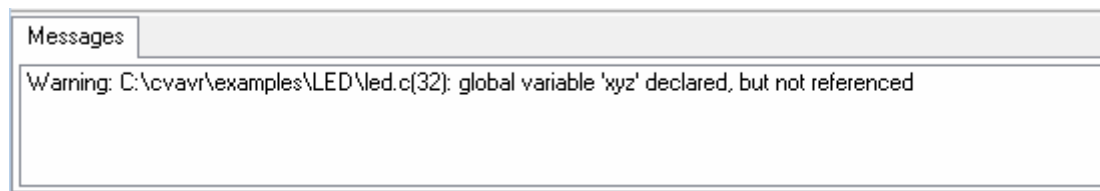
Compilation will be performed only for the program modules that were modified since the previous similar process.

If the complete recompilation of all the program modules is needed, then the **Project|Build All** menu command or the  button of the toolbar must be used.

After successful compilation the object files will be linked and an assembly **.asm** file will be produced. If no compilation or linking errors were encountered, then the Atmel AVR assembler AVRASM2 will be executed, obtaining the output file types specified in **Project|Configure|C Compiler|Code Generation**.

The build process can be stopped using the **Project|Stop Compilation** menu command or by pressing the  button on the toolbar.

Eventual compilation errors and/or warnings will be listed in the **Message** window located under the **Editor** window, or in the **Code Navigator** window.

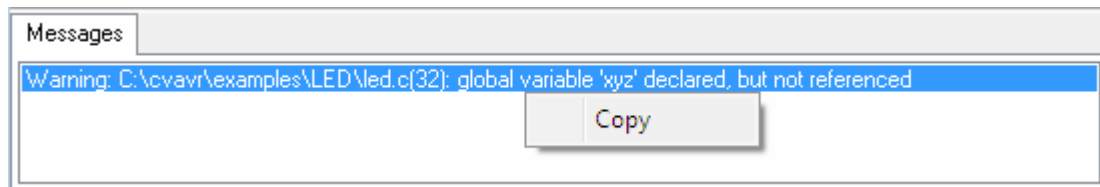


The **Project|Go to Next Error**, respectively **Project|Go to Previous Error** menu commands, the **F8**, respectively **Ctrl+F8** keys or the , respectively  toolbar buttons, allow moving to the next, respectively previous error message.

The **Project|Go to Next Warning**, respectively **Project|Go to Previous Warning** menu commands, the **F4**, respectively **Ctrl+F4** keys or the , respectively  toolbar buttons, allow moving to the next, respectively previous warning message.

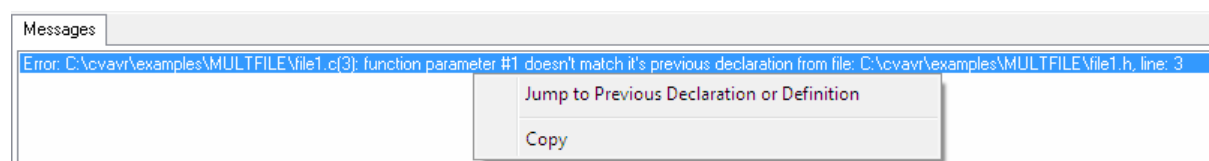
By left clicking with the mouse on the error or warning message, the source line with the problem will be highlighted.

Right clicking with mouse opens a pop-up menu that contains the option to **Copy** the error message to the clipboard:



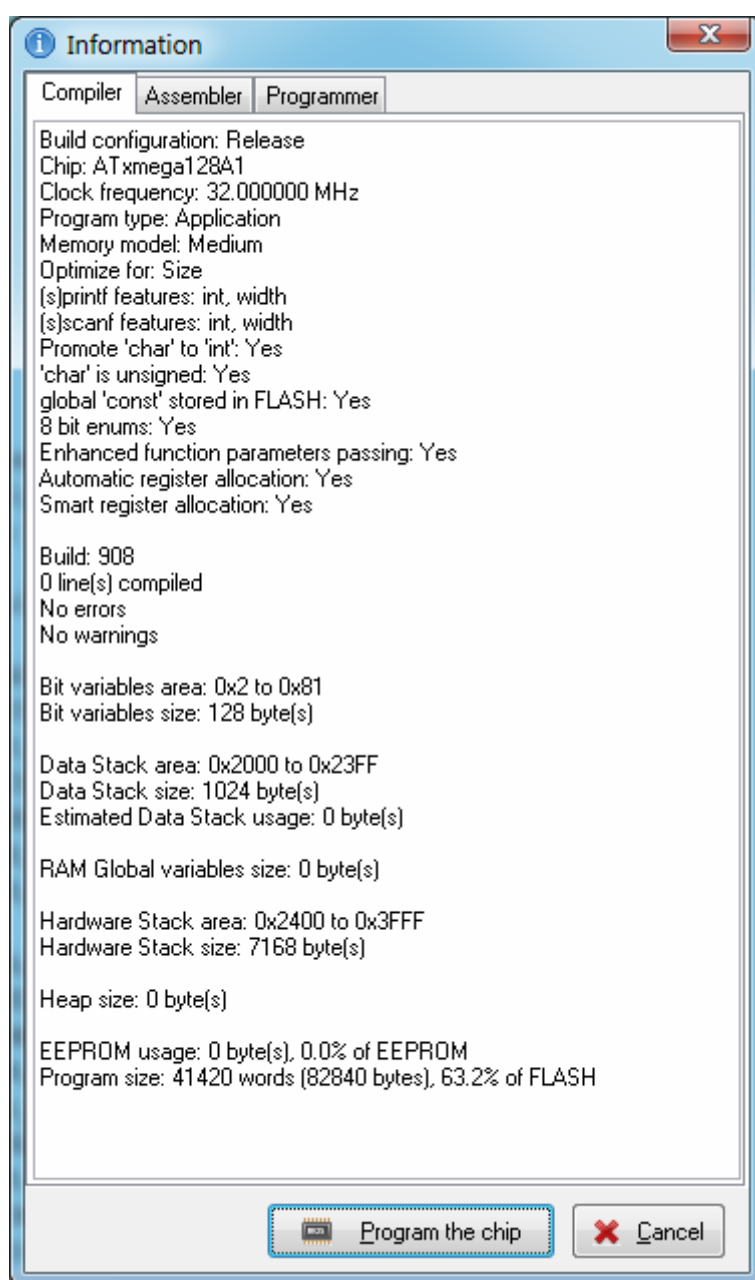
CodeVisionAVR

If the message refers also to a previous declaration or definition from a file that is different than the one where the error was signaled, right clicking with the mouse opens a pop-up menu with the **Jump to Previous Declaration or Definition** option:



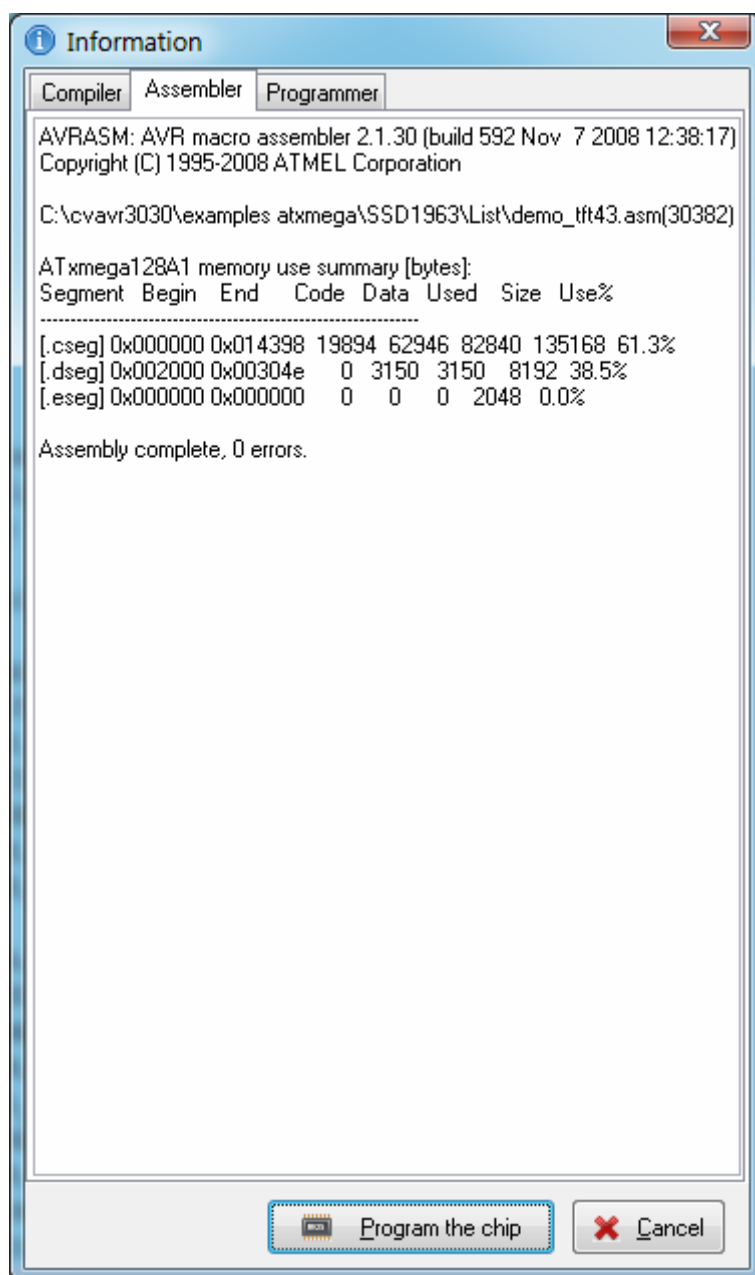
Selecting this option will highlight the source line where the previous declaration or definition was made.

After the build process is completed, an **Information** window will open showing the build results. Pressing the **Compiler** tab will display compilation results.



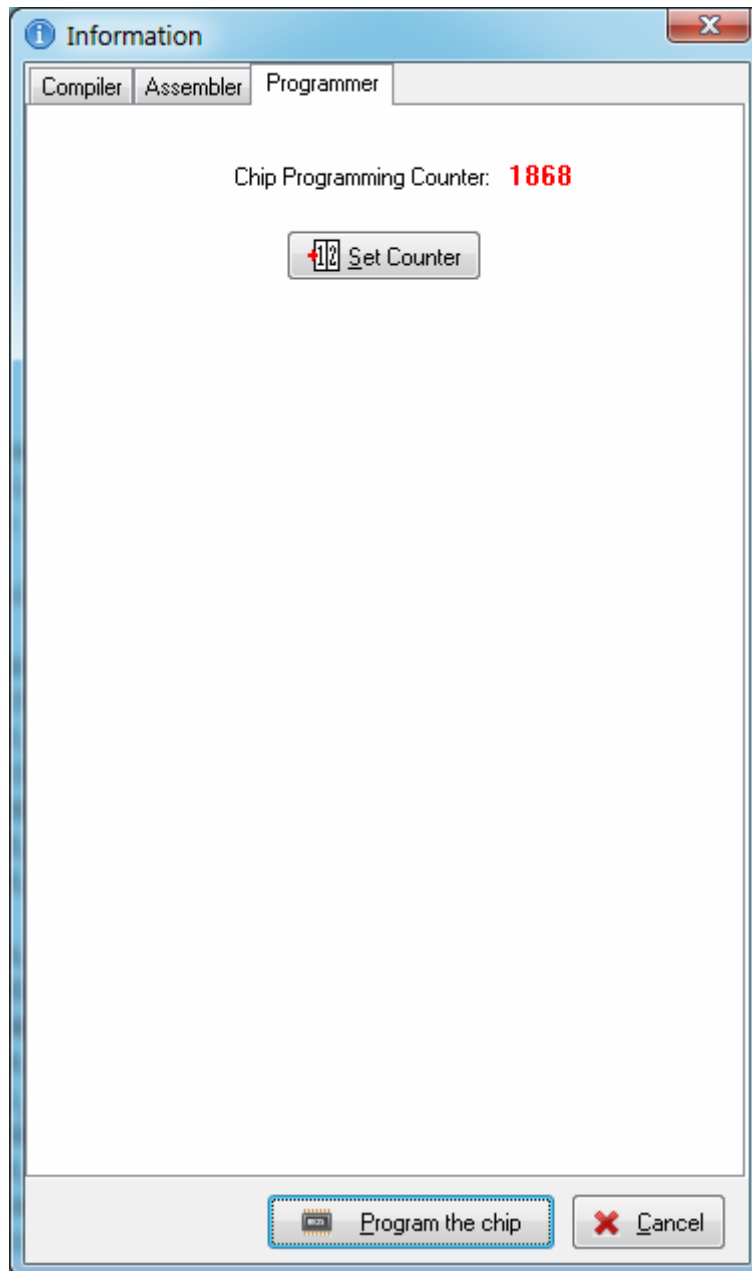
CodeVisionAVR

Pressing the **Assembler** tab will display assembly results.



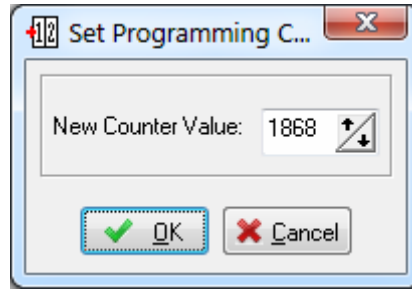
CodeVisionAVR

Pressing the **Programmer** tab will display the **Chip Programming Counter**, which shows how many times was the AVR chip programmed so far.



CodeVisionAVR

Pressing the **Set Counter** button will open the **Set Programming Counter** window:



This dialog window allows setting the new **Chip Programming Counter** value.

Pressing the **Program the chip** button allows automatic programming of the AVR chip after successful build. Pressing **Cancel** will disable automatic programming.

3.3.7.4 Cleaning Up the Project Output Directories

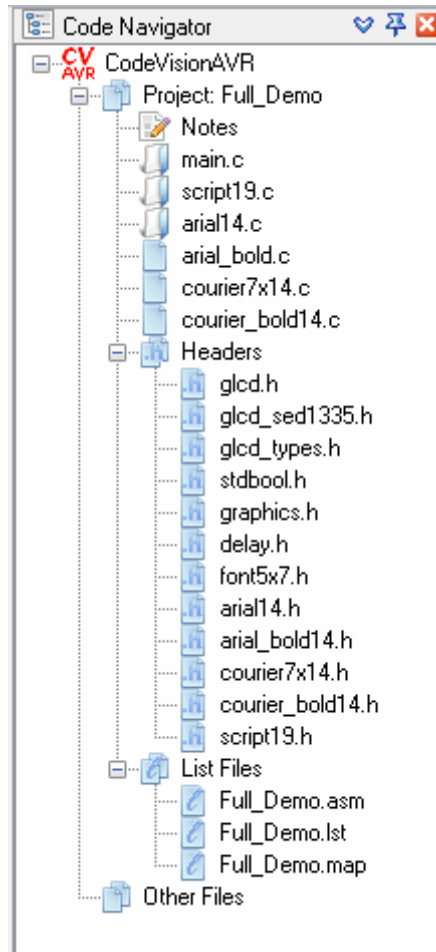
The various files created during the **Project Build** process can be deleted using the **Project|Clean Up** menu or by pressing the  button on the toolbar.

The following **Project Output Directories** will be cleaned:

- **Object Files** directory - all files will be deleted, except the **.cof** COFF object file
- **List Files** directory - all files will be deleted, except the **.asm** and **.vec** assembly source files
- **Linker Files** directory – all files will be deleted.

3.3.7.5 Using the Code Navigator

The **Code Navigator** window allows displaying or opening of the project source files, along with errors or warnings that occurred during the compile or build processes.



The project's program modules are listed as children of the **Project** node. Other opened files, that are not part of the project, are listed as children of the **Other Files** node. By clicking on a closed file node, the appropriate file is opened in the editor. If the file is already opened, clicking on its node, will make it active in the editor.

After a **Compile** or **Build** process there is also displayed a list of header .h files that were #included in the project's program modules during this process.

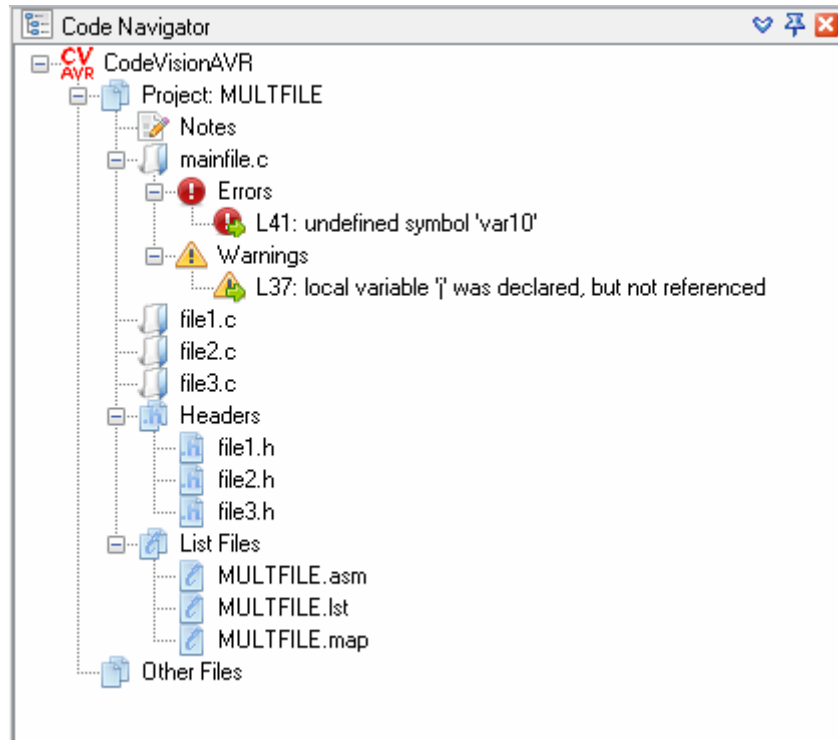
The headers files are available as children of the **Headers** node. By clicking on a closed header file node, the appropriate file is opened in the editor. If the header file is already opened, clicking on its node, will make it active in the editor.

The **List Files** node contains the assembly, list and map files generated by the compiler after the **Compile** or **Build** process.

By clicking on a closed list file node, the appropriate file is opened in the editor. If the list file is already opened, clicking on its node, will make it active in the editor.

CodeVisionAVR

If during compilation there are errors or warnings, these are also displayed in the **Code Navigator** window.



By clicking on the error  or warning  node, the corresponding source line is highlighted in the appropriate file.

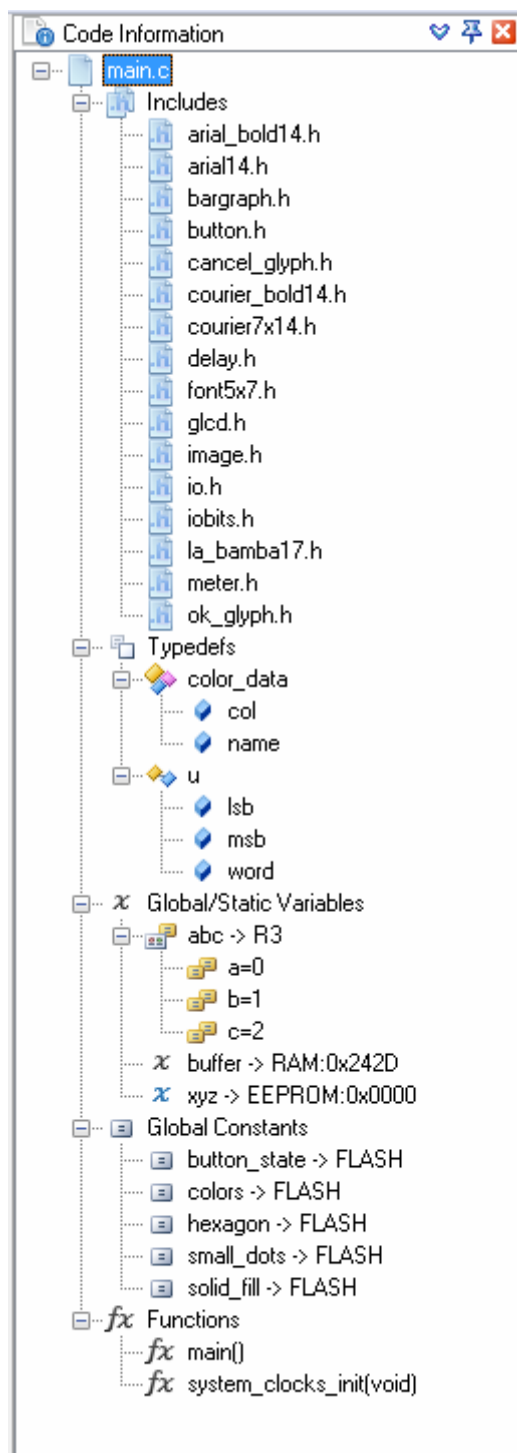
The **Code Navigator** tree branches can be expanded, respectively collapsed, by clicking on the **+**, respectively **-**, buttons.

By right clicking in the **Code Navigator** window you can open a pop-up menu with the following choices:

- **Open** a file
- **Save** the currently edited file
- **Save All** opened files
- **Close** currently edited file
- **Close All** opened files
- Toggle on or off alphabetically sorting the files in the **Code Navigator**
- Toggle on or off expanding the **Errors** and **Warnings** branches after a **Compile** or **Build** process
- Toggle on or off expanding the header file branches.

3.3.7.6 Using the Code Information

The **Code Information** window allows for easy access to declarations and definitions made in the currently edited source file.



The **Code Information** window is accessed using the tab with the same name and appears after the first **Compile** or **Build** process of the currently opened project.

CodeVisionAVR

The information is displayed in the form of a tree with several types of nodes:

- **Includes**  node which displays all the header .h files #included in the currently edited source file. Clicking on a header  node moves the cursor to the corresponding #include directive in the edited source file.
- **Macros**  node which displays all the preprocessor macros defined in the currently edited source file. Clicking on a macro  node moves the cursor to the corresponding #define directive in the edited source file.
- **Typedefs**  node which displays all the data types defined in the currently edited source file. Clicking on a type definition  node moves the cursor to the corresponding data type definition in the edited source file. If the defined data type is a structure , union  or enumeration , then its members/items are displayed as additional  or  nodes.
- **Global/Static Variables**  node which displays all the global and static variables declared in the currently edited source file. Clicking on a RAM variable  node or EEPROM variable  node moves the cursor to the corresponding declaration in the edited source file.
- **Global Constants**  node which displays all the global constants declared in the currently edited source file. Clicking on a constant  node moves the cursor to the corresponding declaration in the edited source file.
- **Functions**  node which displays all the functions that were defined in the currently edited source file. Clicking on a function  node moves the cursor to the corresponding definition in the edited source file.

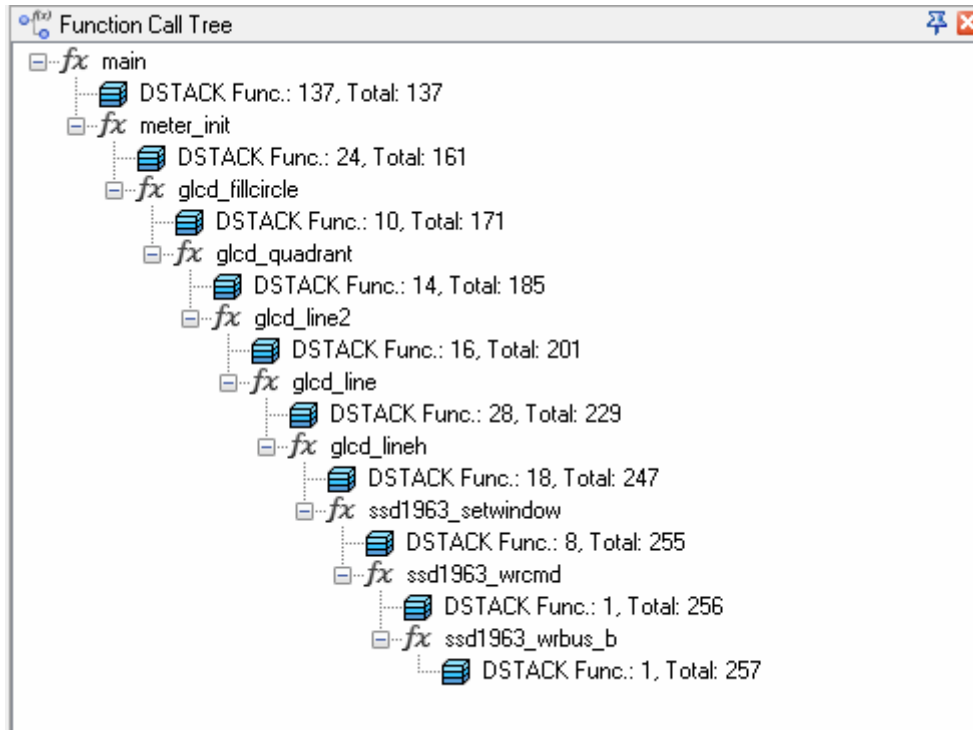
The **Code Information** tree branches can be expanded, respectively collapsed, by clicking on the +, respectively -, buttons.

By right clicking in the **Code Information** window you can open a pop-up menu with the following choices:

- Toggle on or off alphabetically sorting the items in the **Code Information** tree
- Toggle on or off expanding the **Code Information** tree branches.

3.3.7.7 Using the Function Call Tree

The **Function Call Tree** window displays the function call sequence that uses the largest amount of Data Stack during program execution.



The **Function Call Tree** window is accessed using the tab with the same name and appears after the first **Compile** or **Build** process of the currently opened project.

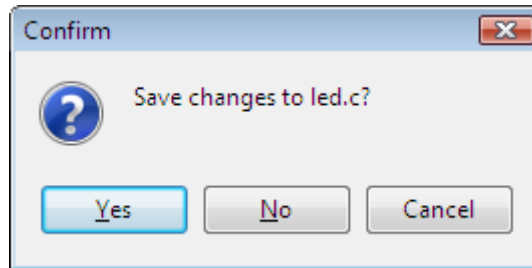
The Data Stack usage information is represented in the form of a tree with two types of nodes:

- Function *fx* nodes. Clicking on a function name moves the cursor to the corresponding definition in the source file.
- DSTACK nodes display the data stack used by the parent function and the total level of the Data Stack when the program is executed inside the function.

3.3.8 Closing a Project

You can quit working with the current Project by using the **File|Close All** menu command or the  toolbar button.

If the Project files were modified, and were not saved yet, you will be asked if you want to do that.



Pressing **Yes** will save changes and close the project.

Pressing **No** will close the project without saving the changes.

Pressing **Cancel** will disable the project closing process.

When saving, the IDE will create a backup file with a **.prj~** extension.

3.4 Tools

Using the **Tools** menu you can execute other programs without exiting the CodeVisionAVR IDE.

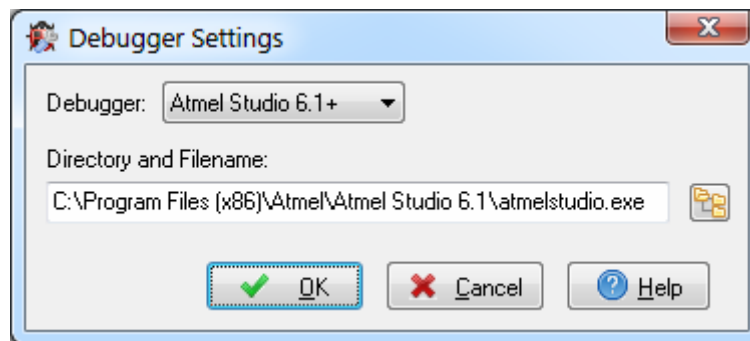
3.4.1 The AVR Debugger

The CodeVisionAVR C Compiler is designed to work along with the following debuggers from Atmel:

- AVR Studio 4.19
- Atmel Studio 6
- Atmel Studio 7

The compiler will generate a .COF object file that can be opened with the above mentioned programs, allowing C source and assembly debugging.

Before you can invoke the debugger, you must first specify its location and file name using the **Settings|Debugger** menu command.



The **Debugger** list box allows to select one of the three versions of debuggers compatible with CodeVisionAVR.

After selecting the debugger, the IDE will detect automatically its installation path and display it in the **Directory and Filename** edit box.

This path can be also manually edited and eventually other location can be selected by pressing the  button.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

The debugger is executed by selecting the **Tools|Debugger** menu command or by pressing the  button on the toolbar.

Details about using the debuggers with CodeVisionAVR can be found in the following chapters:

2. Using the CodeVisionAVR Extension for Atmel Studio

4.21 Using the AVR Studio 4.19 Debugger.

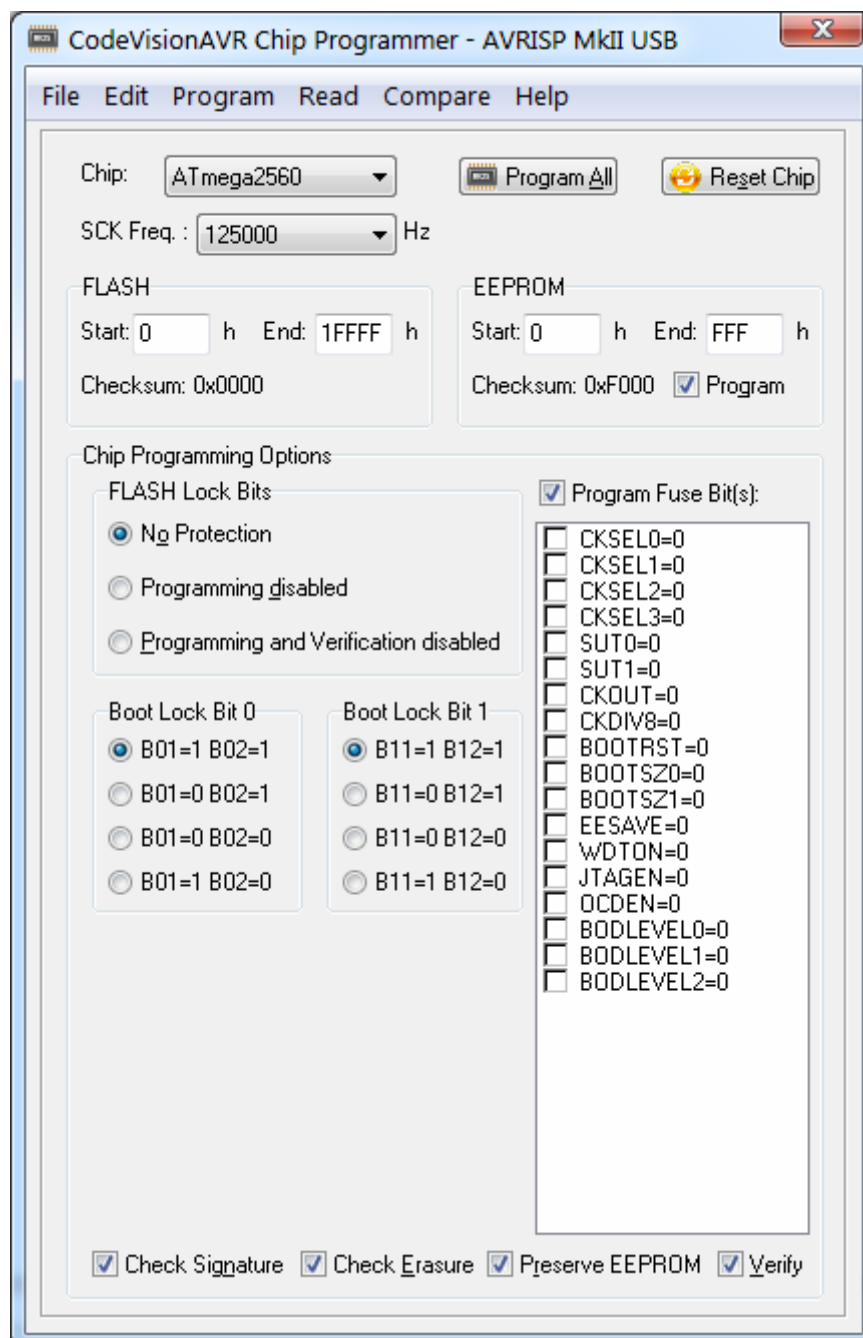
3.4.2 The AVR Chip Programmer

The CodeVisionAVR IDE has a built-in **In-System AVR Chip Programmer** that lets you easily transfer your compiled program to the microcontroller for testing.

The Programmer is designed to work with the Atmel STK500, AVRISP, AVRISP MkII, AVR Dragon, JTAGICE MkII, JTAGICE 3, AVRProg (AVR910 application note), Kanda Systems STK200+, STK300, Dontronics DT006, Vogel Elektronik VTEC-ISP, Futurlec JRAVR or the MicroTronics ATCPU, Mega2000 development boards.

The type of the used programmer and the printer port can be selected by using the **Settings|Programmer** menu command.

The Programmer is executed by selecting the **Tools|Chip Programmer** menu command or by pressing the  button on the toolbar.



CodeVisionAVR

You can select the type of the chip you wish to program using the **Chip** combo box.

The SCK clock frequency used for In-System Programming with the STK500, AVRISP or AVRISP MkII can be specified using the **SCK Freq.** listbox. This frequency must not exceed $\frac{1}{4}$ of the chip's clock frequency.

The **EEPROM|Program** check box allows to enable or disable EEPROM programming when the **Program|All** menu command is executed or when the  **Program All** button is pressed.

If the chip you have selected has Fuse Bit(s) that may be programmed, then a supplementary **Program Fuse Bit(s)** check box will appear.

If it is checked, then the chip's Fuse Bit(s) will be programmed when the **Program|All** menu command is executed or when the  **Program All** button is pressed.

The Fuse Bit(s) can set various chip options, which are described in the Atmel data sheets.

If a Fuse Bit(s) check box is checked, then the corresponding fuse bit will be set to 0, the fuse being considered as programmed (as per the convention from the Atmel data sheets).

If a Fuse Bits(s) check box is not checked, then the corresponding fuse bit will be set to 1, the fuse being considered as not programmed.

If you wish to protect your program from copying, you must select the corresponding option using the **FLASH Lock Bits** radio box.

The Programmer has two memory buffers:

- The FLASH memory buffer
- The EEPROM memory buffer.

You can Load or Save the contents of these buffers using the **File** menu.

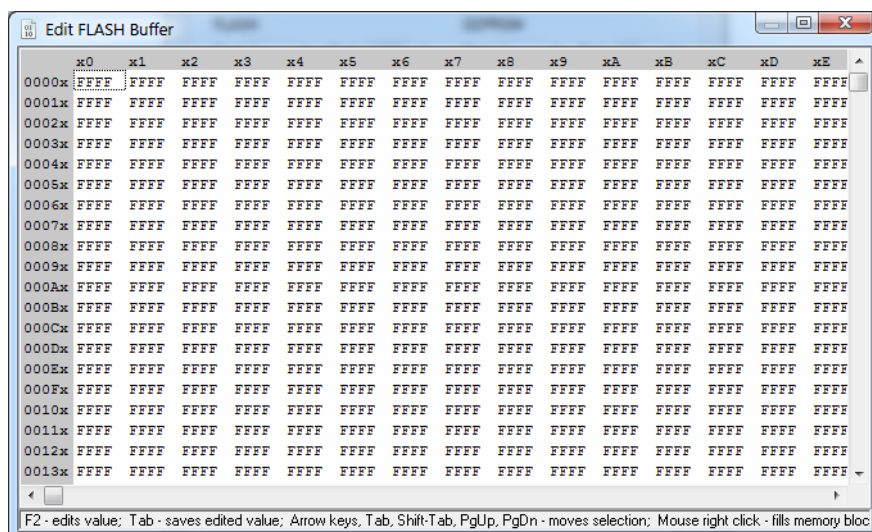
Supported file formats are:

- Atmel ELF production files
- Atmel .rom and .eep
- Intel HEX
- Binary .bin

After loading a file in the corresponding buffer, the **Start** and **End** addresses are updated accordingly. You may also edit these addresses if you wish.

The contents of the FLASH, respectively EEPROM, buffers can be displayed and edited using the **Edit|FLASH**, respectively **Edit|EEPROM** menu commands.

When one of these commands is invoked, an Edit window displaying the corresponding buffer contents will open:

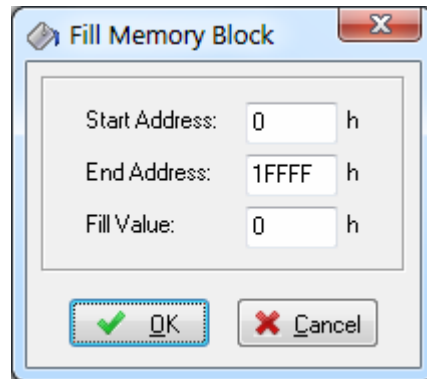


CodeVisionAVR

The buffer's contents, at the highlighted address, can be edited by pressing the **F2** key and typing in the new value. The edited value is saved by pressing the **Tab** or **arrow** keys.

The highlighted address can be modified using the **arrow**, **Tab**, **Shift+Tab**, **PageUp** or **PageDown** keys.

The **Fill Memory Block** window can be opened by right clicking in the Edit window:



This window lets you specify the **Start Address**, **End Address** and **Fill Value** of the memory area to be filled.

If you wish to check the chip's signature before any operation you must use the **Check Signature** option.

To speed up the programming process you can uncheck the **Check Erasure** check box. In this case there will be no verification of the correctness of the FLASH erasure.

The **Preserve EEPROM** checkbox allows preserving the contents of the EEPROM during chip erasure.

To speed up the programming process you also can uncheck the **Verify** check box. In this case there will be no verification of the correctness of the FLASH and EEPROM programming.

For erasing a chip's FLASH and EEPROM you must select the **Program|Erase** menu command.

After erasure the chip's FLASH and EEPROM are automatically blank checked.

For simple blank checking you must use the **Program|Blank Check** menu command.

If you wish to program the FLASH with the contents of the FLASH buffer you must use the **Program|FLASH** menu command.

For programming the EEPROM you must use the **Program|EEPROM** menu command.

After programming the FLASH and EEPROM are automatically verified.

To program the Lock, respectively the Fuse Bit(s) you must use the **Program|Fuse Bit(s)**, respectively **Program|Lock Bits** menu commands.

The **Program|All** menu command allows to automatically:

- Erase the chip
- FLASH and EEPROM blank check
- Program and verify the FLASH
- Program and verify the EEPROM
- Program the Fuse and Lock Bits.

If you wish to read the contents of the chip's FLASH, respectively EEPROM, you must use the **Read|FLASH**, respectively **Read|EEPROM** menu commands.

For reading the chip's signature you must use the **Read|Chip Signature** menu command.

To read the Lock, respectively the Fuse Bits you must use the **Read|Lock Bits**, respectively **Read|Fuse Bits** menu commands.

CodeVisionAVR

For some devices there's also the **Read|Calibration Byte(s)** option available. It allows reading the value of the calibration bytes of the chip's internal RC oscillator.

If the programmer is an Atmel STK500, AVRISP, AVRISP MkII or AVRProg (AVR910 application note), then an additional menu command is present: **Read|Programmer's Firmware Version**. It allows reading the major and minor versions of the above mentioned programmers' firmware.

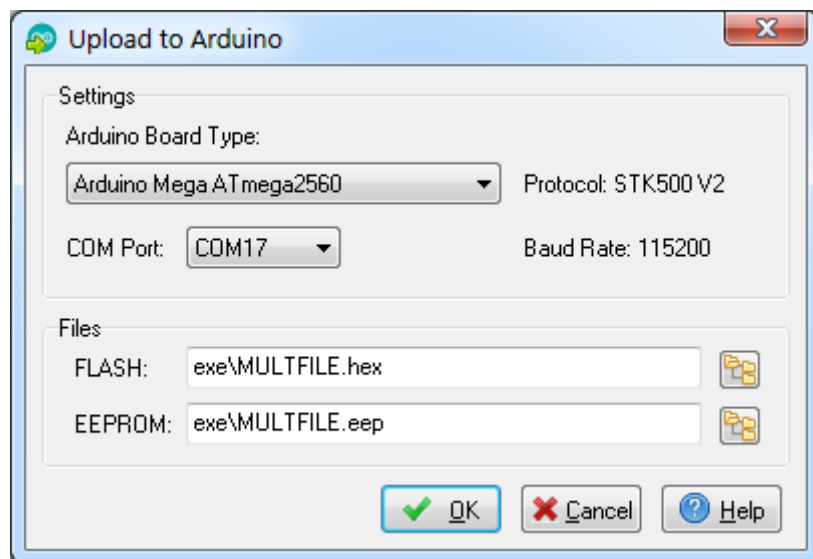
For comparing the contents of the chip's FLASH, respectively EEPROM, with the corresponding memory buffer, you must use the **Compare|FLASH**, respectively **Compare|EEPROM** menu commands.

For exiting the Programmer and returning to the CodeVisionAVR IDE you must use the **File|Close** menu command.

3.4.3 The Arduino Program Uploader

The CodeVisionAVR IDE has a built-in **Arduino Program Uploader**, that lets you easily transfer your compiled program to the microcontroller located on an Arduino compatible development board for testing.

The uploader is executed by selecting the **Tools|Upload to Arduino** menu command or by pressing the  button on the toolbar.



The **Settings** group box allows selecting the **Arduino Board Type** and the serial **COM Port** used for communication with the development board.

The **Files** group box allows specifying the **.hex** FLASH and **.eep**, EEPROM contents files to be uploaded to the AVR microcontroller.

Pressing the  button will open a dialog window, allowing to select the appropriate file.

Pressing the **OK** button will start the uploading process.

The **Arduino Uploader** window can be closed using the **Cancel** button.

The **Help** button will invoke the corresponding Help topic.

Notes:

- The **Upload to Arduino** menu option is enabled only if a microcontroller chip supported by the Arduino platform is selected in the currently opened project, or if no project is opened at all.
- The boot loaders from some Arduino boards don't support EEPROM programming, therefore the **Files|EEPROM** option is disabled in such cases.

3.4.4 The Serial Communication Terminal

The **Terminal** is intended for debugging embedded systems, which employ serial communication (RS232, RS422, RS485).

The Terminal is invoked using the **Tools|Terminal** menu command or the  button on the toolbar.

Connection to the serial port can be toggled on/off by pressing the **Connect/Disconnect**  button.

The characters can be displayed in ASCII or hexadecimal format. The display mode can be toggled using the **ASCII/Hex**  button.

The received characters can be saved to a file using the **Rx File**  button.

Any characters typed in the Terminal window will be transmitted through the PC serial port.

The entered characters can be deleted using the **Backspace** key.

By pressing the **Send**  button, the Terminal will transmit a character whose hexadecimal ASCII code value is specified in the Hex Code edit box on the toolbar.

By pressing the **Tx File**  button, the contents of a file can be transmitted through the serial port.

The Terminal's screen can be cleared by pressing the **Clear**  button.

By pressing the **Reset**  button, the AVR chip on the STK200+/300, STK500, STK600, VTEC-ISP, DT006, ATCPU or Mega2000 development board is reseted.

At the bottom of the Terminal window there is a status bar in which are displayed the:

- computer's communication port;
- communication parameters;
- handshaking mode;
- received characters display mode;
- type of emulated terminal;
- the state of the transmitted characters echo setting.

3.4.5 The LCD Vision Font and Image Editor/Converter

LCD Vision is an application designed for creating, editing font and image data, and exporting it in form of C source code, compatible with the CodeVisionAVR **Graphic LCD Functions**.

Fonts can be created from scratch or imported from the installed system fonts.

Images can be also created from scratch or imported from popular graphic formats like: BMP, JPG, GIF, PNG, ICO, WMF, EMF.

LCD Vision is invoked using the **Tools|LCD Vision** menu command or the  button on the toolbar.

Note: The LCD Vision editor/converter can be used only with an Advanced CodeVisionAVR license.

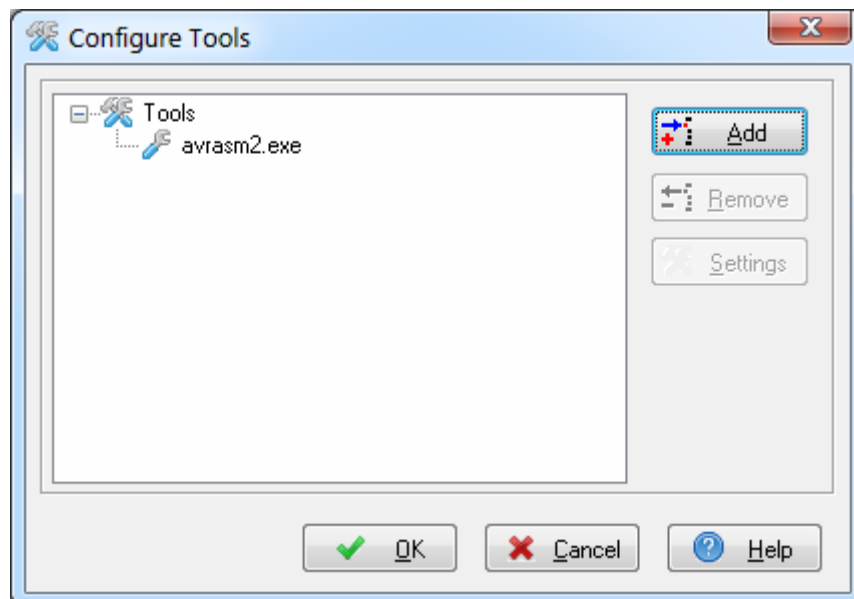
3.4.6 Executing User Programs

User programs are executed by selecting the corresponding command from the **Tools** menu. You must previously add the Program's name to the menu.

3.4.7 Configuring the Tools Menu

You can add or remove User Programs from the **Tools** menu by using the **Tools|Configure** menu command.

A **Configure Tools** dialog window, with a list of User Programs, will open.



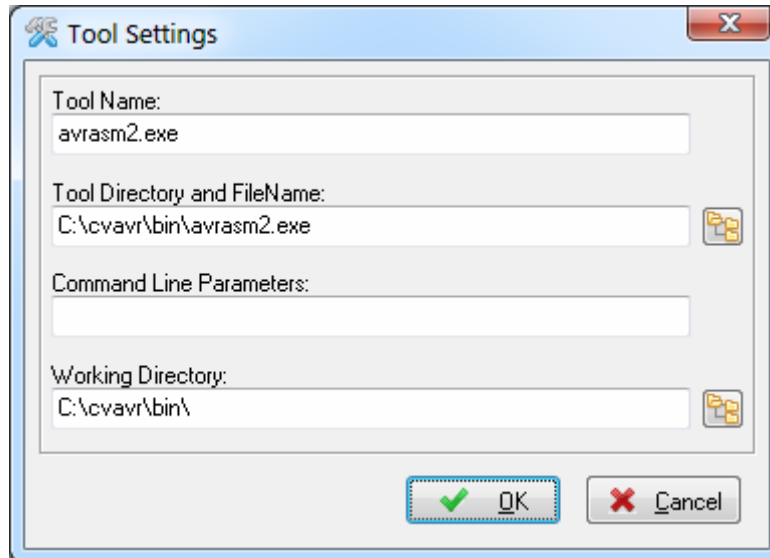
Using the **Add** button you can add a Program to the **Tools** menu.

Using the **Remove** button you can remove a Program from the **Tools** menu.

CodeVisionAVR

Using the **Settings** button you can modify the:

- Tool Menu Name
- Tool Directory and File Name
- Command Line Parameters
- Working Directory of a selected Program from the list



Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

The command line can accept the following parameters:

- %bc substitutes the Active Build Configuration: DEBUG or RELEASE
- %P substitutes the full project path
- %p substitutes the project name without path
- %h substitutes the name of the .hex file created by the compiler
- %e substitutes the name of the .eep file created by the compiler
- %f<project_file_number> substitutes the project's source file name without path
- %F<project_file_number> substitutes the project's source file name with full path.

3.5 IDE Settings

The CodeVisionAVR IDE is configured using the **View** and **Settings** menus.

3.5.1 The View Menu

The following settings can be configured using the **View** menu command:

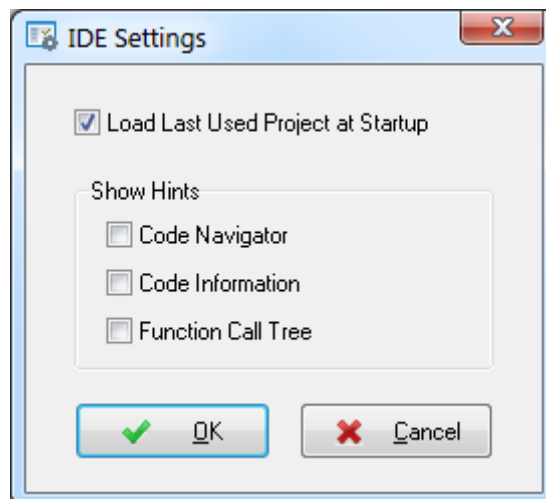
- The **View|Visible Non-Printable Characters** option allows to turn on or off the displaying of non-printable characters in the Editor window. The  toolbar button can be also used for this purpose.
- The **View|Toolbar** option allows to turn on or off the displaying of the various toolbars containing the IDE command buttons;
- The **View|Code Navigator/Code Information/Code Templates/Clipboard History** option allows to turn on or off the displaying of the **Navigator**, **Code Templates** and **Clipboard History** window at the left of the **Editor** window. The  toolbar button can be also used for this purpose;
- The **View|Messages** option allows to turn on or off the displaying of the **Message** window located under the **Editor** window. The  toolbar button can be also used for this purpose;
- The **View|Information Window after Compile/Build** option allows to turn on or off the displaying of the **Information** window after the **Compile** or **Build** processes.

3.5.2 General IDE Settings

Some general IDE settings can be specified using the **Settings|IDE** menu or the  toolbar button. These settings are:

- Load Last Used Project at Startup
- Show Hint for the **Code Navigator** window
- Show Hint for the **Code Information** window
- Show Hint for the **Function Call Tree** window.

The settings can be enabled or disabled by checking or un-checking the appropriate check boxes:



Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

3.5.3 Configuring the Editor

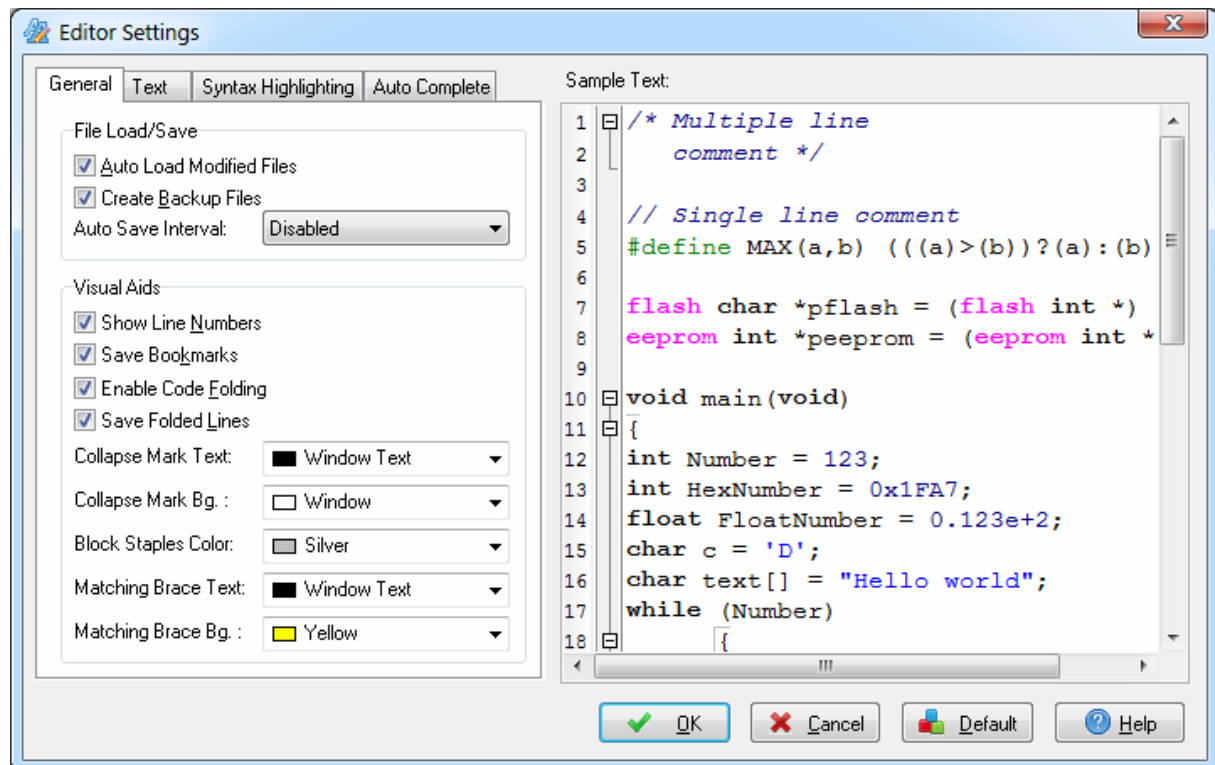
The Editor can be configured using the **Settings|Editor** menu command.

The Editor configuration changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

By pressing the **Default** button the default Editor settings are restored.

3.5.3.1 General Editor Settings

The following groups of Editor settings can be established by clicking on the **General** tab:



- **File Load/Save** settings;
- **Visual Aids** settings.

The **File Load/Save** settings allow for the following options to be set:

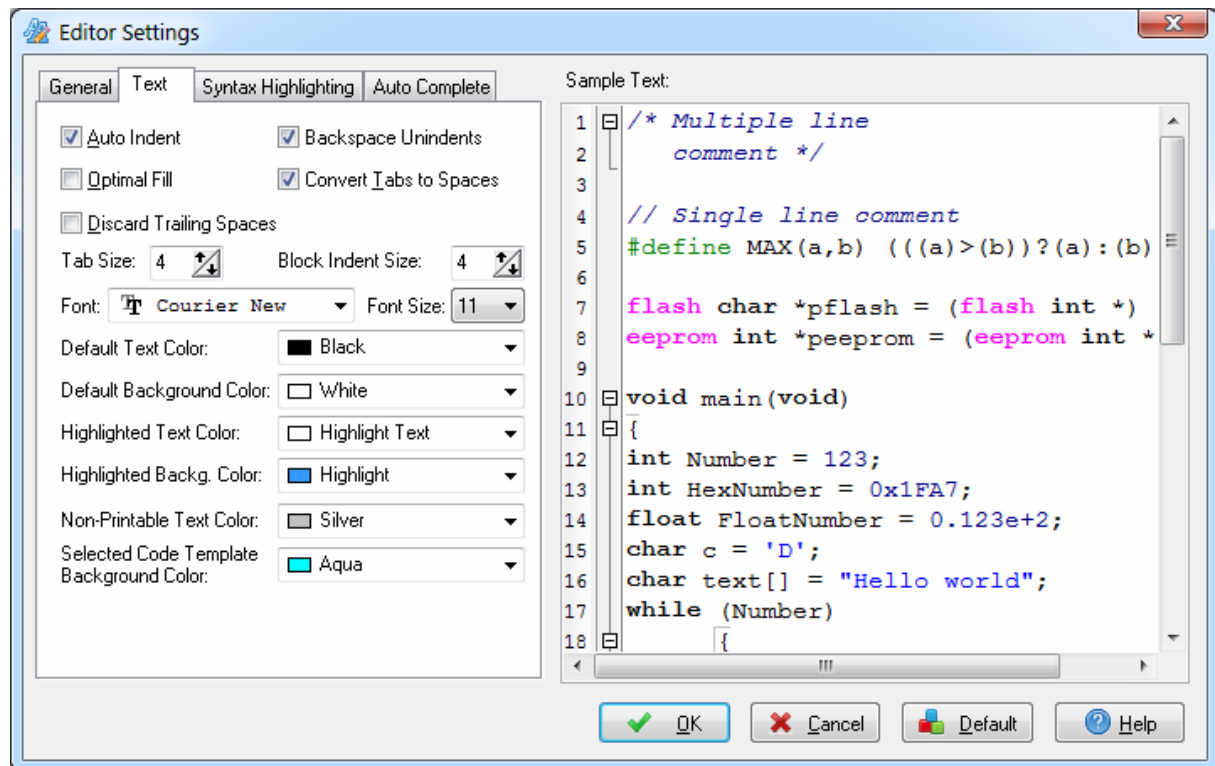
- **Auto Load Modified Files** enables or disables the automatic reloading, in the CodeVisionAVR Editor, of source files that were externally modified by some other program (another editor for example). If this option is disabled, the user will be prompted before the modified file will be reloaded in the Editor.
- **Create Backup Files** enables or disables the creation of backup copies of the files modified in the Editor. Backup copies will have the ~ character appended to their extension.
- **Auto Save Interval** specifies at which time interval all the modified source files will be automatically saved by the Editor.

The **Visual Aids** settings allow for the following options to be set:

- **Show Line Numbers** enables or disables the displaying of line numbers on the gutter located on the left side of the Editor windows;
- **Save Bookmarks** enables or disables saving the bookmarks set in each edited source file;
- **Enable Code Folding** enables or disables displaying of staples on the left side of code blocks delimited by the { } characters. If this option is enabled, block collapse/expansion marks will be also displayed on the gutter located on the left side of the Editor window.
- **Save Folded Lines** enables or disables saving the state of the folded blocks of lines for each edited source file;
- **Collapse Mark Text** specifies the text foreground color of the collapse marks;
- **Collapse Mark Bg.** specifies the text background color of the collapse marks;
- **Block Staples Color** specifies the foreground color of the folding block staples. The background color of the staples will be the same as the **Default Background Color** of the Editor window.
- **Matching Brace Text** specifies the text foreground color of the matching braces, which are automatically highlighted by the Editor when the user places the cursor before them;
- **Matching Brace Bg.** specifies the text background color of the highlighted matching braces.

3.5.3.2 Editor Text Settings

The following Editor settings can be established by clicking on the **Text** tab:



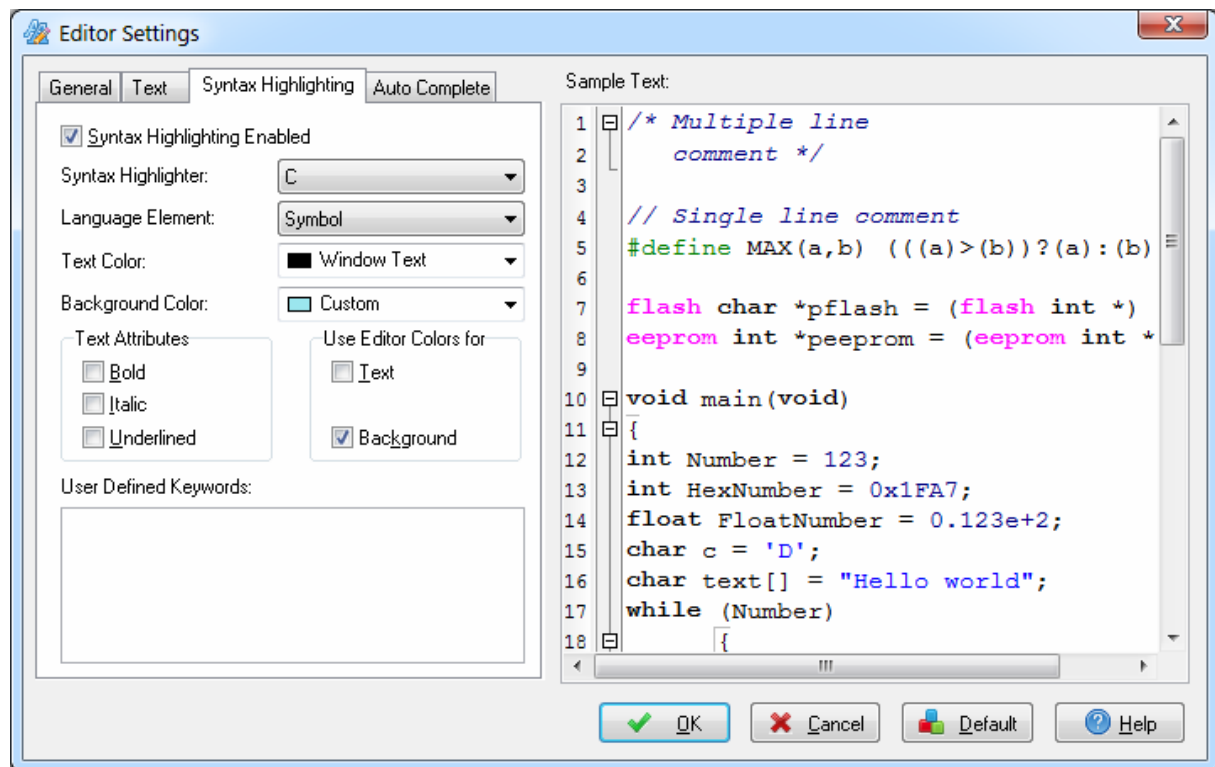
- **Auto Indent** enables or disables text auto indenting during file editing;
- **Backspace Unindents** when enabled, sets the Editor to align the insertion point to the previous indentation level (outdents it) when the user presses the Backspace key, if the cursor is on the first nonblank character of a line. If this option is disabled, pressing the Backspace key just deletes the character located on the left of the cursor.
- **Optimal Fill** enables or disables the beginning of every auto indented line with the minimum number of characters possible, using tabs and spaces as necessary;
- **Convert Tabs to Spaces** enables or disables the automatic replacement, while typing, of tab characters with the appropriate number of spaces, as specified by the **Tab Size** option;
- **Discard Trailing Spaces** enables or disables the automatic deletion from the end of each line, of spaces that are not followed by text,
- **Tab Size** specifies the number of spaces the Editor cursor is moved when the user presses the Tab key;
- **Block Indent Size** specifies the number of spaces the Editor indents a marked block of text;
- **Font** specifies the font type used by the Editor!;
- **Font Size** specifies the font size used by the Editor!;
- **Default Text Color** specifies the foreground color of the default (normal) text in the Editor and Terminal windows;
- **Default Background Color** specifies the background color of the default (normal) text in the Editor and Terminal windows;
- **Highlighted Text Color** specifies the foreground color of the text highlighted by the user in the Editor window;
- **Highlighted Background Color** specifies the background color of the text highlighted by the user in the Editor window;

CodeVisionAVR

- **Non-Printable Text Color** specifies the foreground color of the non-printable character markers displayed in the Editor window when the **View|Visible Non-Printable Characters** menu option is checked. The background color of the non-printable character markers will be the same as the **Default Background Color** of the Editor window.

3.5.3.3 Syntax Highlighting Settings

The following Editor settings can be established by clicking on the **Syntax Highlighting** tab:



- **Syntax Highlighting Enabled** enables or disables source file syntax highlighting;
- **Syntax Highlighter** list box selects the programming language for which the syntax highlighting settings will be applied. The CodeVisionAVR Editor supports syntax highlighting for the C and Atmel AVR Assembler programming languages.
- **Language Element** list box selects the element for which the text colors and attributes will be set;
- **Text Color** specifies the text foreground color for the above selected **Language Element**;
- **Background Color** specifies the text background color for the above selected **Language Element**;
- **Text Attributes** specifies how the text is displayed for the above selected **Language Element**. Text attributes can be combined by appropriately checking the **Bold**, **Italic** and **Underlined** check boxes. The displayed font will be the one selected in the **Text|Font** settings.

The **Text**, respectively **Background**, check boxes from the **Use Editor Colors** group box, when checked will set the foreground, respectively background, text colors for the selected **Language Element** to the default ones specified in the **Text|Default Text Color**, respectively **Text|Default Background Color** settings.

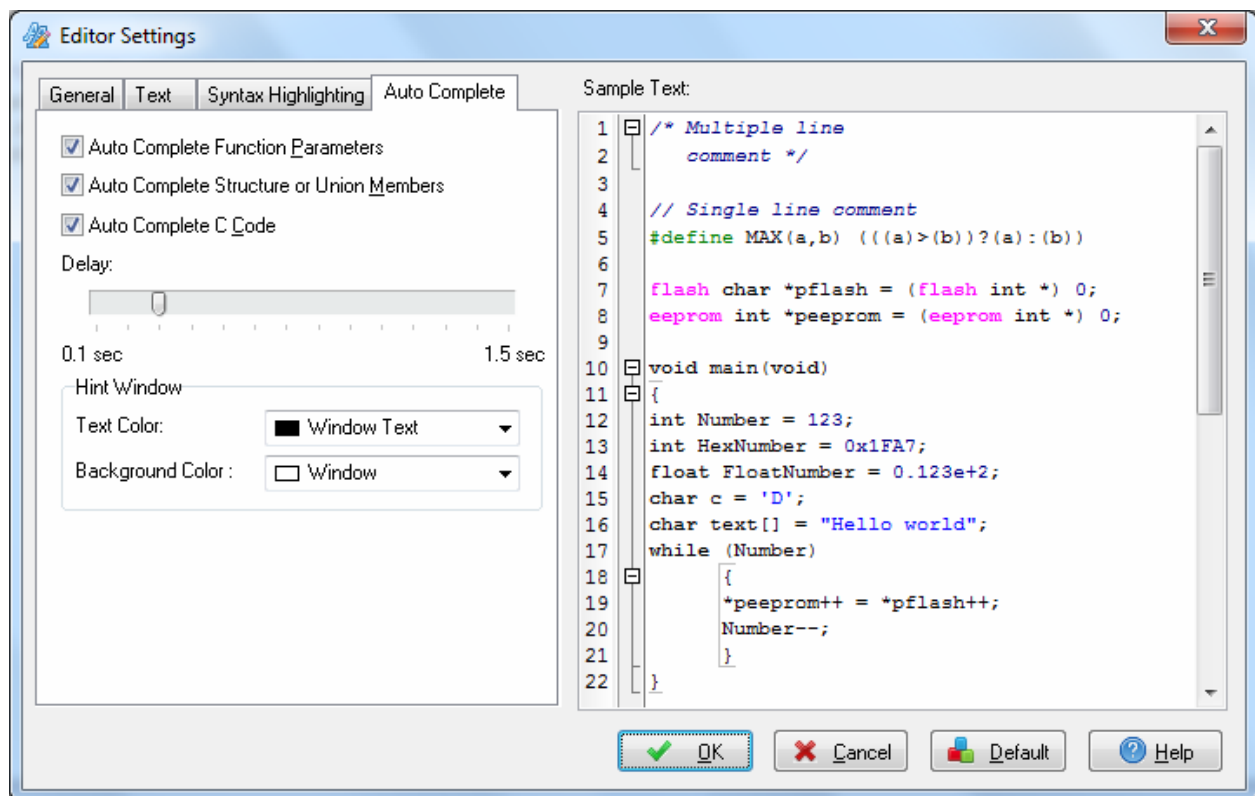
CodeVisionAVR

The **User Defined Keywords** list can contain additional keywords for which syntax highlighting is required. Their text colors and attributes can be specified when selecting the **Language Element** as *User defined keyword*.

The results of the applied syntax highlighting settings can be viewed in the **Sample Text** portion of the window.

3.5.3.4 Auto Complete Settings

The following Editor settings can be established by clicking on the **Auto Complete** tab:



- **Auto Complete Function Parameters** enables or disables displaying a pop-up hint window with the function parameters declaration, after the user writes the function name followed by a '(' auto completion triggering character. The function parameter auto completing works only for the functions defined in the currently edited source file.
- **Auto Complete Structure or Union Members** enables or disables displaying a pop-up hint window with the structure/union members list, after the user writes the structure/union or pointer to structure/union name followed by the '.' or '->' auto completion triggering characters. The structure or union members auto completion works only for global structures/unions defined in the currently edited source file and after a **Project|Compile** or **Project|Build** was performed.
- **Auto Complete C Code** enables or disables displaying a pop-up hint window with C keywords, library functions, data types, predefined macros, based on the first characters of a word typed in the Editor. The user may select the word to be inserted in the text using the mouse, up/down arrow keys and validate the selection by pressing the Enter or Space keys.

The **Delay** slider specifies the time delay that must elapse between entering the auto completion triggering characters and the displaying of the pop-up hint window. If the user writes any other character before this time delay, no pop-up hint window will show.

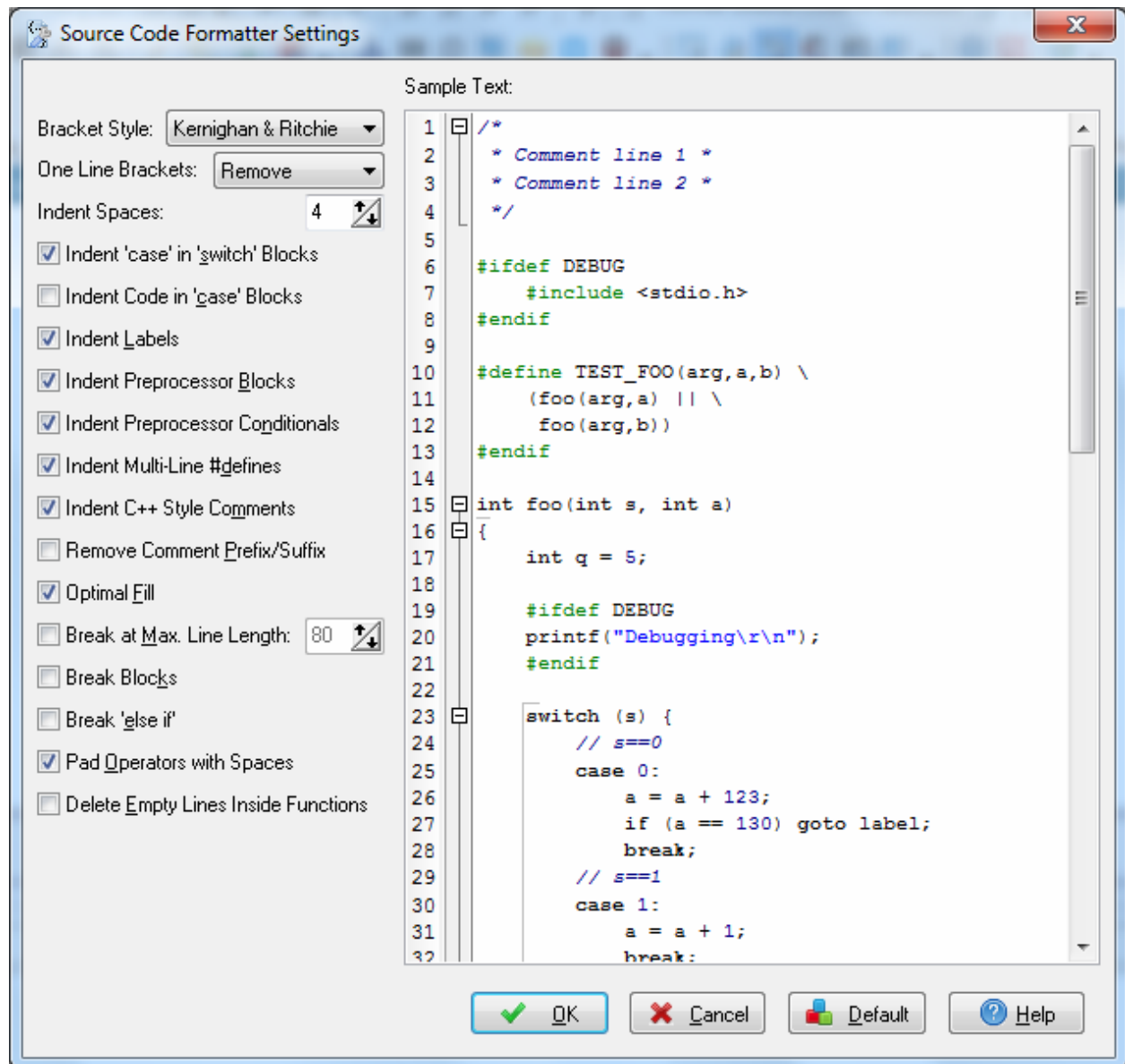
CodeVisionAVR

The **Hint Window** group box allows setting the **Text** and **Background Colors** of the auto complete pop-up hint window.

These colors will be also applied to the character grid pop-up hint window that is invoked using the **Edit|Insert Special Characters** menu, the **Insert Special Characters** right-click pop-up menu or by pressing the **Ctrl+.** keys.

3.5.4 Setting the C Source Code Formatting Options

The source code format style invoked by the **Edit|Format Source Code**, **Edit|Format Source Code in Selection** and **Edit|Format Source Code in Multiple Files** menu commands, can be configured using the **Settings|Source Code Formatter** option:



The selected source code formatting options can be visualized in the **Sample Text** window.

The following **Bracket Style** options are available:

- **Default Artistic Style** - the opening brackets are not changed and the closing brackets will be broken from the preceding line:

```
int foo(int alfa)
{
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **Allman** – uses broken brackets:

```
int foo(int alfa)
{
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **Java** – uses attached brackets:

```
int foo(int alfa) {
    if (alfa) {
        alfa = alfa * 2;
        return alfa;
    } else
        return 0;
}
```

- **Kernighan & Ritchie** - opening brackets are broken from function definitions. Brackets are attached to everything else, including statements within a function, arrays, structures, and enumerations.

```
int foo(int alfa)
{
    if (alfa) {
        alfa = alfa * 2;
        return alfa;
    } else
        return 0;
}
```


- **Whitesmith** – uses broken, indented brackets.

Switch blocks are indented to prevent a 'hanging indent' with following case statements.

```
int foo(int alfa)
{
    switch (alfa)
    {
        case 1:
            alfa = alfa + 20;
            break;
        case 2:
            alfa = alfa + 30;
            break;
    }
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **Banner** - uses attached, indented brackets.

Switch blocks are indented to prevent a 'hanging indent' with following case statements.

```
int foo(int alfa) {
    switch (alfa) {
        case 1:
            alfa = alfa + 20;
            break;
        case 2:
            alfa = alfa + 30;
            break;
    }
    if (alfa) {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **GNU** - uses broken brackets and indented blocks.

Extra indentation is added to blocks within a function.

No indentation is applied to the functions' opening brackets.

```
int foo(int alfa)
{
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **Horstmann** – uses run-in brackets.

Brackets are broken and allow run-in statements.

Switches are indented to allow a run-in to the opening switch block.

```
int foo(int alfa)
{
    switch (alfa)
    {
        case 1:
            alfa = alfa + 20;
            break;
        case 2:
            alfa = alfa + 30;
            break;
    }
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **One True Brace** – is similar to the Kernighan & Ritchie style, adding brackets to unbracketed one-line conditional statements.

```
int foo(int alfa)
{
    if (alfa) {
        alfa = alfa * 2;
        return alfa;
    } else {
        return 0;
    }
}
```

- **Pico** - uses run-in brackets and attached closing brackets.

Opening brackets are broken and allow run-in statements.

The closing bracket is attached to the last line in the block.

Switches are indented to allow a run-in to the opening switch block.

Note: This style implies the **One Line Brackets** option set to **Add**.

```
int foo(int alfa)
{
    switch (alfa)
    {
        case 1:
            alfa = alfa + 20;
            break;
        case 2:
            alfa = alfa + 30;
            break; }
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa; }
    else
    {
        return 0; } }
```

CodeVisionAVR

- **Pyhton** - uses attached opening and closing brackets.

Opening brackets are attached at the end of the statement.

The closing bracket is attached to the last line in the block.

This style implies keep-one-line-statements, but not keep-one-line-blocks.

Note: One-line brackets are not supported. If the One Line Brackets: Add option is selected, the brackets will be added as multiple-line ones.

```
int foo(int alfa) {
    if (alfa) {
        alfa = alfa * 2;
        return alfa; }
    else
        return 0; }
```

- **Google** - uses attached brackets:

```
int foo(int alfa) {
    if (alfa) {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

- **Visualization Toolkit** – uses broken, indented brackets, except for the opening bracket. *Switch* blocks are indented to prevent a 'hanging indent' with following *case* statements.

```
int foo(int alfa)
{
    switch (alfa)
    {
        case 1:
            alfa = alfa + 20;
            break;
        case 2:
            alfa = alfa + 30;
            break;
    }
    if (alfa)
    {
        alfa = alfa * 2;
        return alfa;
    }
    else
        return 0;
}
```

The **One Line Brackets** option allows to insert or remove brackets around single line conditional statements:

- **No change** – leaves the text unchanged
- **Add** – adds brackets:

```
if (alfa)
    alfa = alfa * 2;
```

becomes:

```
if (alfa)
{
    alfa = alfa * 2;
}
```

- **Remove** – remove existing brackets:

```
if (alfa)
{
    alfa = alfa * 2;
}
```

becomes:

```
if (alfa)
    alfa = alfa * 2;
```

The **Indent Spaces** option specifies the number of spaces per indent, to be applied during text formatting.

The **Indent 'case' in 'switch' Blocks** option, if enabled, will add additional indents for **case** statements.

```
switch (alfa)
{
case 1:
    alfa = alfa + 20;
    break;

case 2:
    alfa = alfa + 30;
    ++alfa;
    break;
}
```

becomes:

```
switch (alfa)
{
    case 1:
        alfa = alfa + 20;
        break;

    case 2:
        alfa = alfa * 30;
        ++alfa;
        break;
}
```

The **Indent Code in 'case' Blocks** option, if enabled, will indent case blocks from case headers. Case statements not enclosed in blocks will not be indented.

```
switch (alfa)
{
    case 1:
        alfa = alfa + 20;
        break;

    case 2:
        {
            alfa = alfa * 30;
            ++alfa;
            break;
        }
}
```

becomes:

```
switch (alfa)
{
    case 1:
        alfa = alfa + 20;
        break;

    case 2:
        {
            alfa = alfa * 30;
            ++alfa;
            break;
        }
}
```

The **Indent Labels** option, if enabled, will add extra indentation to labels so they appear one indent less than the current indentation, rather than being flushed to the left by default.

```
switch (alfa)
{
    case 1:
        alfa = alfa + 20;
        goto label;

    case 2:
label:
        alfa = alfa * 30;
        ++alfa;
        break;
}
```

becomes:

```
switch (alfa)
{
    case 1:
        alfa = alfa + 20;
        goto label;

    case 2:
        label:
        alfa = alfa * 30;
        ++alfa;
        break;
}
```

The **Indent Preprocessor Blocks** option, if enabled, will indent preprocessor blocks located at bracket level zero.

Note: Blocks within arrays, structures, enumerations and those containing brackets or multi-line `#define` statements will not be indented.

```
#ifdef DEBUG
#include <stdio.h>
#endif
```

becomes:

```
#ifdef DEBUG
#include <stdio.h>
#endif
```

The **Indent Preprocessor Conditionals** option, if enabled, will indent preprocessor conditional statements to the same level as the source code.

```
int foo(int alfa)
{
    if (alfa)
    {
        alfa = alfa * 2;
#ifdef DEBUG
        printf("alfa = %d\r\n", alfa);
#endif
    }
    return alfa;
}
```

becomes:

```
int foo(int alfa)
{
    if (alfa)
    {
        alfa = alfa * 2;
#ifdef DEBUG
        printf("alfa = %d\r\n", alfa);
#endif
    }
    return alfa;
}
```

CodeVisionAVR

The **Indent Multi-Line #defines** option, if enabled, will indent multi-line preprocessor definitions ending with a backslash.

```
#define TEST_FOO(arg,a,b) \
(foo(arg,a) || \
(foo(arg,b))
```

becomes:

```
#define TEST_FOO(arg,a,b) \
    (foo(arg,a) || \
    (foo(arg,b))
```

The **Indent C++ Style Comments** option, if enabled, will indent C++ comments beginning at column one. By default such comments are assumed to be commented-out code and not indented.

```
void foo(int alfa)
{
    if (alfa)
    {
// Display value
        printf("alfa = %d\r\n",alfa);
    }
}
```

becomes:

```
void foo(int alfa)
{
    if (alfa)
    {
        // Display value
        printf("alfa = %d\r\n",alfa);
    }
}
```

The **Remove Comment Prefix/Suffix** option, if enabled, will remove the preceding/trailing '*' character that begins/ends a comment line.

```
/*
 * Comment line 1 *
 * Comment line 2 *
*/
```

becomes:

```
/*
Comment line 1
Comment line 2
*/
```

The **Optimal Fill** option, if enabled, will use an optimal mix of tabs and space characters during indenting. If disabled, indenting will be performed only by inserting spaces.

The **Break at Max. Line Length** option, if enabled, will insert a line break if the number of characters/line exceeds the specified value.

The **Break Blocks** option, if enabled, will insert padding empty lines around header blocks (e.g. 'if', 'for', 'while', etc.).

```
int foo(int alfa)
{
    int a;
    if (alfa)
        printf("alfa = %d\r\n", alfa);
    else
        printf("alfa is zero\r\n");
    for (a=0; a<alfa; a++)
        printf("a = %d\r\n", a);
    return alfa*2;
}
```

becomes:

```
int foo(int alfa)
{
    int a;

    if (alfa)
        printf("alfa = %d\r\n", alfa);
    else
        printf("alfa is zero\r\n");

    for (a=0; a<alfa; a++)
        printf("a = %d\r\n", a);

    return alfa*2;
}
```

The **Break 'else if'** option, if enabled, will break *else if* header combinations into separate lines.

```
void foo(int alfa)
{
    if (alfa>0)
        printf("alfa is positive\r\n");
    else if (alfa<0)
        printf("alfa is negative\r\n");
    else
        printf("alfa is zero\r\n");
}
```

becomes:

```
void foo(int alfa)
{
    if (alfa>0)
        printf("alfa is positive\r\n");
    else
        if (alfa<0)
            printf("alfa is negative\r\n");
        else
            printf("alfa is zero\r\n");
}
```


The **Pad Operators with Spaces** option, if enabled, will insert padding spaces around operators.

```
int foo(int alfa)
{
    if (alfa>0)
        printf("alfa is positive\r\n");
    else if (alfa<0)
        printf("alfa is negative\r\n");
    else
        printf("alfa is zero\r\n");
    return (alfa*2+123)/3;
}
```

becomes:

```
int foo(int alfa)
{
    if (alfa > 0)
        printf("alfa is positive\r\n");
    else if (alfa < 0)
        printf("alfa is negative\r\n");
    else
        printf("alfa is zero\r\n");
    return (alfa * 2 + 123) / 3;
}
```

The **Delete Empty Lines Inside Functions** option, if enabled, will remove empty the empty lines inside a function body.

```
int foo(int alfa)
{
    int a=100;

    if (alfa>=0)
        printf("alfa is zero or positive\r\n");

    else if (alfa<0)
        printf("alfa is negative\r\n");
    return alfa*2+a;
}
```

becomes:

```
int foo(int alfa)
{
    int a=100;
    if (alfa>=0)
        printf("alfa is zero or positive\r\n");
    else if (alfa<0)
        printf("alfa is negative\r\n");
    return alfa*2+a;
}
```

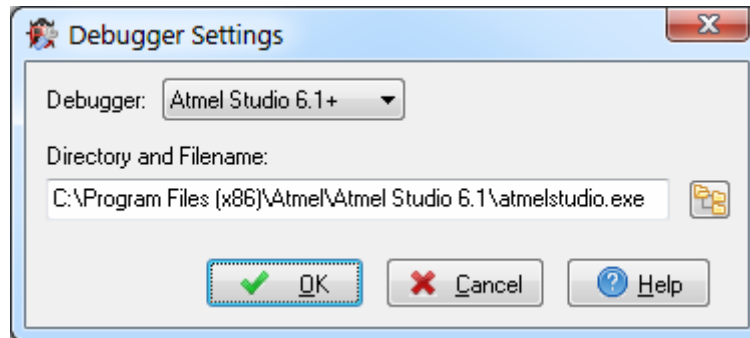
The configuration changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

By pressing the **Default** button the default source code formatting settings are restored.

3.5.5 Setting the Debugger Path

The CodeVisionAVR C Compiler is designed to work in conjunction with the AVR Studio 4.19 and Atmel Studio 6 or 7 debuggers.

Before you can invoke the debugger, you must first specify its location and file name using the **Settings|Debugger** menu command.



Pressing the  button opens a dialog window that allows selecting the debugger's directory and filename.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

3.5.6 AVR Chip Programmer Setup

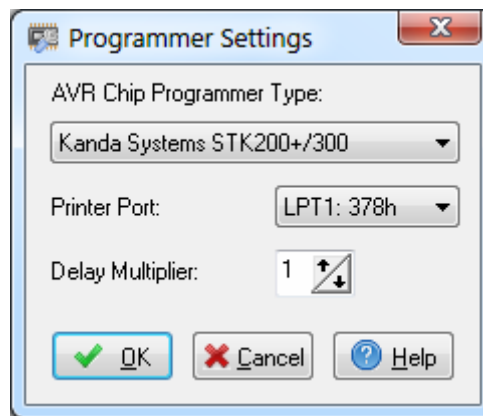
Using the **Settings|Programmer** menu command, you can select the type of the in-system programmer that is used, and the computer's port to which the programmer is connected. The current version of CodeVisionAVR supports the following in-system programmers:

- Kanda Systems STK200+ and STK300
- Atmel STK500 and AVRISP (serial connection)
- Atmel AVRISP MkII (USB connection)
- Atmel AVR Dragon (USB connection)
- Atmel JTAGICE MkII (USB connection)
- Atmel JTAGICE 3 (USB connection)
- Atmel-ICE (USB connection)
- Atmel AVRProg (AVR910 application note)
- Dontronics DT006
- Vogel Elektronik VTEC-ISP
- Futurlec JRAVR
- MicroTronics ATCPU and Mega2000

The STK200+, STK300, DT006, VTEC-ISP, JRAVR, ATCPU and Mega2000 in-system programmers use the parallel printer port.

The following choices are available through the **Printer Port** radio group box:

- LPT1, at base address 378h;
- LPT2, at base address 278h;
- LPT3, at base address 3BCh.



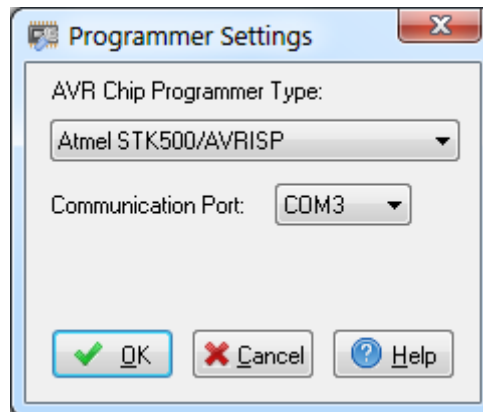
The **Delay Multiplier** value can be increased in case of programming problems on very fast machines. Of course this will increase overall programming time.

The **Atmega169 CKDIV8 Fuse Warning** check box, if checked, will enable the generation of a warning that further low voltage serial programming will be impossible for the *Atmega169 Engineering Samples*, if the CKDIV8 fuse will be programmed to 0.

For usual Atmega169 chips this check box must be left unchecked.

CodeVisionAVR

The STK500, AVRISP and AVRProg programmers use the RS232C serial communication port, which can be specified using the **Communication Port** list box.

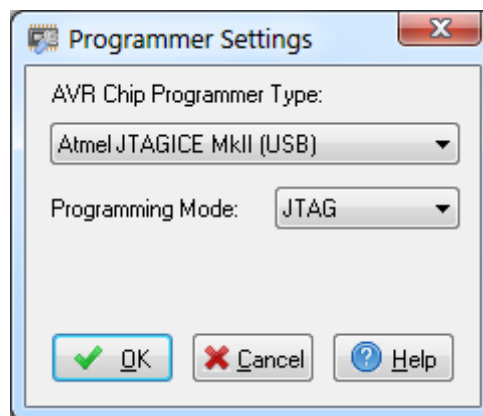


The Atmel AVRISP MkII, AVR Dragon, JTAGICE MkII, JTAGICE 3 and Atmel-ICE use the USB connection for communication with the PC.
Usage of these programmers requires the Atmel Studio 6.2 or later software to be installed on the PC.

The Atmel AVR Dragon, JTAGICE MkII, JTAGICE 3 and Atmel-ICE can use the following programming modes:

- JTAG
- ISP/PDI

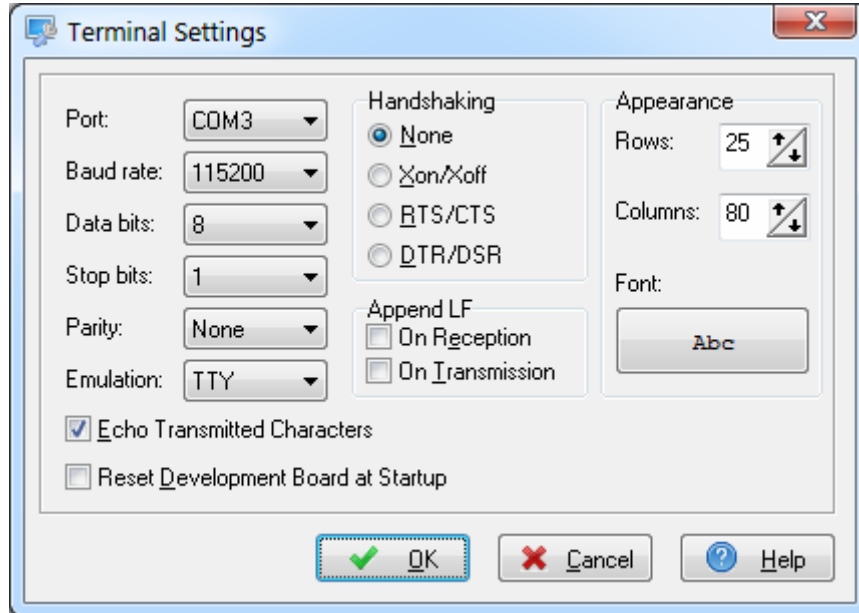
These can be selected using the **Programming Mode** list box:



Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

3.5.7 Serial Communication Terminal Setup

The serial communication **Terminal** is configured using the **Settings|Terminal** menu command.



In the **Terminal Settings** window you can select the:

- computer's communication port used by the Terminal: COM1 to COM6;
- Baud rate used for communication: 110 to 115200;
- number of data bits used in reception and transmission: 5 to 8;
- number of stop bits used in reception and transmission: 1, 1.5 or 2;
- parity used in reception and transmission: None, Odd, Even, Mark or Space;
- type of emulated terminal: TTY, VT52 or VT100;
- type of handshaking used in communication: None, Hardware (CTS or DTR) or Software (XON/XOFF);
- possibility to append LF characters after CR characters on reception and transmission;
- enabling or disabling the echoing of the transmitted characters
- number of character **Rows** and **Columns** in the Terminal window
- **Font** type used for displaying characters in the Terminal window.

The **Reset Development Board at Startup** option, if enabled, allows to issue a chip reset when the Terminal is started, if a chip programmer is connected to the AVR microcontroller.

Changes can be saved, respectively canceled, using the **OK**, respectively **Cancel** buttons.

3.6 Accessing the Help

The CodeVisionAVR help system is accessed by invoking the **Help|Help** menu command or by pressing the  toolbar button.

3.7 Connecting to HP InfoTech's Web Site

The **Help|HP InfoTech on the Web** menu command or the  toolbar button opens the default web browser and connects to HP InfoTech's web site <http://www.hpinfotech.com>

3.8 Quitting the CodeVisionAVR IDE

To quit working with the CodeVisionAVR IDE you must select the **File|Exit** menu command. If some source files were modified and were not saved yet, you will be prompted if you want to do that.

4. CodeVisionAVR C Compiler Reference

This section describes the general syntax rules for the CodeVisionAVR C compiler. Only specific aspects regarding the implementation of the C language by this compiler are exposed. This help is not intended to teach you the C language; you can use any good programming book to do that.

You must also consult the appropriate AVR data sheets from Atmel.

4.1 The C Preprocessor

The C Preprocessor directives allows you to:

- include text from other files, such as header files containing library and user function prototypes
- define macros that reduce programming effort and improve the legibility of the source code
- set up conditional compilation for debugging purposes and to improve program portability
- issue compiler specific directives

The Preprocessor output is saved in a text file with the same name as the source, but with the **.i** extension.

The **#include** directive may be used to include another file in your source.

You may nest as many as 300 **#include** files.

Example:

```
/* File will be looked for in the /inc directory of the compiler. */
#include <file_name>
```

or

```
/* File will be looked for in the current project directory.
   If it's not located there, then it will be included from
   the /inc directory of the compiler. */
#include "file_name"
```

The **#define** directive may be used to define a macro.

Example:

```
#define ALFA 0xff
```

This statement defines the symbol 'ALFA' to the value 0xff.

The C preprocessor will replace 'ALFA' with 0xff in the source text before compiling.

Macros can also have parameters. The preprocessor will replace the macro with its expansion and the formal parameters with the real ones.

Example:

```
#define SUM(a,b) a+b
/* the following code sequence will be replaced with int i=2+3; */
int i=SUM(2,3);
```

CodeVisionAVR

When defining macros you can use the **#** operator to convert the macro parameter to a character string.

Example:

```
#define PRINT_MESSAGE(t)    printf(#t)

/* ..... */
/* the following code sequence will be replaced with printf("Hello"); */
PRINT_MESSAGE>Hello);
```

Two parameters can be concatenated using the **##** operator.

Example:

```
#define ALFA(a,b) a ## b

/* the following code sequence will be replaced with char xy=1; */
char ALFA(x,y)=1;
```

A macro definition can be extended to a new line by using ****.

Example:

```
#define MESSAGE "This is a very \
long text..."
```

A macro can be undefined using the **#undef** directive.

Example:

```
#undef ALFA
```

The **#ifdef**, **#ifndef**, **#else** and **#endif** directives may be used for conditional compilation.

The syntax is:

```
#ifdef macro_name
[set of statements 1]
#else
[set of statements 2]
#endif
```

If 'alfa' is a defined macro name, then the **#ifdef** expression evaluates to true and the set of statements 1 will be compiled.

Otherwise the set of statements 2 will be compiled.

The **#else** and set of statements 2 are optional.

If 'alfa' is not defined, the **#ifndef** expression evaluates to true.

The rest of the syntax is the same as that for **#ifdef**.

The **#if**, **#elif**, **#else** and **#endif** directives may be also used for conditional compilation.

```
#if expression1
[set of statements 1]
#elif expression2
[set of statements 2]
#else
[set of statements 3]
#endif
```

If **expression1** evaluates to true, the set of statements 1 will be compiled.

If **expression2** evaluates to true, the set of statements 2 will be compiled.

Otherwise the set of statements 3 will be compiled.

The **#else** and set of statements 3 are optional.

CodeVisionAVR

There are the following predefined macros:

CODEVISIONAVR the version and revision of the compiler represented as an integer, example for V3.28 this will be 3280

STDC equals to 1

LINE the current line number of the compiled file

FILE the name of the currently compiled source file

MODULE the name of the currently compiled source file, without extension

TIME the current time in *hh:mm:ss* format

_UNIX_TIME_ unsigned long that represents the number of seconds elapsed since midnight UTC of 1 January 1970, not counting leap seconds

DATE the current date in *mmm dd yyyy* format

BUILD the build number

_CHIP_ATXXXXX_ where ATXXXXX is the chip type, in uppercase letters, specified in the **Project|Configure|C Compiler|Code Generation|Chip** option

_MCU_CLOCK_FREQUENCY_ the AVR clock frequency specified in the **Project|Configure|C Compiler|Code Generation|Clock** option, expressed as an unsigned long integer in Hz

_MODEL_TINY_ if the program is compiled using the TINY memory model

_MODEL_SMALL_ if the program is compiled using the SMALL memory model

_MODEL_MEDIUM_ if the program is compiled using the MEDIUM memory model

_MODEL_LARGE_ if the program is compiled using the LARGE memory model

_OPTIMIZE_SIZE_ if the program is compiled with optimization for size (**Project|Configure|C Compiler|Code Generation|Optimize for: Size** option or **#pragma optimize+**)

_OPTIMIZE_SPEED_ if the program is compiled with optimization for speed (**Project|Configure|C Compiler|Code Generation|Optimize for: Speed** option or **#pragma optimize-**)

_WARNINGS_ON_ if the warnings are enabled by the **Project|Configure|C Compiler|Messages|Enable Warnings** option or **#pragma warn+**

_WARNINGS_OFF_ if the warnings are disabled by the **Project|Configure|C Compiler|Messages|Enable Warnings** option or **#pragma warn-**

_PROMOTE_CHAR_TO_INT_ON_ if the automatic ANSI char to int type promotion is enabled by the **Project|Configure|C Compiler|Code Generation|Promote char to int** option or **#pragma promotechar+**

_PROMOTE_CHAR_TO_INT_OFF_ if the automatic ANSI char to int type promotion is disabled by the **Project|Configure|C Compiler|Code Generation|Promote char to int** option or **#pragma promotechar-**

_AVR8L_CORE_ signals that the program is compiled using the reduced core instruction set, used in chips like ATtiny10, ATtiny20, ATtiny40. No ADIW, SBIW, LDD and STD instructions are generated in this case.

_ENHANCED_CORE_ if the program is compiled using the enhanced core instructions available in the new ATmega chips

_ENHANCED_FUNC_PAR_PASSING_ if the program is compiled with the **Project|Configure|C Compiler|Code Generation|Enhanced Function Parameter Passing Mode 1** or **Mode 2** options enabled

_ENHANCED_FUNC_PAR_PASSING_MODE1_ if the program is compiled with the **Project|Configure|C Compiler|Code Generation|Enhanced Function Parameter Passing Mode 1** option enabled

_ENHANCED_FUNC_PAR_PASSING_MODE2_ if the program is compiled with the **Project|Configure|C Compiler|Code Generation|Enhanced Function Parameter Passing Mode 2** option enabled

_ATXMEGA_DEVICE_ signals that the program is compiled for an XMEGA chip type

_EXTERNAL_STARTUP_ signals that the **Project|Configure|C Compiler|Code Generation|Use an External Startup Initialization File** option is enabled

_IO_BITS_DEFINITIONS_ if the **Project|Configure|C Compiler|Code Generation|Preprocessor|Include I/O Registers Bits Definitions** option is enabled

_SRAM_START_ the start address of on-chip SRAM

_SRAM_END_ the end address of the SRAM accessible to the compiled program, including the eventual external memory

_DSTACK_START_ the data stack starting address
_DSTACK_END_ the last address of SRAM allocated for the data stack
_DSTACK_SIZE_ the data stack size specified in the **Project|Configure|C Compiler|Code Generation|Data Stack Size** option
_HSTACK_START_ the hardware stack starting address
_HEAP_START_ the heap starting address
_HEAP_SIZE_ the heap size specified in the **Project|Configure|C Compiler|Code Generation|Heap Size** option
_UNSIGNED_CHAR_ if the **Project|Configure|C Compiler|Code Generation|char is unsigned** compiler option is enabled or **#pragma uchar+** is used
_8BIT_ENUMS_ if the **Project|Configure|C Compiler|Code Generation|8 bit enums** compiler option is enabled or **#pragma 8bit_enums+** is used
_ATXMEGA_USART_ specifies which XMEGA chip USART is used by the **getchar** and **putchar** Standard C Input/Output Functions
_ATXMEGA_SPI_ specifies which XMEGA chip SPI controller is used by the SPI Functions
_ATXMEGA_SPI_PORT_ specifies which XMEGA chip I/O port is used by the SPI controller.

The **#line** directive can be used to modify the predefined **__LINE__** and **__FILE__** macros.
The syntax is:

```
#line integer_constant ["file_name"]
```

Example:

```
/* This will set __LINE__ to 50 and  
__FILE__ to "file2.c" */  
#line 50 "file2.c"  
  
/* This will set __LINE__ to 100 */  
#line 100
```

The **#error** directive can be used to stop compilation and display an error message.
The syntax is:

```
#error error_message
```

Example:

```
#error This is an error!
```

The **#warning** directive can be used to display a warning message.
The syntax is:

```
#warning warning_message
```

Example:

```
#warning This is a warning!
```

The **#message** directive can be used to display a message dialog window in the CodeVisionAVR IDE.
The syntax is:

```
#message general_message
```

Example:

```
#message Hello world
```

4.2 Comments

The character string `/*` marks the beginning of a comment.
The end of the comment is marked with `*/`.

Example:

```
/* This is a comment */  
/* This is a  
    multiple line comment */
```

One-line comments may be also defined by using the string `//`.

Example:

```
// This is also a comment
```

Nested comments are not allowed.

4.3 Reserved Keywords

Following is a list of keywords reserved by the compiler. These can not be used as identifier names.

```
__eeprom  
__flash  
__interrupt  
__task  
_Bool  
_Bit  
break  
bit  
bool  
case  
char  
const  
continue  
default  
defined  
do  
double  
eeprom  
else  
enum  
extern  
flash  
float  
for  
goto  
if  
inline  
int  
interrupt  
long  
register  
return  
short  
signed  
sizeof  
sfrb  
sfrw  
static  
struct  
switch  
typedef  
union  
unsigned  
void  
volatile  
while
```

4.4 Identifiers

An identifier is the name you give to a variable, function, label or other object.

An identifier can contain letters (A...Z, a...z) and digits (0...9), as well as the underscore character (_).

However an identifier can only start with a letter or an underscore.

Case is significant; i.e. **variable1** is not the same as **Variable1**.

Identifiers can have up to 64 characters.

4.5 Data Types

The following table lists all the data types supported by the CodeVisionAVR C compiler, their range of possible values and their size:

Type	Size (Bits)	Range
bit, _Bit	1	0 , 1
bool, _Bool	8	0 , 1
char	8	-128 to 127
unsigned char	8	0 to 255
signed char	8	-128 to 127
int	16	-32768 to 32767
short int	16	-32768 to 32767
unsigned int	16	0 to 65535
signed int	16	-32768 to 32767
long int	32	-2147483648 to 2147483647
unsigned long int	32	0 to 4294967295
long64_t	64	-9223372036854775808 to 9223372036854775807
ulong64_t	64	0 to 18446744073709551615
signed long int	32	-2147483648 to 2147483647
float	32	$\pm 1.175e-38$ to $\pm 3.402e38$

The **bit** or **_Bit** data types are not allowed as the type of an array element, structure/union member, function parameter or return value.

In order to use the **bool** data type, the **stdbool.h** header file must be **#included** in the source files where this data type is referenced.

If the **Project|Configure|C Compiler|Code Generation|char is unsigned** option is checked or **#pragma uchar+** is used, then **char** has by default the range 0..255.

Note: The **long64_t**, respectively **ulong64_t**, data types, defined in the **math64.h** header of the **64-bit Integer Mathematical Functions**, can be used instead of the not supported **long long**, respectively **unsigned long long**, types.

4.6 Constants and FLASH Memory Access

Integer or long integer constants may be written in decimal form (e.g. 1234), in binary form with **0b** prefix (e.g. 0b101001), in hexadecimal form with **0x** prefix (e.g. 0xff) or in octal form with **0**-prefix (e.g. 0777).

Unsigned integer constants may have the suffix **U** (e.g. 10000U).

Long integer constants may have the suffix **L** (e.g. 99L).

Unsigned long integer constants may have the suffix **UL** (e.g. 99UL).

Floating point constants may have the suffix **F** (e.g. 1.234F).

Character constants must be enclosed in single quotation marks. E.g. 'a'.

Literal string constants must be enclosed in double quotation marks. E.g. "Hello world".

Constant expressions are automatically evaluated during compilation.

Program constants can be declared as global (accessible to all the functions in the program) or local (accessible only inside the function they are declared).

The constant declarations syntax is similar to that of variables, but preceded by the **const** keyword:

```
const <type definition> <identifier> = constant expression;
```

Example:

```
/* Global constants declaration */
const char char_constant='a';
const int b=1234+5;
const long long_int_constant1=99L;
const long long_int_constant2=0x10000000;
const float pi=3.14;

void main(void) {
/* Local constants declaration */
const long f=22222222;
const float x=1.5;

}
```

Constants can be grouped in arrays, which can have up to 64 dimensions.

The first element of an array has always the index 0.

Example:

```
const char string_constant2[]="This is a string constant";
const int abc[3]={1,2,3};
/* The first two elements will be 1 and 2,
   the rest will be 0 */
const int integer_array2[10]={1,2};
/* multidimensional array */
const int multidim_array[2][3]={{1,2,3},{4,5,6}};
```

If the **Project|Configure|C Compiler|Code Generation|Store Global Constants in FLASH Memory** option is enabled, global constants that were declared using the **const** keyword will be placed by the compiler in FLASH memory.

If the above option is not enabled, global constants declared using the **const** keyword will be located in RAM memory.

Local constants will be always placed in RAM memory.

The **flash** or **__flash** keywords can be used to specify that a constant must be placed in FLASH memory, no matter what is the state of the **Store Global Constants in FLASH Memory** option:

```
flash <type definition> <identifier> = constant expression;
__flash <type definition> <identifier> = constant expression;
```

Example:

```
flash int   integer_constant=1234+5;
flash char  char_constant='a';
flash long  long_int_constant1=99L;
flash long  long_int_constant2=0x10000000;
flash int   integer_array1[]={1,2,3};
flash char  string_constant1[]="This is a string constant located in FLASH";
```

The constant literal char strings, enclosed in double quotation marks, that are passed as function arguments, are stored in the memory type pointed by the pointer used as function parameter.

Example:

```
/* This function displays a string located in RAM. */
void display_ram(char *s) {
/* ..... */

}

/* This function displays a string located in FLASH. */
void display_flash(flash char *s) {
/* ..... */

}

/* This function displays a string located in EEPROM. */
void display_eeprom(eeprom char *s) {
/* ..... */

}

void main(void) {
/* The literal string "Hello world" will be placed
   by the compiler in FLASH memory and copied at program
   startup to RAM, so it can be accessed by the pointer
   to RAM used as function parameter.
   The code efficiency is low, because both FLASH and
   RAM memories are used for the string storage. */
display_ram("Hello world");

/* The literal string "Hello world" will be placed
   by the compiler in FLASH memory only, good code
   efficiency beeing achieved. */
display_flash("Hello world");

/* The literal string "Hello world" will be placed
   by the compiler in EEPROM memory only.
   The code efficiency is very good because no
   FLASH memory will be allocated for the string. */
display_eeprom("Hello world");

while(1);
}
```

CodeVisionAVR

For compatibility with AVR GCC programs the **pgmspace.h** header file is supplied with CodeVisionAVR.

It contains the following macros:

For the TINY and SMALL memory models (16 bit FLASH address):

pgm_read_byte_near(address_short)

Reads an unsigned char value from FLASH **address_short**.

pgm_read_word_near(address_short)

Reads an unsigned short value starting from FLASH **address_short**.

pgm_read_dword_near(address_short)

Reads an unsigned long value starting from FLASH **address_short**.

pgm_read_float_near(address_short)

Reads a float value starting from FLASH **address_short**.

pgm_read_ptr_near(address_short)

Reads a 16 bit pointer to FLASH starting from FLASH **address_short**.

For the MEDIUM and LARGE memory models (32 bit FLASH address):

pgm_read_byte_far(address_long)

Reads an unsigned char value from FLASH **address_long**.

pgm_read_word_far(address_long)

Reads an unsigned long value starting from FLASH **address_long**.

pgm_read_dword_far(address_long)

Reads an unsigned long value starting from FLASH **address_long**.

pgm_read_float_far(address_long)

Reads a float value starting from FLASH **address_long**.

pgm_read_ptr_far(address_long)

Reads a 32 bit pointer to FLASH starting from FLASH **address_long**.

Memory model independent:

pgm_read_byte(address)

Reads an unsigned char value from FLASH **address**.

pgm_read_word(address)

Reads an unsigned short value starting from FLASH **address**.

pgm_read_dword(address)

Reads an unsigned long value starting from FLASH **address**.

pgm_read_float(address)

Reads a float value starting from FLASH **address**.

pgm_read_ptr(address)

Reads a pointer to FLASH starting from FLASH **address**.

4.7 Variables

CodeVisionAVR uses the little-endian convention for storing variables: the LSB is always stored at the lower address or register, the MSB(s) at the consecutive address(es) or register(s).

Program variables can be global (accessible to all the functions in the program) or local (accessible only inside the function they are declared).

If not specifically initialized, the global variables are automatically set to 0 at program startup.

The local variables are not automatically initialized on function call.

The syntax is:

```
[<memory attribute>] [<storage modifier>] <type definition> <identifier>
                                                                [= constant expression];
```

Example:

```
/* Global variables declaration */
char a;
int b;
/* and initialization */
long c=11111111;

void main(void) {
/* Local variables declaration */
char d;
int e;
/* and initialization */
long f=22222222;
}
```

Variables can be grouped in arrays, which can have up to 64 dimensions.

The first element of an array has always the index 0.

If not specifically initialized, the elements of global variable arrays are automatically set to 0 at program startup.

Example:

```
/* All the elements of the array will be 0 */
int global_array1[32];

/* Array is automatically initialized */
int global_array2[]={1,2,3};
int global_array3[4]={1,2,3,4};
char global_array4[]="This is a string";

/* Only the first 3 elements of the array are
   initialized, the rest 29 will be 0 */
int global_array5[32]={1,2,3};

/* Multidimensional array */
int multidim_array[2][3]={{1,2,3},{4,5,6}};

void main(void) {
/* local array declaration */
int local_array1[10];

/* local array declaration and initialization */
int local_array2[3]={11,22,33};
char local_array3[7]="Hello";
}
```

Local variables that must conserve their values during different calls to a function must be declared as **static**. Example:

```
int alfa(void) {
/* declare and initialize the static variable */
static int n=1;
return n++;
}

void main(void) {
int i;

/* the function will return the value 1 */
i=alfa();

/* the function will return the value 2 */
i=alfa();
}
```

If not specifically initialized, **static** variables are automatically set to 0 at program startup.

Variables that are declared in other files must be preceded by the **extern** keyword.

Example:

```
extern int xyz;

/* now include the file which contains
the variable xyz definition */
#include <file_xyz.h>
```

To instruct the compiler to allocate a variable to registers, the **register** modifier must be used.

Example:

```
register int abc;
```

The compiler may automatically allocate a variable to registers, even if this modifier is not used.

The **volatile** modifier must be used to warn the compiler that it may be subject to outside change during evaluation.

Example:

```
volatile int abc;
```

Variables declared as volatile will not be allocated to registers.

All the global variables, not allocated to registers, are stored in the **Global Variables** area of RAM.

All the local variables, not allocated to registers, are stored in dynamically allocated space in the **Data Stack** area of RAM.

If a global variable declaration is preceded by the **EEPROM** or **__EEPROM** memory attribute, the variable will be located in EEPROM.

Example:

```
EEPROM float xyz=12.9;
__EEPROM int w[5]={1,2,3,4,5};
```

The initialization data for the EEPROM is stored in an .EEP file in Intel hex format.

The contents of this file must be programmed to the chip's EEPROM.

4.7.1 Specifying the RAM and EEPROM Storage Address for Global Variables

Global variables can be stored at specific RAM and EEPROM locations at design-time using the @ operator.

Example:

```
/* the integer variable "a" is stored
   in RAM at address 80h */
int a @0x80;
```

```
/* the structure "alfa" is stored
   in RAM at address 90h */
struct s1 {
    int a;
    char c;
} alfa @0x90;
```

```
/* the float variable "b" is stored
   in EEPROM at address 10h */
eeprom float b @0x10;
```

```
/* the structure "beta" is stored
   in EEPROM at address 20h */
eeprom struct s2 {
    int i;
    long j;
} beta @0x20;
```

The following procedure must be used if a global variable, placed at a specific address using the @ operator, must be initialized during declaration:

```
/* the variable will be stored in RAM at address 0x182 */
float pi @0x182;
/* and it will be initialized with the value 3.14 */
float pi=3.14;
```

```
/* the variable will be stored in EEPROM at address 0x10 */
eeprom int abc @0x10;
/* and it will be initialized with the value 123 */
eeprom int abc=123;
```

4.7.2 Bit Variables

The global bit variables located in the GPIOR register(s) and R2 to R14 memory space.

These variables are declared using the **bit** or **_Bit** keywords.

The syntax is:

```
bit <identifier>;
```

Example:

```
/* declaration and initialization for an ATtiny2313 chip
   which has GPIOR0, GPIOR1 and GPIOR2 registers */
bit alfa=1; /* bit0 of GPIOR0 */
bit beta; /* bit1 of GPIOR0 */

void main(void)
{
    if (alfa) beta=!beta;

    /* ..... */
}
```

Memory allocation for the global bit variables is done, in the order of declaration, starting with bit 0 of GPIOR0, then bit 1 of GPIOR0 and so on, in ascending order.

After all the GPIOR registers are allocated, further bit variables are allocated in R2 up to R14.

If the chip does not have GPIOR registers, the allocation begins directly from register R2.

The size of the global bit variables allocated to the program can be specified in the

Project|Configure|C Compiler|Code Generation|Bit Variables Size list box.

This size should be as low as possible, in order to free registers for allocation to other global variables.

If not specifically initialized, the global bit variables are automatically set to 0 at program startup.

The compiler allows also to declare up to 8 local bit variables which will be allocated in register R15.

Example:

```
void main(void)
{
    bit alfa; /* bit 0 of R15 */
    bit beta; /* bit 1 of R15 */
    /* ..... */
}
```

In expression evaluation bit variables are automatically promoted to **unsigned char**.

As there is no support for the bit data type in the COFF object file format, the CodeVisionAVR compiler generates debugging information for the whole register where a bit variable is located.

Therefore when watching bit variables in the AVR Studio debugger, the value of the register is displayed instead of a single bit from it.

However it is quite simple to establish the value of the bit variable based on the register bit number allocated for it, which is displayed in the **Code Information** tab of the CodeVisionAVR IDE, and the register value displayed in hexadecimal in AVR Studio's **Watch** window.

4.7.3 Allocation of Variables to Registers

In order to fully take advantage of the AVR architecture and instruction set, the compiler allocates some of the program variables to chip registers.

The registers from R2 up to R14 can be allocated for global **bit** variables.

The register R15 can be allocated to local **bit** variables.

You may specify how many registers in the R2 to R14 range are allocated for global **bit** variables using the **Project|Configure|C Compiler|Code Generation|Bit Variables Size** list box. This value must be as low as required by the program.

If the **Project|Configure|C Compiler|Code Generation|Automatic Global Register Allocation** option is checked or the **#pragma regalloc+** compiler directive is used, the rest of registers in the R2 to R14 range, that aren't used for global **bit** variables, are allocated to **char** and **int** global variables and global pointers.

The **Reserved Registers** option in the **Project|Configure|C Compiler|Advanced** menu, allows to prevent the automatic allocation of some of the registers R2 to R14 to global variables, if the **Automatic Global Registers Allocation** option is enabled.

The reserved registers can in this case be used for inline assembly code or be allocated manually for a specific global variable.

Example:

```
register unsigned char abc @14; /* the global variable abc is allocated
                                to the reserved register R14 */
register unsigned char abc=123; /* the variable abc, allocated to R14,
                                is also initialized with the value 123
                                during definition */
```

CodeVisionAVR uses the little-endian convention for storing variables: the LSB is always stored in the lower register, the MSB in the consecutive register.

If the **Project|Configure|C Compiler|Code Generation|Smart Register Allocation** option is checked, the allocation of registers R2 to R14 (not used for bit variables) is performed in such a way that 16bit variables will be preferably located in even register pairs, thus favouring the usage of the enhanced core MOVW instruction for their access.

Otherwise the allocation is performed in order of variable declaration until the R14 register is allocated.

If the automatic register allocation is disabled, you can use the **register** keyword to specify which global variable to be allocated to registers.

Example:

```
/* disable automatic register allocation */
#pragma regalloc-
/* allocate the variable 'alfa' to a register */
register int alfa;
/* allocate the variable 'beta' to the register pair R10, R11 */
register int beta @10;
```

Local **char**, **int** and **pointer** local variables are allocated to registers R16 to R21.

If the **Project|Configure|C Compiler|Code Generation|Smart Register Allocation** option is checked, the allocation of these registers for local variables is performed in such a way that 16bit variables will be preferably located in even register pairs, thus favouring the usage of the enhanced core MOVW instruction for their access.

Otherwise the local variables are automatically allocated to registers in the order of declaration.

The **Project|Configure|C Compiler|Code Generation|Smart Register Allocation** option should be disabled if the program was developed using CodeVisionAVR prior to V1.25.3 and it contains inline assembly code that accesses the variables located in registers R2 to R14 and R16 to R21.

4.7.4 Structures

Structures are user-defined collections of named members.

The structure members can be any of the supported data types, arrays of these data types or pointers to them.

Structures are defined using the **struct** reserved keyword.

The syntax is:

```
[<memory attribute>] struct [<structure tag-name>] {
    [<type> <variable-name>[,<variable-name>, ...]];
    [<type> [<bitfield-id>]:<width>[, [<bitfield-id>]:<width>, ...]];
    ...
} [<structure variables>;
```

Example:

```
/* Global structure located in RAM */
struct ram_structure {
    char a,b;
    int  c;
    char d[30],e[10];
    char *pp;
} sr;

/* Global constant structure located in FLASH */
flash struct flash_structure {
    int  a;
    char b[30], c[10];
} sf;

/* Global structure located in EEPROM */
eeprom struct eeprom_structure {
    char a;
    int  b;
    char c[15];
} se;

void main(void) {
/* Local structure */
struct local_structure {
    char a;
    int  b;
    long c;
} sl;

/* ..... */
}
```

The space allocated to the structure in memory is equal to sum of the sizes of all the members.

The same generic structure type can be declared in any memory type: RAM, FLASH or EEPROM:

```
/* Generic structure type */
struct my_structure {
    char a,b;
    int  c;
    char d[30],e[10];
    char *pp;
};

/* Global structure located in RAM */
struct my_structure sr;

/* Global pointer located in RAM to the RAM located structure */
struct my_structure *ptrsr = &sr;

/* Global pointer located in FLASH to the RAM located structure */
struct my_structure * flash ptrfsr = &sr;

/* Global pointer located in EEPROM to the RAM located structure */
struct my_structure * eeprom ptresr = &sr;

/* Global constant structure located in FLASH */
flash struct my_structure sf = {0,0,0,{0},{0},0};

/* Global pointer located in RAM to the FLASH located structure */
flash struct my_structure *ptrsf = &sf;

/* Global pointer located in FLASH to the FLASH located structure */
flash struct my_structure * flash ptrfsf = &sf;

/* Global pointer located in EEPROM to the FLASH located structure */
flash struct my_structure * eeprom ptresf = &sf;

/* Global constant structure located in EEPROM */
eeprom struct my_structure se;

/* Global pointer located in RAM to the EEPROM located structure */
eeprom struct my_structure *ptrse = &se;

/* Global pointer located in FLASH to the EEPROM located structure */
eeprom struct my_structure * flash ptrfse = &se;

/* Global pointer located in EEPROM to the EEPROM located structure */
eeprom struct my_structure * eeprom ptrese = &se;

void main(void) {
/* Local structure */
struct my_structure sl;
/* Local pointer to the RAM located global structure */
struct my_structure *ptrlsr = &sr;
/* Local pointer to the FLASH located global structure */
flash struct my_structure *ptrlsf = &sf;
/* Local pointer to the EEPROM located global structure */
eeprom struct my_structure *ptrlse = &se;

/* ..... */

}
```


Structures can be grouped in arrays.

Example how to initialize and access an global structure array stored in EEPROM:

```
/* Global structure array located in EEPROM */
eeprom struct eeprom_structure {
    char a;
    int b;
    char c[15];
    } se[2]={{'a',25,"Hello"},
            {'b',50,"world"}};

void main(void) {
char k1,k2,k3,k4;
int i1, i2;

/* define a pointer to the structure */
struct eeprom_structure eeprom *ep;

/* direct access to structure members */
k1=se[0].a;
i1=se[0].b;
k2=se[0].c[2];
k3=se[1].a;
i2=se[1].b;
k4=se[1].c[2];

/* same access to structure members using a pointer */
ep=&se; /* initialize the pointer with the structure address */
k1=ep->a;
i1=ep->b;
k2=ep->c[2];
++ep; /* increment the pointer */
k3=ep->a;
i2=ep->b;
k4=ep->c[2];
}
```

Because some AVR devices have a small amount of RAM, in order to keep the size of the **Data Stack** small, it is recommended not to pass structures as function parameters and use pointers for this purpose.

Example:

```
struct alpha {
    int a,b, c;
    } s={2,3};
/* define the function */
struct alpha *sum_struct(struct alpha *sp) {
/* member c=member a + member b */
sp->c=sp->a + sp->b;
/* return a pointer to the structure */
return sp;
}
void main(void) {
int i;
/* s->c=s->a + s->b */
/* i=s->c */
i=sum_struct(&s)->c;
}
```

Structure members can be also declared as bit fields, having a width from 1 to 32.
Bit fields are allocated in the order of declaration starting from the least significant bit.

Example:

```
/* this structure will occupy 1 byte in RAM
   as the bit field data type is unsigned char */
struct alpha1 {
    unsigned char a:1; /* bit 0 */
    unsigned char b:4; /* bits 1..4 */
    unsigned char c:3; /* bits 5..7 */
};

/* this structure will occupy 2 bytes in RAM
   as the bit field data type is unsigned int */
struct alpha2 {
    unsigned int a:2; /* bits 0..1 */
    unsigned int b:8; /* bits 2..9 */
    unsigned int c:4; /* bits 10..13 */
                    /* bits 14..15 are not used */
};

/* this structure will occupy 4 bytes in RAM
   as the bit field data type is unsigned long */
struct alpha3 {
    unsigned long a:10; /* bits 0..9 */
    unsigned long b:8;  /* bits 10..17 */
    unsigned long c:6;  /* bits 18..23 */
                    /* bits 24..31 are not used */
};
```

4.7.5 Unions

Unions are user-defined collections of named members that share the same memory space. The union members can be any of the supported data types, arrays of these data types or pointers to them.

Unions are defined using the **union** reserved keyword.

The syntax is:

```
[<memory attribute>] [<storage modifier>] union [<union tag-name>] {
    [<type> <variable-name>[,<variable-name>, ...]];
    [<type> <bitfield-id>:<width>[,<bitfield-id>:<width>, ...]];
    ...
} [<union variables>;
```

The space allocated to the union in memory is equal to the size of the largest member.

Union members can be accessed in the same way as structure members. Example:

```
/* union declaration */
union alpha {
    unsigned char lsb;
    unsigned int  word;
} data;

void main(void) {
    unsigned char k;

    /* define a pointer to the union */
    union alpha *dp;

    /* direct access to union members */
    data.word=0x1234;
    k=data.lsb; /* get the LSB of 0x1234 */

    /* same access to union members using a pointer */
    dp=&data; /* initialize the pointer with the union address */
    dp->word=0x1234;
    k=dp->lsb; /* get the LSB of 0x1234 */
}
```

Because some AVR devices have a small amount of RAM, in order to keep the size of the **Data Stack** small, it is recommended not to pass unions as function parameters and use pointers for this purpose.

Example:

```
#include <stdio.h> /* printf */
union alpha {
    unsigned char lsb;
    unsigned int  word;
} data;

/* define the function */
unsigned char low(union alpha *up) {
    /* return the LSB of word */
    return up->lsb;
}

void main(void) {
    data.word=0x1234;
    printf("the LSB of %x is %2x",data.word,low(&data));
}
```

Union members can be also declared as bit fields, having a width from 1 to 32.
Bit fields are allocated in the order of declaration starting from the least significant bit.
Example:

```
/* this union will occupy 1 byte in RAM
   as the bit field data type is unsigned char */
union alpha1 {
    unsigned char a:1; /* bit 0 */
    unsigned char b:4; /* bits 0..3 */
    unsigned char c:3; /* bits 0..2 */
};

/* this union will occupy 2 bytes in RAM
   as the bit field data type is unsigned int */
union alpha2 {
    unsigned int a:2; /* bits 0..1 */
    unsigned int b:8; /* bits 0..7 */
    unsigned int c:4; /* bits 0..3 */
                    /* bits 8..15 are not used */
};

/* this union will occupy 4 bytes in RAM
   as the bit field data type is unsigned long */
union alpha3 {
    unsigned long a:10; /* bits 0..9 */
    unsigned long b:8;  /* bits 0..7 */
    unsigned long c:6;  /* bits 0..5 */
                    /* bits 10..31 are not used */
};
```

4.7.6 Enumerations

The enumeration data type can be used in order to provide mnemonic identifiers for a set of **char** or **int** values.

The **enum** keyword is used for this purpose.

The syntax is:

```
[<memory attribute>] [<storage modifier>] enum [<enum tag-name>] {  
    [<constant-name[=constant-initializer], constant-name, ...]>}]  
    [<enum variables>];
```

Example:

```
/* The enumeration constants will be initialized as follows:  
   sunday=0 , monday=1 , tuesday=2 , ..., saturday=6 */  
enum days {  
    sunday, monday, tuesday, wednesday,  
    thursday, friday, saturday} days_of_week;  
  
/* The enumeration constants will be initialized as follows:  
   january=1 , february=2 , march=3 , ..., december=12 */  
enum months {  
    january=1, february, march, april, may, june,  
    july, august, september, october, november, december}  
    months_of_year;  
  
void main {  
    /* the variable days_of_week is initialized with  
       the integer value 6 */  
    days_of_week=saturday;  
}
```

Enumerations can be stored in RAM, EEPROM or FLASH.

The **eprom** or **__eprom** memory attributes must be used to specify enumeration storage in EEPROM.

Example:

```
eprom enum days {  
    sunday, monday, tuesday, wednesday,  
    thursday, friday, saturday} days_of_week;
```

The **flash** or **__flash** memory attributes must be used to specify enumeration storage in FLASH memory.

Example:

```
flash enum months {  
    january, february, march, april, may, june,  
    july, august, september, october, november,  
    december}  
    months_of_year;
```

It is recommended to treat enumerations as having 8 bit **char** data type, by checking the **8 bit enums** check box in **Project|Configure|CompilerCode Generation**. This will improve the size and execution speed of the compiled program.

4.8 Defining Data Types

User defined data types are declared using the **typedef** reserved keyword.
The syntax is:

```
typedef <type definition> <identifier>;
```

The symbol name <identifier> is assigned to <type definition>.
Examples:

```
/* type definitions */
typedef unsigned char byte;
typedef struct {
    int a;
    char b[5];
} struct_type;

/* variable declarations */
byte alfa;

/* structure stored in RAM */
struct_type struct1;

/* structure stored in FLASH */
flash struct_type struct2;

/* structure stored in EEPROM */
eeprom struct_type struct3;
```

4.9 Type Conversions

In an expression, if the two operands of a binary operator are of different types, then the compiler will convert one of the operands into the type of the other.

The compiler uses the following rules:

If either of the operands is of type **float** then the other operand is converted to the same type.

If either of the operands is of type **long int** or **unsigned long int** then the other operand is converted to the same type.

Otherwise, if either of the operands is of type **int** or **unsigned int** then the other operand is converted to the same type.

Thus **char** type or **unsigned char** type gets the lowest priority.

Using casting you can change these rules.

Example:

```
void main(void) {
    int  a, c;
    long b;
    /* The long integer variable b will be treated here as an integer */
    c=a+(int) b;
}
```

It is important to note that if the **Project|Configure|C Compiler|Code Generation|Promote char to int** option isn't checked or the **#pragma promotechar+** isn't used, the **char**, respectively **unsigned char**, type operands are not automatically promoted to **int**, respectively **unsigned int**, as in compilers targeted for 16 or 32 bit CPUs.

This helps writing more size and speed efficient code for an 8 bit CPU like the AVR.

To prevent overflow on 8 bit addition or multiplication, casting may be required.

The compiler issues warnings in these situations.

Example:

```
void main(void) {
    unsigned char a=30;
    unsigned char b=128;
    unsigned int c;

    /* This will generate an incorrect result, because the multiplication
       is done on 8 bits producing an 8 bit result, which overflows.
       Only after the multiplication, the 8 bit result is promoted to
       unsigned int */
    c=a*b;

    /* Here casting forces the multiplication to be done on 16 bits,
       producing an 16 bit result, without overflow */
    c=(unsigned int) a*b;
}
```

The compiler behaves differently for the following operators:

`+=`
`-=`
`*=`
`/=`
`%=`
`&=`
`|=`
`^=`
`<<=`
`>>=`

For these operators, the result is to be written back onto the left-hand side operand (which must be a variable). So the compiler will always convert the right hand side operand into the type of left-hand side operand.

4.10 Operators

The compiler supports the following operators:

<code>+</code>	<code>-</code>
<code>*</code>	<code>/</code>
<code>%</code>	<code>++</code>
<code>--</code>	<code>=</code>
<code>==</code>	<code>~</code>
<code>!</code>	<code>!=</code>
<code><</code>	<code>></code>
<code><=</code>	<code>>=</code>
<code>&</code>	<code>&&</code>
<code> </code>	<code> </code>
<code>^</code>	<code>? :</code>
<code><<</code>	<code>>></code>
<code>-=</code>	<code>+=</code>
<code>/=</code>	<code>%=</code>
<code>&=</code>	<code>*=</code>
<code>^=</code>	<code> =</code>
<code>>>=</code>	<code><<=</code>
<code>sizeof</code>	

4.11 Functions

You may use function prototypes to declare a function.
These declarations include information about the function parameters.
Example:

```
int alfa(char par1, int par2, long par3);
```

The actual function definition may be written somewhere else as:

```
int alfa(char par1, int par2, long par3) {  
/* Write some statements here */  
  
}
```

The old Kernighan & Ritchie style of writing function definitions is not supported.
Function parameters are passed through the **Data Stack**.
Function values are returned in registers R30, R31, R22 and R23 (from LSB to MSB).

The special **__reset** attribute can be applied to a function that must be executed immediately after the chip reset before that startup initialization sequence.
This may be useful for XMEGA chips when **SDRAM** is used as external memory and a different clock source is used instead of the internal 2MHz oscillator, which will ensure that correct timing is used for later **SDRAM** access by the startup code.
Example:

```
__reset void system_clocks_init(void)  
{  
// Initialization code ...  
  
}
```

4.12 Pointers

Due to the Harvard architecture of the AVR microcontroller, with separate address spaces for data (RAM), program (FLASH) and EEPROM memory, the compiler implements three types of pointers. The syntax for pointer declaration is:

```
[<memory attribute>] type * [<memory attribute>]  
                        [* [<memory attribute>] ...] pointer_name;
```

or

```
type [<memory attribute>] * [<memory attribute>]  
                        [* [<memory attribute>] ...] pointer_name;
```

where type can be any data type.

Variables placed in RAM are accessed using normal pointers.

For accessing constants placed in FLASH memory, the **flash** or **__flash** memory attributes are used.

For accessing variables placed in EEPROM, the **eeprom** or **__eeprom** memory attributes are used.

Although the pointers may point to different memory areas, they are by default stored in RAM.

Example:

```
/* Pointer to a char string placed in RAM */  
char *ptr_to_ram="This string is placed in RAM";  
  
/* Pointer to a char string placed in FLASH */  
flash char *ptr_to_flash1="This string is placed in FLASH";  
char flash *ptr_to_flash2="This string is also placed in FLASH";  
  
/* Pointer to a char string placed in EEPROM */  
eeprom char *ptr_to_eeprom1="This string is placed in EEPROM";  
char eeprom *ptr_to_eeprom2="This string is also placed in EEPROM";
```

In order to store the pointer itself in other memory areas, like FLASH or EEPROM, the **flash** (**__flash**) or **eeprom** (**__eeprom**) pointer storage memory attributes must be used as in the examples below:

```
/* Pointer stored in FLASH to a char string placed in RAM */  
char * flash flash_ptr_to_ram="This string is placed in RAM";  
  
/* Pointer stored in FLASH to a char string placed in FLASH */  
flash char * flash flash_ptr_to_flash="This string is placed in FLASH";  
  
/* Pointer stored in FLASH to a char string placed in EEPROM */  
eeprom char * flash eeprom_ptr_to_eeprom="This string is placed in EEPROM";  
  
/* Pointer stored in EEPROM to a char string placed in RAM */  
char * eeprom eeprom_ptr_to_ram="This string is placed in RAM";  
  
/* Pointer stored in EEPROM to a char string placed in FLASH */  
flash char * eeprom eeprom_ptr_to_flash="This string is placed in FLASH";  
  
/* Pointer stored in EEPROM to a char string placed in EEPROM */  
eeprom char * eeprom eeprom_ptr_to_eeprom="This string is placed in  
EEPROM";
```

In order to improve the code efficiency several memory models are implemented.

The **TINY** memory model uses 8 bits for storing pointers to the variables placed in RAM. In this memory model you can only have access to the first 256 bytes of RAM.

The **SMALL** memory model uses 16 bits for storing pointers the variables placed in RAM. In this memory model you can have access to 65536 bytes of RAM.

In both **TINY** and **SMALL** memory models pointers to the FLASH memory area use 16 bits. Because in these memory models pointers to the FLASH memory are 16 bits wide, the total size of the constant arrays and literal char strings is limited to 64K. However the total size of the program can be the full amount of FLASH.

In order to remove the above mentioned limitation, there are available two additional memory models: **MEDIUM** and **LARGE**.

The **MEDIUM** memory model is similar to the **SMALL** memory model, except it uses pointers to constants in FLASH that are 32 bits wide. The pointers to functions are however 16 bit wide because they hold the *word* address of the function, so 16 bits are enough to address a function located in all 128kbytes of FLASH.

The **MEDIUM** memory model can be used only for chips with 128kbytes of FLASH.

The **LARGE** memory model is similar to the **SMALL** memory model, except it uses pointers to the FLASH memory area that are 32 bits wide.

The **LARGE** memory model can be used for chips with 256kbytes or more of FLASH.

In all memory models pointers to the EEPROM memory area are 16 bit wide.

Pointers can be grouped in arrays, which can have up to 8 dimensions.

Example:

```
/* Declare and initialize a global array of pointers to strings
   placed in RAM */
char *strings[3]={"One","Two","Three"};

/* Declare and initialize a global array of pointers to strings
   placed in FLASH
   The pointer array itself is also stored in FLASH */
flash char * flash messages[3]={"Message 1","Message 2","Message 3"};

/* Declare some strings in EEPROM */
eeprom char m1[]="aaaa";
eeprom char m2[]="bbbb";

void main(void) {
/* Declare a local array of pointers to the strings placed in EEPROM
   You must note that although the strings are located in EEPROM,
   the pointer array itself is located in RAM */
char eeprom *pp[2];

/* and initialize the array */
pp[0]=m1;
pp[1]=m2;
}
```

Pointers to functions always access the FLASH memory area. There is no need to use the **flash** or **__flash** memory attributes for these types of pointers.

Example:

```
/* Declare a function */
int sum(int a, int b) {
    return a+b;
}

/* Declare and initialize a global pointer to the function sum */
int (*sum_ptr) (int a, int b)=sum;

void main(void) {
    int i;

    /* Call the function sum using the pointer */
    i=(*sum_ptr) (1,2);
}
```

4.13 Compiler Directives

Compiler specific directives are specified using the **#pragma** command.

You can use the **#pragma warn** directive to globally enable or disable compiler warnings.

Example:

```
/* Warnings are disabled */
#pragma warn-
/* Write some code here */

/* Warnings are enabled */
#pragma warn+
```

Warnings can also be enabled or disabled individually using the following #pragma format:

```
#pragma <warn_xxxx><+/->
```

detailed in the table below:

warn_xxxx	Warning message:
warn_const_range	constant out of range
warn_loss_precision	possible loss of precision
warn_array_index_range	array index is out of range
warn_global_var_addr	RAM location address is out of range
warn_int_vector	interrupt vector exceeds the allowable range
warn_const_not_init	constant not initialized
warn_susp_ptr_conv	suspicious pointer conversion
warn_reg_alloc	register is already allocated
warn_macro_redef	macro was redefined
warn_func_ret	function must have a return value
warn_unref_func	unused function was removed by the linker
warn_unref_param	function parameter was not referenced
warn_param_name	function parameter name doesn't match its previous declaration
warn_cant_inline	function can't be inlined
warn_unref_local	local variable was declared, but not referenced
warn_local_set_not_used	local variable set, but not used
warn_var_used_not_set	local variable is used before its value is set
warn_unref_global_var	global variable/constant was declared, but not referenced
warn_unref_label	label declared, but not referenced
warn_empty_line	empty line
warn_expr_no_effect	expression with possibly no effect
warn_unknown_esc_sequence	unknown escape sequence
warn_shift_result0	shift result will be 0
warn_shift_count0	shift count is 0
warn_neg_shift	shift count is negative
warn_8bit_add_ovf	overflow is possible in 8 bit addition
warn_8bit_mul_ovf	overflow is possible in 8 bit multiplication
warn_8bit_shift_left_ovf	overflow is possible in 8 bit shift left
warn_16bit_add_ovf	overflow is possible in 16 bit addition
warn_16bit_mul_ovf	overflow is possible in 16 bit multiplication
warn_16bit_shift_left_ovf	overflow is possible in 16 bit shift left
warn_incorrect_assign	possibly incorrect assignment
warn_pointless_comp	pointless integer comparison
warn_const_ctrl_expr	controlling expression is constant

warn_xxxx	Warning message:
warn_undef_sym	undefined symbol, assumed 0
warn_cant_alloc_reg	can't allocate variable to a register
warn_explicit_type_missing	explicit type is missing
warn_enum_type	enumerated type mixed with another type
warn_typedef_name	typedef name required
warn_typedef_redec	typedef name has already been declared with the same type
warn_extra_braces	extra braces are non-standard
warn_incomp_assign	incompatible assignment
warn_incomp_init	incompatible initialization
warn_incomp_op_ternary	incompatible operands of '? : ' operator
warn_incomp_func_arg	incompatible function argument
warn_incomp_func_ret	incompatible return expression
warn_mem_attr	memory attribute ignored
warn_pragma_vector	more than one '#pragma vector' directives were used
warn_data_stack_recursion	function not used in data stack usage calculation due to possible recursive calls
warn_hardware_stack_low	hardware stack size has a dangerously low value
warn_coff_array_dim	array has more than the 4 dimensions allowed by the COFF format
warn_coff_data_complex	data type too complex for the COFF format
warn_ram_eeprom_alloc_const	static RAM or EEPROM storage allocated for constant string literal

The compiler's code optimizer can be turned on or off using the **#pragma opt** directive. This directive must be placed at the start of the source file.

The default is optimization turned on.

Example:

```
/* Turn optimization off, for testing purposes */
#pragma opt-
```

or

```
/* Turn optimization on */
#pragma opt+
```

If the code optimization is enabled, you can optimize some portions or all the program for size or speed using the **#pragma optsize** directive.

The default state is determined by the **Project|Configure|C Compiler|Code Generation|Optimization** menu setting.

Example:

```
/* The program will be optimized for minimum size */
#pragma optsize+

/* Place your program functions here */

/* Now the program will be optimized for maximum execution speed */
#pragma optsize-

/* Place your program functions here */
```

CodeVisionAVR

The default optimization for **Size** or **Speed** specified the **Project|Configure|C Compiler|Code Generation|Optimization** menu setting can be restored using the **#pragma optsize_default** directive.

Example:

```
/* The program will be optimized for maximum speed */
#pragma optsize-

/* Place your program functions here */

/* Now the program will be optimized for the setting
   specified in the project configuration */
#pragma optsize_default

/* Place your program functions here */
```

The automatic saving and restoring of registers affected by the interrupt handler, can be turned on or off using the **#pragma savereg** directive.

Example:

```
/* Turn registers saving off */
#pragma savereg-

/* interrupt handler */
interrupt [1] void my_irq(void) {
/* now save only the registers that are affected by the routines in the
   interrupt handler, for example R30, R31 and SREG */
#asm
    push r30
    push r31
    in    r30,SREG
    push r30
#endasm

/* place the C code here */
/* .... */
/* now restore SREG, R31 and R30 */
#asm
    pop r30
    out SREG,r30
    pop r31
    pop r30
#endasm
}
/* re-enable register saving for the other interrupts */
#pragma savereg+
```

The default state is automatic saving of registers during interrupts.

The **#pragma savereg** directive is maintained only for compatibility with versions of the compiler prior to V1.24.1. This directive is not recommended for new projects.

CodeVisionAVR

The automatic allocation of global variables to registers can be turned on or off using the **#pragma regalloc** directive.

The default state is determined by the **Project|Configure|C Compiler|Code Generation|Automatic Global Register Allocation** check box.

Example:

```
/* the following global variable will be automatically
allocated to a register */
#pragma regalloc+
unsigned char alfa;

/* the following global variable will not be automatically
allocated to a register and will be placed in normal RAM */
#pragma regalloc-
unsigned char beta;
```

The ANSI **char** to **int** operands promotion can be turned on or off using the **#pragma promotechar** directive.

Example:

```
/* turn on the ANSI char to int promotion */
#pragma promotechar+

/* turn off the ANSI char to int promotion */
#pragma promotechar-
```

This option can also be specified in the **Project|Configure|C Compiler|Code Generation|Promote char to int** menu.

Treating **char** by default as an unsigned 8 bit can be turned on or off using the **#pragma uchar** directive.

Example:

```
/* char will be unsigned by default */
#pragma uchar+

/* char will be signed by default */
#pragma uchar-
```

This option can also be specified in the **Project|Configure|C Compiler|Code Generation|char is unsigned** menu.

The **#pragma library** directive is used for specifying the necessity to compile/link a specific library file.

Example:

```
#pragma library mylib.lib
```

The **#pragma glbdef+** directive is used for compatibility with projects, created with versions of CodeVisionAVR prior to V1.0.2.2, where the **Project|Configure|C Compiler|Global #define** option was enabled.

It signals the compiler that macros are globally visible in all the program modules of a project.

This directive must be placed in beginning of the first source file of the project.

By default this directive is not active, so macros are visible only in the program module where they are defined.

CodeVisionAVR

The **#pragma vector** directive is used for specifying that the next declared function is an interrupt service routine.

Example:

```
/* Vector numbers are for the AT90S8515 */
/* Specify the vector number using the #pragma vector directive */
#pragma vector=8

/* Called automatically on TIMER0 overflow */
__interrupt void timer0_overflow(void) {
/* Place your code here */

}
```

The **#pragma vector** directive and the **__interrupt** keyword are used for compatibility with other C compilers for the Atmel AVR.

The **#pragma keep+** directive forces a function, global variable or global constant to be linked even if it wasn't used anywhere in the program.

Example:

```
/* force the next function to be linked even if it's not used */
#pragma keep+

int func1(int a, int b)
{
return a+b;
}

/* the next function will not be linked if it's not used
#pragma keep-

int func2(int a, int b)
{
return a-b;
}
```

The **#pragma data_alignment=value** directive is used to align variables located in RAM at addresses which are multiples of **value**.

Example:

```
#pragma data_alignment=2

unsigned char alfa; /* alfa will be located at an even RAM address */
```

The **#pragma dstack_par+** directive is used to force passing function parameters using the **Data Stack**, even if the **Enhanced Parameter Mode 2** is selected in the **Project|Configure|C Compiler|Code Generation** menu.

This ensures compatibility with C functions containing inline assembly code, that references the function's parameters.

The directive remains valid until **#pragma dstack_par-** or the end of the current C program module is encountered.

Example:

```
/* This will force passing the function parameters using the data stack */
#pragma dstack_par+

int sum_abc(int a, int b, unsigned char c) {
    #asm
        ldd    r30,y+3 ;R30=LSB a
        ldd    r31,y+4 ;R31=MSB a
        ldd    r26,y+1 ;R26=LSB b
        ldd    r27,y+2 ;R27=MSB b
        add    r30,r26 ; (R31,R30)=a+b
        adc    r31,r27
        ld     r26,y    ;R26=c
        clr    r27      ;promote unsigned char c to int
        add    r30,r26 ; (R31,R30)=(R31,R30)+c
        adc    r31,r27
    #endasm
}

/* Re-enable passing the function parameters using registers,
   if Enhanced Parameter Passing Mode 2 is set in the
   Project|Configure|C Compiler|Code Generation menu */
#pragma dstack_par-
```

The **pragma lock_bits** directive allows embedding lock bits programming data into the production **.elf** file created after a successful project build.

This directive can be used only once in the whole program.

The syntax is:

```
#pragma lock_bits=n
```

where **n** is the value to be used for lock bits programming.

Example:

```
#pragma lock_bits=0x3F
```

will disable further FLASH and EEPROM programming and reading for an ATmega328P chip.

The **pragma fuses** directive allows embedding fuse byte(s) programming data into the production **.elf** file created after a successful project build.

This directive can be used only once in the whole program.

The syntax is:

```
#pragma fuses=low_byte[, high_byte[, extended_byte]]
```

where **low_byte**, **high_byte**, **extended_byte** are the values to be used for fuse byte(s) programming.

Example:

```
#pragma fuses=0xFF,0xDE,0xFD
```

4.14 Accessing the I/O Registers

The compiler uses the **sfrb** and **sfrw** keywords to access the AVR microcontroller's I/O registers, located in the 0..3Fh address range, using the IN and OUT assembly instructions.

Example:

```
/* Define the SFRs */
sfrb PINA=0x19; /* 8 bit access to the SFR */
sfrw TCNT1=0x2c; /* 16 bit access to the SFR */

void main(void)
{
    unsigned char a;

    a=PINA;          /* Read PORTA input pins */
    TCNT1=0x1111; /* Write to TCNT1L & TCNT1H registers */
}
```

The **io.h** header file, located in the .\INC subdirectory, contains the definitions of the I/O registers for all the chips supported by the compiler.

The definitions are selected based on the AVR chip setting, specified by the **Project|Configure|C Compiler|Code Generation|Chip** option.

This header must be **#include -d** at the beginning of the .C source file.

For XMEGA chips the following syntax must be used for accessing I/O registers:

```
/* I/O register definitions for the XMEGA128A1 chip */
#include <io.h>

void main(void)
{
    unsigned char a;

    /* Set all PORTA pins as inputs */
    PORTA.DIR=0x00;

    /* Read PORTA input pins */
    a=PORTA.IN;

    /* Set all PORTB pins as outputs */
    PORTB.DIR=0xFF;

    /* Write data to PORTB outputs */
    PORTB.OUT=0x11;

    /* Set PORTB pin 2 to 1 */
    PORTB.OUTSET=1 << 2;

    /* Set PORTB pin 4 to 0 */
    PORTB.OUTCLR=1 << 4;

    /* Toggle PORTB pin 0 */
    PORTB.OUTTGL=1 << 0;
}
```

The XMEGA I/O ports can be also accessed using the Virtual Ports:

```
/* I/O register definitions for the XMEGA128A1 chip */
#include <io.h>

void main(void)
{
    unsigned char a;

    /* Map PORTA to virtual port VPORT0 and
       PORTB to virtual port VPORT1 */
    PORTCFG.VPCTRLA=PORTCFG_VP1MAP_PORTB_gc | PORTCFG_VP0MAP_PORTA_gc;

    /* Set all VPORT0 (PORTA) pins as inputs */
    VPORT0_DIR=0x00;

    /* Read VPORT0 (PORTA) input pins */
    a=VPORT0_IN;

    /* Set all VPORT1 (PORTB) pins as outputs */
    VPORT1_DIR=0xFF;

    /* Write data to VPORT1 (PORTB) outputs */
    VPORT1_OUT=0x11;

    /* Set VPORT1 (PORTB) pin 2 to 1 */
    VPORT1_OUT|=1 << 2;

    /* Set VPORT1 (PORTB) pin 4 to 0 */
    VPORT1_OUT&=~1 << 4;

    /* Toggle VPORT1 (PORTB) pin 0 */
    VPORT1_OUT^=1 << 0;
}
```

More details about accessing I/O ports for the XMEGA chips can be found in the following Atmel documents:

- AVR1000: Getting Started Writing C-code for XMEGA
- XMEGA A Manual
- XMEGA AU Manual
- XMEGA B Manual
- XMEGA C Manual
- XMEGA D Manual
- XMEGA E Manual

4.14.1 Bit level access to the I/O Registers

Bit level access to the I/O registers can be performed by using the special macros that are defined in the *iobits.h* header file, located in the `.INC` subdirectory.

The following macros are available:

SETBIT(port,b)

sets bit **b** of **port** to logic 1 state.

Example:

```
/* set bit 5 of I/O Port A output to logic 1 for non-XMEGA chips */
SETBIT(PORTA, 5);

/* set bit 5 of I/O Port A output to logic 1 for XMEGA chips */
SETBIT(PORTA.OUT, 5);
```

CLRBIT(port,b)

sets bit **b** of **port** to logic 0 state.

Example:

```
/* set bit 5 of I/O Port A output to logic 0 for non-XMEGA chips */
CLRBIT(PORTA, 5);

/* set bit 5 of I/O Port A output to logic 0 for XMEGA chips */
CLRBIT(PORTA.OUT, 5);
```

TGLBIT(port,b)

toggles (inverts) the logic state of bit **b** of **port**.

Example:

```
/* toggles bit 5 of I/O Port A output for non-XMEGA chips */
TGLBIT(PORTA, 5);

/* toggles bit 5 of I/O Port A output for XMEGA chips */
TGLBIT(PORTA.OUT, 5);
```

EQUBIT(port,b,value)

assigns a **value** to bit **b** of **port**.

If the assigned value is different from 0, then the bit is set to logic 1 state.

If the assigned value is 0, then the bit is set to logic 0 state.

Example:

```
/* sets bit 5 of I/O Port A output to the logic state of variable i
for non-XMEGA chips */
EQUBIT(PORTA,5,i);

/* sets bit 5 of I/O Port A output to the logic state of variable i
for XMEGA chips */
EQUBIT(PORTA.OUT,5,i);
```

Note: The **SETBIT**, **CLRBIT**, **TGLBIT** and **EQUBIT** macros always perform atomic I/O port bit access for the XMEGA chips.

For non-XMEGA chips, the atomic I/O port bit access using the **SETBIT**, **CLRBIT** and **EQUBIT** macros can be performed only for I/O ports with addresses located in I/O register space in the 0 to 1Fh range.

TSTBIT(port,b)

returns the logic state of bit **b** of **port**.

Example:

```
/* tests bit 5 of PINA (I/O Port A input) for non-XMEGA chips */
if (TSTBIT(PINA,5))
{
    /* bit 5 of I/O Port A input is logic 1, do something... */
}

/* tests bit 5 of PORTA.IN (I/O Port A input) for XMEGA chips */
if (TSTBIT(PORTA.IN,5))
{
    /* bit 5 of I/O Port A input is logic 1, do something... */
}
```

The bit level access to the I/O registers can be also accomplished by using bit selectors appended after the name of the I/O register.

Because bit level access to I/O registers is done using the CBI, SBI, SBIC and SBIS instructions, the register address must be in the 0 to 1Fh range for **sfrb** and in the 0 to 1Eh range for **sfrw**.

Example:

```
sfrb PORTA=0x1b;
sfrb DDRA=0x18;
sfrb PINA=0x19;

void main(void) {
    /* set bit 0 of Port A as output */
    DDRA.0=1;

    /* set bit 1 of Port A as input */
    DDRA.1=0;

    /* set bit 0 of Port A output to logic 1 */
    PORTA.0=1;
```

```
/* test bit 1 input of Port A */
if (PINA.1) { /* place some code here */ };

/* ..... */

}
```

The same program for XMEGA chips using the Virtual Port VPORT0:

```
/* I/O register definitions for the ATxmega128A1 chip */
#include <xmega128a1.h>

void main(void) {
/* Map PORTA to virtual port VPORT0 and
   PORTB to virtual port VPORT1 */
PORTCFG.VPCTRLA=PORTCFG_VP1MAP_PORTB_gc | PORTCFG_VP0MAP_PORTA_gc;

/* set bit 0 of Port A as output */
VPORT0_DIR.0=1;

/* set bit 1 of Port A as input */
VPORT0_DIR.1=0;

/* set bit 0 of Port A output to logic 1 */
VPORT0_OUT.0=1;

/* test bit 1 input of Port A */
if (VPORT0_IN.1) { /* place some code here */ };

/* ..... */

}
```

To improve the readability of the program you may wish to **#define** symbolic names to the bits in I/O registers:

```
sfrb PINA=0x19;
#define alarm_input PINA.2
void main(void)
{
/* test bit 2 input of Port A */
if (alarm_input) { /* place some code here */ };
/* ..... */
}
```

Note: Bit selector access to I/O registers located in internal RAM above address 5Fh (like PORTF for the ATmega128 for example) will not work, because the CBI, SBI, SBIC and SBIS instructions can't be used for RAM access.

4.15 Accessing the EEPROM

Accessing the AVR internal EEPROM is accomplished using global variables, preceded by the **EEPROM** or **__EEPROM** memory attributes.

Example:

```
/* The value 1 is stored in the EEPROM during chip programming */
EEPROM int alfa=1;

EEPROM char beta;
EEPROM long array1[5];

/* The string is stored in the EEPROM during chip programming */
EEPROM char string[]="Hello";

void main(void) {
    int i;

    /* Pointer to EEPROM */
    int EEPROM *ptr_to_EEPROM;

    /* Write directly the value 0x55 to the EEPROM */
    alfa=0x55;
    /* or indirectly by using a pointer */
    ptr_to_EEPROM=&alfa;
    *ptr_to_EEPROM=0x55;

    /* Read directly the value from the EEPROM */
    i=alfa;
    /* or indirectly by using a pointer */
    i=*ptr_to_EEPROM;
}
```

Pointers to the EEPROM always occupy 16 bits in memory.

The initialization data for the EEPROM is stored in an .EEP file in Intel hex format.

The contents of this file must be programmed to the chip's EEPROM.

For compatibility with AVR GCC programs, the **EEPROM.h** header file is supplied with CodeVisionAVR. It contains the following macros and functions:

EEPROM_read_byte(addr)

Reads an unsigned char value from EEPROM address **addr**.

EEPROM_read_word(addr)

Reads an unsigned short value starting from EEPROM address **addr**.

EEPROM_read_dword(addr)

Reads an unsigned long value starting from EEPROM address **addr**.

EEPROM_read_float(addr)

Reads a float value starting from EEPROM address **addr**.

For the TINY memory model:

void eeprom_read_block(void *dst, eeprom void *src, unsigned char n)

For the rest of memory models:

void eeprom_read_block(void *dst, eeprom void *src, unsigned short n)

Reads a block of **n** bytes, pointed by **src**, from EEPROM to RAM, pointed by **dst**.

eeprom_write_byte(addr, value)

Writes the unsigned char **value** to EEPROM address **addr**.

eeprom_write_word(addr, value)

Writes the unsigned short **value** starting with EEPROM address **addr**.

eeprom_write_dword(addr, value)

Writes the unsigned long **value** starting with EEPROM address **addr**.

eeprom_write_float(addr, value)

Writes the unsigned short **value** starting with EEPROM address **addr**.

For the TINY memory model:

void eeprom_write_block(void *src, eeprom void *dst, unsigned char n)

For the rest of memory models:

void eeprom_write_block(void *src, eeprom void *dst, unsigned short n)

Writes a block of **n** bytes, pointed by **src**, from RAM to EEPROM, pointed by **dst**.

eeprom_update_byte(addr, value)

Writes the unsigned char **value** to EEPROM address **addr**.

eeprom_update_word(addr, value)

Writes the unsigned short **value** starting with EEPROM address **addr**.

eeprom_update_dword(addr, value)

Writes the unsigned long **value** starting with EEPROM address **addr**.

eeeprom_update_float(addr, value)

Writes the unsigned short **value** starting with EEPROM address **addr**.

For the TINY memory model:

void eeeprom_update_block(void *src, eeeprom void *dst, unsigned char n)

For the rest of memory models:

void eeeprom_update_block(void *src, eeeprom void *dst, unsigned short n)

Writes a block of **n** bytes, pointed by **src**, from RAM to EEPROM, pointed by **dst**.

Note: For CodeVisionAVR both the EEPROM *write* and *update* macros/functions are equivalent. They check if the EEPROM location contains the same data as the value to be written to. In this case no write is performed in order to not wear out the EEPROM.

4.16 Using Interrupts

The access to the AVR interrupt system is implemented with the **interrupt** keyword.

Example:

```
/* Vector numbers are for the AT90S8515 */

/* Called automatically on external interrupt */
interrupt [2] void external_int0(void) {
/* Place your code here */

}

/* Called automatically on TIMER0 overflow */
interrupt [8] void timer0_overflow(void) {
/* Place your code here */

}
```

Interrupt vector numbers start with 1.

The compiler will automatically save the affected registers when calling the interrupt functions and restore them back on exit.

A RETI assembly instruction is placed at the end of the interrupt function.

Interrupt functions can't return a value nor have parameters.

You must also set the corresponding bits in the peripheral control registers to configure the interrupt system and enable the interrupts.

Another possibility to declare an interrupt service routine is by using the **#pragma vector** preprocessor directive and the **__interrupt** keyword.

#pragma vector is used for specifying that the next declared function is an interrupt service routine.

Example:

```
/* Vector numbers are for the AT90S8515 */

/* Specify the vector number using the #pragma vector directive */
#pragma vector=2

/* Called automatically on external interrupt */
__interrupt void external_int0(void) {
/* Place your code here */

}

/* Specify the vector number using the #pragma vector directive */
#pragma vector=8

/* Called automatically on TIMER0 overflow */
__interrupt void timer0_overflow(void) {
/* Place your code here */

}
```

The **#pragma vector** preprocessor directive and the **__interrupt** keyword are used for compatibility with other C compilers for the Atmel AVR.

CodeVisionAVR

The automatic saving and restoring of registers affected by the interrupt handler, can be turned on or off using the **#pragma savereg** directive.

Example:

```
/* Turn registers saving off */
#pragma savereg-

/* interrupt handler */
interrupt [1] void my_irq(void) {
/* now save only the registers that are affected by the routines in the
   interrupt handler, for example R30, R31 and SREG */
#asm
    push r30
    push r31
    in    r30,SREG
    push r30
#endasm

/* place the C code here */
/* .... */
/* now restore SREG, R31 and R30 */
#asm
    pop r30
    out SREG,r30
    pop r31
    pop r30
#endasm
}
/* re-enable register saving for the other interrupts */
#pragma savereg+
```

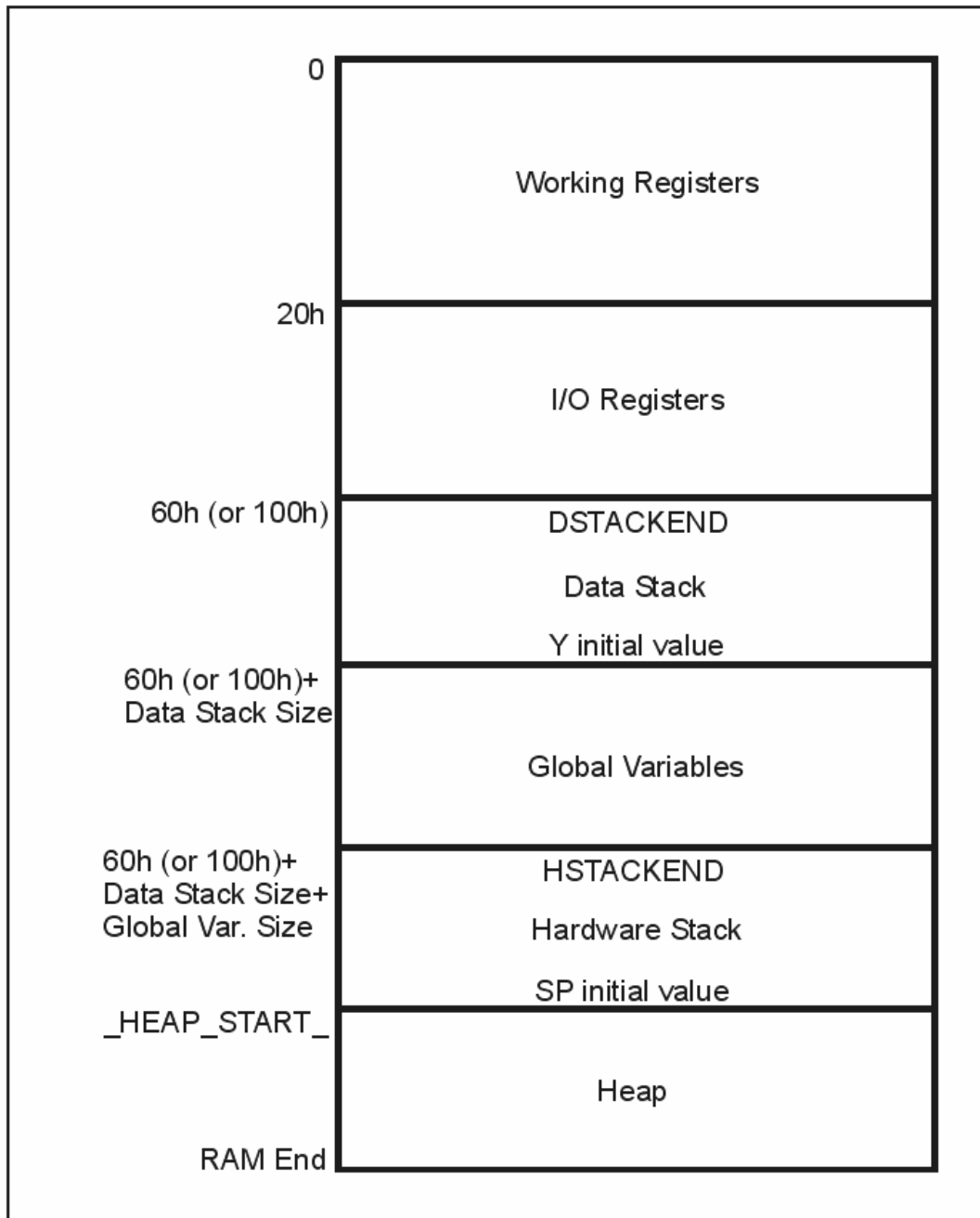
The default state is automatic saving of registers during interrupts.

The **#pragma savereg** directive is maintained only for compatibility with versions of the compiler prior to V1.24.1. This directive is not recommended for new projects.

4.17 RAM Memory Organization and Register Allocation

CodeVisionAVR uses the little-endian convention for storing variables: the LSB is always stored at the lower address or register, the MSB(s) at the consecutive address(es) or register(s).

A compiled program has the following memory map:



The **Working Registers** area contains 32x8 bit general purpose working registers.

The register usage depends on the type of the AVR core for which code is generated:

- **standard core**: the compiler uses the following registers: R0, R1, R15, R22, R23, R24, R25, R26, R27, R28, R29, R30 and R31.

Also some of the registers from R2 to R15 may be allocated by the compiler for global and local bit variables.

The rest of unused registers, in this range, are allocated for global char and int variables and pointers.

Registers R16 to R21 are allocated for local char and int variables.

If **Enhanced Parameter: Mode 2** is selected in the **Project|Configure|C Compiler|Code Generation** menu, then the remaining registers R16 to R21, that were not allocated for local variables, are used for storing char and int function parameters.

- **reduced core** (ATtiny10): the compiler uses the following registers: R16, R17, R22, R23, R24, R25, R26, R27, R28, R29, R30 and R31.

No registers may be allocated by the compiler for global and local bit variables.

Registers R18 to R21 are allocated for local char and int variables.

If **Enhanced Parameter: Mode 2** is selected in the **Project|Configure|C Compiler|Code Generation** menu, then the remaining registers R18 to R21, that were not allocated for local variables, are used for storing char and int function parameters.

The **I/O Registers** area contains 64 addresses for the CPU peripheral functions as Port Control Registers, Timer/Counters and other I/O functions. You may freely use these registers in your assembly programs.

The **Data Stack** area is used to dynamically store local variables, passing function parameters and saving registers during interrupt routine servicing:

- **standard core**: R0, R1, R15, R22, R23, R24, R25, R26, R27, R30, R31 and SREG
- **reduced core**: R16, R17, R22, R23, R24, R25, R26, R27, R30, R31 and SREG.

The **Data Stack Pointer** is implemented using the Y register.

At start-up the **Data Stack Pointer** is initialized with the value 5Fh (or FFh for some chips)+Data Stack Size.

When saving a value in the **Data Stack**, the **Data Stack Pointer** is decremented.

When the value is retrieved, the **Data Stack Pointer** is incremented back.

When configuring the compiler, in the **Project|Configure|C Compiler|Code Generation** menu, you must specify a sufficient **Data Stack Size**, so it will not overlap the **I/O Register** area during program execution.

The following modes, specified in the **Project|Configure|C Compiler|Code Generation** menu, are used for function parameter passing and storage:

- **Enhanced Parameter: No** - all function parameters are passed using the **Data Stack** and accessed using the **LDD Rn, Y+d** and **STD Y+d,Rn** instructions
- **Enhanced Parameter: Mode 1** - all function parameters, except the last one, are passed using the **Data Stack**.

The last parameter is passed in registers R26 for 1 byte, R26, R27 for 2 byte and R26, R27, R24, R25 for 4 byte parameters.

However in the function prologue this last parameter is pushed in the **Data Stack** too.

So in this mode all function parameters are also accessed using the **LDD Rn, Y+d** and **STD Y+d,Rn** instructions.

Better code size is obtained, because register accessing instructions are used when passing the last function parameter during function call.

- **Enhanced Parameter: Mode 2** - all function parameters, except the last one, are passed using the **Data Stack**.

The last parameter is passed in registers R26 for 1 byte, R26, R27 for 2 byte and R26, R27, R24, R25 for 4 byte parameters.

In the function prologue the function parameters are copied from the **Data Stack** or registers R26, R27, R24, R25 to the registers R16..R21, that were not allocated for local variables.

CodeVisionAVR

In this mode function parameters that could be allocated/copied to registers R16..R21 are accessed using more efficient instructions.

The rest of the parameters are still accessed using the **LDD Rn, Y+d** and **STD Y+d,Rn** instructions. Even better code size is obtained, because register accessing instructions are used when passing the last parameter and for accessing the parameters stored in registers inside the function.

Note: If this mode is used for programs which contain functions that use inline assembly code to access function parameters, then such functions must be enclosed between **#pragma dstack+** and **#pragma dstack-** like in the following example:

```
/* This will force passing the function parameters
   using the data stack */
#pragma dstack_par+

int sum_abc(int a, int b, unsigned char c) {
#asm
    ldd    r30,y+3 ;R30=LSB a
    ldd    r31,y+4 ;R31=MSB a
    ldd    r26,y+1 ;R26=LSB b
    ldd    r27,y+2 ;R27=MSB b
    add    r30,r26 ; (R31,R30)=a+b
    adc    r31,r27
    ld     r26,y    ;R26=c
    clr    r27      ;promote unsigned char c to int
    add    r30,r26 ; (R31,R30)=(R31,R30)+c
    adc    r31,r27
#endasm
}

/* Re-enable passing the function parameters using registers,
   if Enhanced Parameter Passing Mode 2 is set in the
   Project|Configure|C Compiler|Code Generation menu */
#pragma dstack_par-
```

The **Global Variables** area is used to statically store the global variables during program execution. The size of this area can be computed by summing the size of all the declared global variables.

The **Hardware Stack** area is used for storing the functions return addresses.

The SP register is used as a stack pointer and is initialized at start-up with value of the **_HEAP_START_-1** address.

During the program execution the **Hardware Stack** grows downwards to the **Global Variables** area.

When configuring the compiler you have the option to place the strings **DSTACKEND**, respectively **HSTACKEND**, at the end of the **Data Stack**, respectively **Hardware Stack** areas.

When you debug the program with AVR Studio you may see if these strings are overwritten, and consequently modify the **Data Stack Size** using the **Project|Configure|C Compiler|Code Generation** menu command.

When your program runs correctly, you may disable the placement of the strings in order to reduce code size.

The **Heap** is a memory area located between the **Hardware Stack** and the **RAM end**.

It is used by the memory allocation functions from the Standard Library (stdlib.h): malloc, calloc, realloc and free.

The **Heap** size must be specified in the **Project|Configure|C Compiler|Code Generation** menu. It can be calculated using the following formulae:

$$heap\_size = (n + 1) \cdot 4 + \sum_{i=1}^n block\_size_i$$

where: n is the number of memory blocks that will be allocated in the **Heap**

$block\_size_i$ is the size of the memory block i

If the memory allocation functions will not be used, then the **Heap** size must be specified as zero.

4.18 Using an External Startup Assembly File

In every program the CodeVisionAVR C compiler automatically generates a code sequence to make the following initializations immediately after the AVR chip reset:

1. interrupt vector jump table
2. global interrupt disable
3. EEPROM access disable
4. Watchdog Timer disable
5. external RAM access and wait state enable if necessary
6. clear registers R2 ... R14 (for AVR8 standard core chips)
7. clear the RAM
8. initialize the global variables located in RAM
9. initialize the **Data Stack Pointer** register Y
10. initialize the **Stack Pointer** register SP
11. initialize the UBRR register if necessary

The automatic generation of code sequences 2 to 8 can be disabled by checking the **Use an External Startup Initialization File** check box in the **Project|Configure|C Compiler|Code Generation** dialog window. The C compiler will then include, in the generated .asm file, the code sequences from an external file that must be named **STARTUP.ASM**. This file must be located in the directory where your main C source file resides.

You can write your own **STARTUP.ASM** file to customize or add some features to your program. The code sequences from this file will be immediately executed after the chip reset.

A basic **STARTUP.ASM** file is supplied with the compiler distribution and is located in the .\BIN directory.

Here's the content of this file:

```
;CodeVisionAVR C Compiler
;(C) 1998-2013 Pavel Haiduc, HP InfoTech s.r.l.

;EXAMPLE STARTUP FILE FOR CodeVisionAVR V3.05 OR LATER

;START ADDRESS OF SRAM AREA TO CLEAR
.EQU __CLEAR_START=__SRAM_START

;SIZE OF SRAM AREA TO CLEAR IN BYTES
.EQU __CLEAR_SIZE=__SRAM_END-__SRAM_START+1

CLI                ;DISABLE INTERRUPTS
CLR R30
OUT EECR,R30      ;DISABLE EEPROM ACCESS

;DISABLE THE WATCHDOG
LDI R31,0x18
OUT WDTCR,R31
OUT WDTCR,R30

OUT MCUCR,R30 ;MCUCR=0, NO EXTERNAL RAM ACCESS

;CLEAR R2-R14
LDI R24,13
LDI R26,2
CLR R27
__CLEAR_REG:
ST X+,R30
DEC R24
BRNE __CLEAR_REG
```

```
;CLEAR RAM
    LDI R24,LOW(__CLEAR_SIZE)
    LDI R25,HIGH(__CLEAR_SIZE)
    LDI R26,LOW(__CLEAR_START)
    LDI R27,HIGH(__CLEAR_START)
__CLEAR_RAM:
    ST X+,R30
    SBIW R24,1
    BRNE __CLEAR_RAM

; __GLOBAL_INI_TBL_PRESENT is predefined by the compiler
; if global variables are initialized during declaration
#ifdef __GLOBAL_INI_TBL_PRESENT

;GLOBAL VARIABLES INITIALIZATION
    LDI R30,LOW(__GLOBAL_INI_TBL*2)
    LDI R31,HIGH(__GLOBAL_INI_TBL*2)
__GLOBAL_INI_NEXT:
    LPM
    ADIW R30,1
    MOV R24,R0
    LPM
    ADIW R30,1
    MOV R25,R0
    SBIW R24,0
    BREQ __GLOBAL_INI_END
    LPM
    ADIW R30,1
    MOV R26,R0
    LPM
    ADIW R30,1
    MOV R27,R0
    LPM
    ADIW R30,1
    MOV R1,R0
    LPM
    ADIW R30,1
    MOV R22,R30
    MOV R23,R31
    MOV R31,R0
    MOV R30,R1
__GLOBAL_INI_LOOP:
    LPM
    ADIW R30,1
    ST X+,R0
    SBIW R24,1
    BRNE __GLOBAL_INI_LOOP
    MOV R30,R22
    MOV R31,R23
    RJMP __GLOBAL_INI_NEXT
__GLOBAL_INI_END:

#endif
```

The **__CLEAR_START** and **__CLEAR_SIZE** constants can be changed to specify which area of RAM to clear at program initialization.

The **__GLOBAL_INI_TBL** label must be located at the start of a table containing the information necessary to initialize the global variables located in RAM. This table is automatically generated by the compiler.

4.19 Including Assembly Language in Your Program

You can include assembly language anywhere in your program using the **#asm** and **#endasm** directives.

Example:

```
void delay(unsigned char i) {  
while (i--) {  
    /* Assembly language code sequence */  
    #asm  
        nop  
        nop  
    #endasm  
};  
}
```

Inline assembly may also be used.

Example:

```
#asm("sei") /* enable interrupts */
```

The registers R0, R1, R22, R23, R24, R25, R26, R27, R30 and R31 can be freely used in assembly routines.

However when using them in an interrupt service routine the programmer must save, respectively restore, them on entry, respectively on exit, of this routine.

4.19.1 Calling Assembly Functions from C

The following example shows how to access functions written in assembly language from a C program:

```
/* Function in assembler declaration
   This function will return a+b+c */

/* This will prevent warnings */
#pragma warn-

/* This will force passing the function parameters using the data stack */
#pragma dstack_par+

int sum_abc(int a, int b, unsigned char c) {
#asm
    ldd    r30,y+3 ;R30=LSB a
    ldd    r31,y+4 ;R31=MSB a
    ldd    r26,y+1 ;R26=LSB b
    ldd    r27,y+2 ;R27=MSB b
    add    r30,r26 ; (R31,R30)=a+b
    adc    r31,r27
    ld     r26,y    ;R26=c
    clr    r27      ;promote unsigned char c to int
    add    r30,r26 ; (R31,R30)=(R31,R30)+c
    adc    r31,r27
#endasm
}

/* Re-enable passing the function parameters using registers,
   if Enhanced Parameter Passing Mode 2 is set in the
   Project|Configure|C Compiler|Code Generation menu */
#pragma dstack_par-

/* Re-enable warnings */
#pragma warn+

void main(void) {
    int r;

    /* Now we call the function and store the result in r */
    r=sum_abc(2,4,6);
}
```

If **Enhanced Parameter Passing: No** or **Mode 1** are selected in the **Project|Configure|C Compiler|Code Generation** menu, the compiler passes function parameters using the **Data Stack**. First it pushes the integer parameter a, then b, and finally the unsigned char parameter c. On every push the Y register pair decrements by the size of the parameter (4 for long int, 2 for int, 1 for char).

For multiple byte parameters the MSB is pushed first.

As it is seen the **Data Stack** grows downward.

After all the functions parameters were pushed on the **Data Stack**, the Y register points to the last parameter c, so the function can read its value in R26 using the instruction: `ld r26,y`.

The b parameter was pushed before c, so it is at a higher address in the **Data Stack**.

The function will read it using: `ldd r27,y+2` (MSB) and `ldd r26,y+1` (LSB).

The MSB was pushed first, so it is at a higher address.

The a parameter was pushed before b, so it is at a higher address in the **Data Stack**.

The function will read it using: `ldd r31,y+4` (MSB) and `ldd r30,y+3` (LSB).

The functions return their values in the registers (from LSB to MSB):

- R30 for char and unsigned char
- R30, R31 for int and unsigned int
- R30, R31, R22, R23 for long and unsigned long.

So our function must return its result in the R30, R31 registers.

After the return from the function the compiler automatically generates code to reclaim the **Data Stack** space used by the function parameters.

The **#pragma warn-** compiler directive will prevent the compiler from generating a warning that the function does not return a value.

This is needed because the compiler does not know what it is done in the assembler portion of the function.

4.20 Creating Libraries

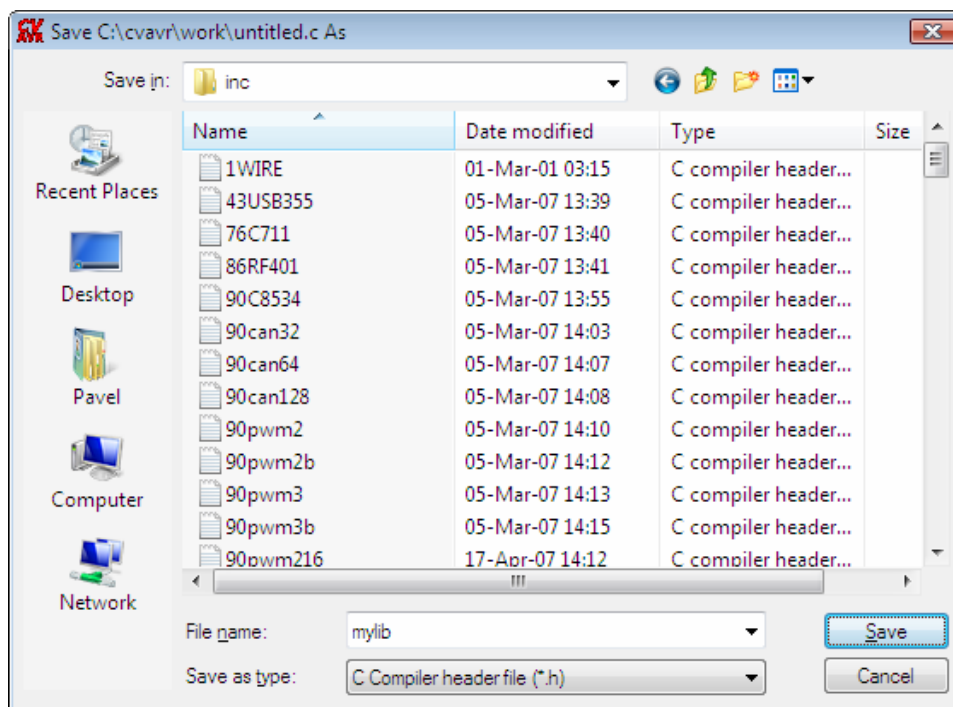
In order to create your own libraries, the following steps must be followed:

1. Create a header .h file with the prototypes of the library functions using the **File|New|Source File** menu command, by pressing the **Ctrl+N** keys or the  and  buttons on the toolbar.

A new editor window will be opened for the **untitled.c** source file.
Type in the prototype for your function. Example:

```
/* this #pragma directive will prevent the compiler from generating a
   warning that the function was declared, but not used in the program */
#pragma used+
/* library function prototypes */
int sum(int a, int b);
int mul(int a, int b);
#pragma used-
/* this #pragma directive will tell the compiler to compile/link the
   functions from the mylib.lib library */
#pragma library mylib.lib
```

Save the file, using the **File|Save As** menu command or the  toolbar button, in the **.INC** directory using the **File|Save As** menu command, for example **mylib.h** :



CodeVisionAVR

Create the library file using the **File|New|Source File** menu command, by pressing the **Ctrl+N** keys or the  and  buttons on the toolbar.

A new editor window will be opened for the **untitled.c** source file.

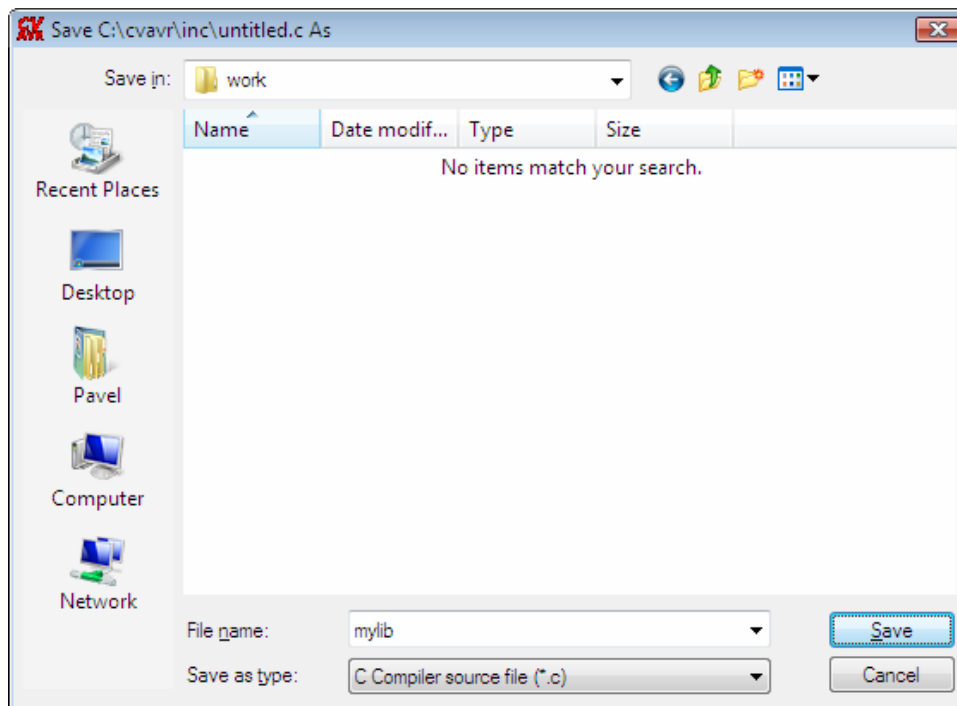
Type in the definitions for your functions.

Example:

```
int sum(int a, int b) {  
    return a+b;  
}
```

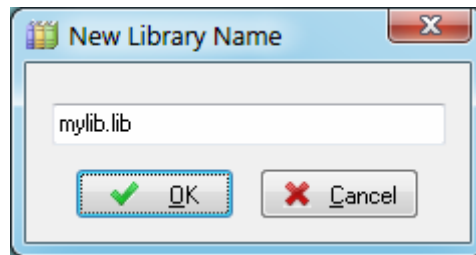
```
int mul(int a, int b) {  
    return a*b;  
}
```

Save the file, under a new name, for example **mylib.c** , in any directory using the **File|Save As** menu command or the  toolbar button:



CodeVisionAVR

Finally use the **File|Convert to Library** menu command or the  toolbar button, to save the currently opened .c file under the name **mylib.lib** in the **.LIB** directory:



In order to use the newly created **mylib.lib** library, just **#include** the **mylib.h** header file in the beginning of your program.

Example:

```
#include <mylib.h>
```

Library files usually reside in the **.LIB** directory, but paths to additional directories can be added in the **Project|Configure|C Compiler|Paths|Library paths** menu.

4.21 Using the AVR Studio 4.19 Debugger

CodeVisionAVR is designed to work in conjunction with the Atmel AVR Studio 4.19 debugger.

In order to be able to do C source level debugging using AVR Studio, you must select the **COFF Output File Format** in the **Project|Configure|C Compiler|Code Generation** menu option.

Important Note: It is highly recommended to set the **Optimize for: Speed** option in the **Project|Configure|C Compiler|Code Generation** menu, which will allow correct debugging of the program. Once debugging was finished, this option can be also set to **Optimize for: Size**.

The debugger is invoked using the **Tools|Debugger** menu command or the  toolbar button. In order to be able to do this, the debugger version and its installation path must be first specified using the **Settings|Debugger** menu.

After AVR Studio is launched, the user must first select **File|Open File (Ctrl+O keys)** in order to load the COFF file to be debugged.

After the COFF file is loaded, and no AVR Studio project file exists for this COFF file, the debugger will open a **Select device and debug platform** dialog window.

In this window the user must specify the Debug Platform: ICE or AVR Simulator and the AVR Device type.

Pressing the **Finish** button will create a new AVR Studio project associated with the COFF file.

If an AVR Studio project associated with the COFF file already exists, the user will be asked if the debugger may load it.

Once the program is loaded, it can be launched in execution using the **Debug|Run** menu command, by pressing the **F5** key or by pressing the **Run** toolbar button.

Program execution can be stopped at any time using the **Debug|Break** menu command, by pressing **Ctrl+F5** keys or by pressing the **Break** toolbar button.

To single step the program, the **Debug|Step Into (F11 key)**, **Debug|Step Over (F10 key)**, **Debug|Step Out (Shift+F11 keys)** menu commands or the corresponding toolbar buttons should be used.

In order to stop the program execution at a specific source line, the **Debug|Toggle Breakpoint** menu command, the **F9** key or the corresponding toolbar button should be used.

In order to watch program variables, the user must select **Debug|Quickwatch (Shift+F9 keys)** menu command or press the **Quickwatch** toolbar button, and specify the name of the variable in the **QuickWatch** window in the **Name** column.

The AVR chip registers can be viewed using the **View|Register** menu command or by pressing the **Alt+0** keys. The registers can be also viewed in the **Workspace|I/O** window in the **Register 0-15** and **Register 16-31** tree branches.

The AVR chip PC, SP, X, Y, Z registers and status flags can be viewed in the **Workspace|I/O** window in the **Processor** tree branch.

The contents of the FLASH, RAM and EEPROM memories can be viewed using the **View|Memory** menu command or by pressing the **Alt+4** keys.

The I/O registers can be viewed in the **Workspace|I/O** window in the **I/O** branch.

To obtain more information about using AVR Studio 4.19, please consult its Help system.

4.22 Using the Command Line Compiler

The CodeVisionAVR C Compiler can be also executed from the command line, allowing for the automation of program build tasks.

The following syntax is used when invoking the compiler from the command line:

cvavrcl <project_file> <command> [options] [arguments]

where **project_file** is the full path of the project **.prj** file created/modified using the CodeVisionAVR IDE. The path must be enclosed between " " if it contains long file names.

The following commands are accepted:

-b [options] [-m <message_out_file>]	<i>Build</i> project - only the modified source files are re-compiled
-ba [options] [-m <message_out_file>]	<i>Build All</i> project files – all source files are re-compiled
-s <source_file> [-m <message_out_file>]	Check <i>Syntax</i> for source_file
-cl	<i>Cleanup</i> project directory.

If the **-m** argument is used, the output of the command line compiler is written to the **message_out_file**, otherwise it is directed to the console.

The following options are available:

-dbg	Forces build using the <i>Debug</i> project configuration
-rel	Forces build using the <i>Release</i> project configuration
-p {STK500 STK600 JTAGICE2 JTAGICE3 AVRDRAGON AVRISP2 AVR910}	Select the <i>Programmer</i> type used for After Build chip programming
-com <n>	Specifies the <i>COM</i> port number used for communication with the STK500, AVR910 programmers
-pi {ISP_PDI JTAG}	Specifies the <i>Programming Interface</i> used by the programmer
-sck <n>	Specifies the <i>SCK</i> frequency [Hz] used for ISP programming
-rc	Specifies that the build results or messages will be directed to the <i>console</i>
-rw	Specifies that the build results or messages will be displayed in a <i>window</i> in the GUI
-dm "<macro_definition>"	Define a global macro
-df <macro_definitions_file>	Define a set of global macros from a text file.

Examples:

cvavrcl "c:\cvavr303\examples\ds1820\ds1820.prj" -ba -rc

Re-compiles all source files in the **ds1820.prj** project and outputs the results to the console.

cvavrcl "c:\cvavr303\examples\ds1820\ds1820.prj" -ba -rw -p AVRISP2 -pi ISP_PDI -sck 115200 -m messages.txt

Re-compiles all source files in the **ds1820.prj** project, outputs the build results to the GUI and automatically programs the chip using the AVRISP MKII programmer with a SCK frequency of 115200 Hz.

All messages will be also written to the **messages.txt** file, that will be located in the directory where the **ds1820.prj** project file is located.

```
cvavrcl "c:\cvavr\examples\ds1820\ds1820.prj" -ba -dm "BAUD_RATE 9600"
```

Re-compiles all source files in the **ds1820.prj** project, defining the additional global preprocessor macro BAUD_RATE with the value 9600.

```
cvavrcl "c:\cvavr303\examples\ds1820\ds1820.prj" -s ds1820.c -m messages.txt
```

Checks the syntax for the **ds1820.c** file from the **ds1820.prj** project and writes the results to the **messages.txt** file.

4.23 Compiling the Sample Code of the XMEGA Application Notes from Atmel

In order to support the new XMEGA chips, Atmel has released a number of Application Notes that are available for download from www.atmel.com.

The sample code for these Application Notes can be easily compiled with CodeVisionAVR. For this purpose the header file **avr_compiler.h** supplied for each Application Note must be replaced with the same file located in the `..INC` directory of the CodeVisionAVR installation.

4.24 Hints

In order to decrease code size and improve the execution speed, you must apply the following rules:

- If possible use **unsigned** variables;
- Use the smallest data type possible, i.e. **bit** and **unsigned char**;
- The size of the bit variables, allocated to the program in the **Project|Configure|C Compiler|Code Generation|Bit Variables Size** list box, should be as low as possible, in order to free registers for allocation to other global variables;
- If possible use the smallest possible memory model (TINY or SMALL);
- Always store constant strings in FLASH by using the **flash** or **__flash** memory models;
- After finishing debugging your program, compile it again with the **Stack End Markers** option disabled.

4.25 Limitations

The current version of the CodeVisionAVR C compiler has the following limitations:

- the **long long**, **double**, **_Complex** and **_Imaginary** data types are not yet supported
- the **bit** data type is not supported for the reduced core, used in chips like ATtiny10
- functions with variable number of parameters are not supported for reduced core chips
- signal handling (`signal.h`) is not implemented
- date and time functions (`time.h`) are not implemented
- extended multibyte/wide character utilities (`wchar.h`) are not implemented
- wide character classification and mapping utilities (`wctype.h`) are not implemented
- the **printf**, **sprintf**, **snprintf**, **vprintf**, **vsprintf** and **vsnprintf** Standard C Input/Output Functions can't output strings longer than 255 characters for the **%s** format specifier
- the size of the compiled code is limited for the Evaluation version
- XMEGA TWI EBI, RTC and RTC32 support are not available in the Evaluation version
- the libraries for color graphic displays are available and can be used only with Advanced licenses.

Note: The **long64_t**, respectively **ulong64_t**, data types, defined in the **math64.h** header of the **64-bit Integer Mathematical Functions**, can be used instead of the not supported **long long**, respectively **unsigned long long**, types.

5. Library Functions Reference

You must **#include** the appropriate header files for the library functions that you use in your program.

Example:

```
/* Header files are included before using the functions */
#include <stdlib.h> // for abs
#include <stdio.h> // for putsf

void main(void) {
    int a,b;
    a=-99;
    /* Here you actually use the functions */
    b=abs(a);
    putsf("Hello world");
}
```

5.1 Character Type Functions

The prototypes for these functions are placed in the file **ctype.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the functions.

unsigned char isalnum(char c)

returns 1 if c is alphanumeric.

unsigned char isalpha(char c)

returns 1 if c is alphabetic.

unsigned char isascii(char c)

returns 1 if c is an ASCII character (0..127).

unsigned char iscntrl(char c)

returns 1 if c is a control character (0..31 or 127).

unsigned char isdigit(char c)

returns 1 if c is a decimal digit.

unsigned char islower(char c)

returns 1 if c is a lower case alphabetic character.

unsigned char isprint(char c)

returns 1 if c is a printable character (32..127).

unsigned char ispunct(char c)

returns 1 if c is a punctuation character (all but control and alphanumeric).

unsigned char isspace(char c)

returns 1 c is a white-space character (space, CR, HT).

unsigned char isupper(char c)

returns 1 if c is an upper-case alphabetic character.

unsigned char isxdigit(char c)

returns 1 if c is a hexadecimal digit.

char toascii(char c)

returns the ASCII equivalent of character c.

unsigned char toint(char c)

interprets c as a hexadecimal digit and returns an unsigned char from 0 to 15.

char tolower(char c)

returns the lower case of c if c is an upper case character, else c.

char toupper(char c)

returns the upper case of c if c is a lower case character, else c.

5.2 Standard C Input/Output Functions

The prototypes for these functions are placed in the file **stdio.h**, located in the .INC subdirectory. This file must be **#include -d** before using the functions.

The standard C language I/O functions were adapted to work on embedded microcontrollers with limited resources.

The lowest level Input/Output functions are:

char getchar(void)

returns a character received by the UART, using polling.

void putchar(char c)

transmits the character c using the UART, using polling.

Prior to using these functions you must:

- initialize the UART's Baud rate
- enable the UART transmitter
- enable the UART receiver.

Example:

```
#include <mega8515.h>
#include <stdio.h>

/* quartz crystal frequency [Hz] */
#define xtal 4000000L

/* Baud rate */
#define baud 9600

void main(void) {
    char k;

    /* initialize the USART control register
       TX and RX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x18;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/ baud-1) >> 8;
    UBRL=(xtal/16/ baud-1) & 0xFF;
```

```
while (1) {
    /* receive the character */
    k=getchar();
    /* and echo it back */
    putchar(k);
};
}
```

If you intend to use other peripherals for Input/Output, you must modify accordingly the **getchar** and **putchar** functions like in the example below:

```
#include <stdio.h>

/* inform the compiler that an alternate version
   of the getchar function will be used */
#define _ALTERNATE_GETCHAR_

/* now define the new getchar function */
char getchar(void) {
    /* write your code here */

}

/* inform the compiler that an alternate version
   of the putchar function will be used */
#define _ALTERNATE_PUTCHAR_

/* now define the new putchar function */
void putchar(char c) {
    /* write your code here */

}
```

For the XMEGA chips the **getchar** and **putchar** functions use by default the **USARTC0**. If you wish to use another USART, you must define the **_ATXMEGA_USART_** preprocessor macro prior to **#include** the **stdio.h** header file, like in the example below:

```
/* use the ATxmegal28A1 USARTD0 for getchar and putchar functions */
#define _ATXMEGA_USART_ USARTD0

/* use the Standard C I/O functions */
#include <stdio.h>
```

The **_ATXMEGA_USART_** macro needs to be defined only once in the whole program, as the compiler will treat it like it is globally defined.

All the high level Input/Output functions use **getchar** and **putchar**.

void puts(char *str)

outputs, using **putchar**, the null terminated character string **str**, located in RAM, followed by a new line character.

void putsf(char flash *str)

outputs, using **putchar**, the null terminated character string **str**, located in FLASH, followed by a new line character.

int printf(char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, using **putchar**, according to the format specifiers in the **fmtstr** string. The format specifier string **fmtstr** is constant and must be located in FLASH memory. The implementation of **printf** is a reduced version of the standard C function. This was necessary due to the specific needs of an embedded system and because the full implementation would require a large amount of FLASH memory space. The function returns the number of outputted characters.

The format specifier string has the following structure:

```
%[flags][width][.precision][l]type_char
```

The optional **flags** characters are:

- '-' left-justifies the result, padding on the right with spaces. If it's not present, the result will be right-justified, padded on the left with zeros or spaces;
- '+' signed conversion results will always begin with a '+' or '-' sign;
- ' ' if the value isn't negative, the conversion result will begin with a space. If the value is negative then it will begin with a '-' sign.

The optional **width** specifier sets the minimal width of an output value. If the result of the conversion is wider than the field width, the field will be expanded to accommodate the result, so not to cause field truncation.

The following width specifiers are supported:

- n - at least n characters are outputted. If the result has less than n characters, then its field will be padded with spaces. If the '-' flag is used, the result field will be padded on the right, otherwise it will be padded on the left;

- 0n - at least n characters are outputted. If the result has less than n characters, it is padded on the left with zeros.

The optional **precision** specifier sets the maximal number of characters or minimal number of integer digits that may be outputted.

For the 'e', 'E' and 'f' conversion type characters the precision specifier sets the number of digits that will be outputted to the right of the decimal point.

The precision specifier always begins with a '.' character in order to separate it from the width specifier.

The following precision specifiers are supported:

- none - the precision is set to 1 for the 'i', 'd', 'u', 'x', 'X' conversion type characters. For the 's' and 'p' conversion type characters, the char string will be outputted up to the first null character;

- .0 - the precision is set to 1 for the 'i', 'd', 'u', 'x', 'X' type characters;

- .n - n characters or n decimal places are outputted.

For the 'i', 'd', 'u', 'x', 'X' conversion type characters, if the value has less than n digits, then it will be padded on the left with zeros. If it has more than n digits then it will not be truncated.

For the 's' and 'p' conversion type characters, no more than n characters from the char string will be outputted.

For the 'e', 'E' and 'f' conversion type characters, n digits will be outputted to the right of the decimal point.

The precision specifier has no effect on the 'c' conversion type character.

The optional 'l' input size modifier specifies that the function argument must be treated as a long int for the 'i', 'd', 'u', 'x', 'X' conversion type characters.

The **type_char** conversion type character is used to specify the way the function argument will be treated.

The following conversion type characters are supported:

- 'i' - the function argument is a signed decimal integer;
- 'd' - the function argument is a signed decimal integer;
- 'u' - the function argument is an unsigned decimal integer;
- 'e' - the function argument is a float, that will be outputted using the `[-]d.dddddd e[±]dd` format
- 'E' - the function argument is a float, that will be outputted using the `[-]d.dddddd E[±]dd` format
- 'f' - the function argument is a float, that will be outputted using the `[-]ddd.dddddd` format
- 'x' - the function argument is an unsigned hexadecimal integer, that will be outputted with lowercase characters;
- 'X' - the function argument is an unsigned hexadecimal integer, that will be outputted with uppercase characters;
- 'c' - the function argument is a single character;
- 's' - the function argument is a pointer to a null terminated char string located in RAM;
- 'p' - the function argument is a pointer to a null terminated char string located in FLASH;
- '%' - the '%' character will be outputted.

int sprintf(char *str, char flash *fmtstr [, arg1, arg2, ...])

this function is identical to **printf** except that the formatted text is placed in the null terminated character string **str**.

The function returns the number of outputted characters.

int snprintf(char *str, unsigned char size, char flash *fmtstr [, arg1, arg2, ...])
for the TINY memory model.

int snprintf(char *str, unsigned int size, char flash *fmtstr [, arg1, arg2, ...])
for the other memory models.

this function is identical to **sprintf** except that at most **size** (including the null terminator) characters are placed in the character string **str**.

The function returns the number of outputted characters.

In order to reduce program code size, there is the **Project|Configure|C Compiler|Code Generation|(s)printf Features** option.

It allows linking different versions of the printf and sprintf functions, with only the features that are really required by the program.

The following **(s)printf features** are available:

- **int** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', no width or precision specifiers are supported, only the '+' and '-' flags are supported, no input size modifiers are supported
- **int, width** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', the width specifier is supported, the precision specifier is not supported, only the '+', '-', '0' and '-' flags are supported, no input size modifiers are supported
- **long, width** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', the width specifier is supported, the precision specifier is not supported, only the '+', '-', '0' and '-' flags are supported, only the 'l' input size modifier is supported
- **long, width, precision** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'x', 'X', '%', the width and precision specifiers are supported, only the '+', '-', '0' and '-' flags are supported, only the 'l' input size modifier is supported
- **float, width, precision** - the following conversion type characters are supported: 'c', 's', 'p', 'i', 'd', 'u', 'e', 'E', 'f', 'x', 'X', '%', the width and precision specifiers are supported, only the '+', '-', '0' and '-' flags are supported, only the 'l' input size modifier is supported.

The more features are selected, the larger is the code size generated for the printf and sprintf functions.

int vprintf(char flash *fmtstr, va_list argptr)

this function is identical to **printf** except that the **argptr** pointer, of **va_list** type, points to the variable list of arguments. The **va_list** type is defined in the `stdarg.h` header file.
The function returns the number of outputed characters.

int vsprintf(char *str, char flash *fmtstr, va_list argptr)

this function is identical to **sprintf** except that the **argptr** pointer, of **va_list** type, points to the variable list of arguments. The **va_list** type is defined in the `stdarg.h` header file.
The function returns the number of outputed characters.

int vsnprintf(char *str, unsigned char size, char flash *fmtstr, va_list argptr) *for the TINY memory model.*

int vsnprintf(char *str, unsigned int size, char flash *fmtstr, va_list argptr) *for the other memory models.*

this function is identical to **vsprintf** except that at most **size** (including the null terminator) characters are placed in the character string **str**.
The function returns the number of outputed characters.

char *gets(char *str, unsigned char len)

inputs, using **getchar**, the character string **str** terminated by the new line character.
The new line character will be replaced with 0.
The maximum length of the string is **len**. If **len** characters were read without encountering the new line character, then the string is terminated with 0 and the function ends.
The function returns a pointer to **str**.

signed char scanf(char flash *fmtstr [, arg1 address, arg2 address, ...])

formatted text input by scanning, using **getchar**, a series of input fields according to the format specifiers in the **fmtstr** string.
The format specifier string **fmtstr** is constant and must be located in FLASH memory.
The implementation of **scanf** is a reduced version of the standard C function.
This was necessary due to the specific needs of an embedded system and because the full implementation would require a large amount of FLASH memory space.
The format specifier string has the following structure:

`%[width][l]type_char`

The optional **width** specifier sets the maximal number of characters to read. If the function encounters a whitespace character or one that cannot be converted, then it will continue with the next input field, if present.

The optional 'l' input size modifier specifies that the function argument must be treated as a long int for the 'i', 'd', 'u', 'x' conversion type characters.

The **type_char** conversion type character is used to specify the way the input field will be processed.

The following conversion type characters are supported:

- 'd' - inputs a signed decimal integer in a pointer to int argument;
- 'i' - inputs a signed decimal integer in a pointer to int argument;
- 'u' - inputs an unsigned decimal integer in a pointer to unsigned int argument;
- 'x' - inputs an unsigned hexadecimal integer in a pointer to unsigned int argument;
- 'f', 'e', 'E', 'g', 'G' - inputs a floating point value, with an optional exponent ('e' or 'E' followed by an optionally signed decimal integer value), in a pointer to float argument;
- 'c' - inputs an ASCII character in a pointer to char argument; 'C' - inputs an ASCII character in a pointer to char argument;
- 's' - inputs an ASCII character string in a pointer to char argument;
- '%' - no input is done, a '%' is stored.

The function returns the number of successful entries, or -1 on error.

signed char sscanf(char *str, char flash *fmtstr [, arg1 address, arg2 address, ...])

this function is identical to **scanf** except that the formatted text is inputted from the null terminated character string **str**, located in RAM.

In order to reduce program code size, there is the **Project|Configure|C Compiler|Code Generation|(s)scanf Features** option.

It allows linking different versions of the scanf and sscanf functions, with only the features that are really required by the program.

The following **(s)scanf features** are available:

- **int, width** - the following conversion type characters are supported: 'c', 's', 'i', 'd', 'u', 'x', '%', the width specifier is supported, no input size modifiers are supported
- **long, width** - the following conversion type characters are supported: 'c', 's', 'i', 'd', 'u', 'x', '%', the width specifier is supported, only the 'l' input size modifier is supported
- **long, float, width** - the following conversion type characters are supported: 'c', 's', 'i', 'd', 'u', 'x', 'f', 'e', 'E', 'g', 'G', '%', the width specifier is supported, the 'l' input size modifier is supported only for integer types.

The more features are selected, the larger is the code size generated for the scanf and sscanf functions.

The following Standard C Input/Output functions are used for file access on MMC/SD/SD HC FLASH memory cards.

Before using any of these functions, the logical drive that needs to be accessed must be mounted using the **f_mount** function and the appropriate file must be opened using the **f_open** function.

int feof(FIL *fp)

establishes if the end of file was reached during the last file access.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

If the end of file was reached, a non-zero value (1) will be returned.
Otherwise, the function will return 0.

int ferror(FIL *fp)

establishes if an error occurred during the last file access.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

If an error occurred, a non-zero value (1) will be returned.
Otherwise, the function will return 0.

int fgetc(FIL *fp)

reads a character from a file.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value: an 8bit character in the LSB, the MSB being 0.

In case of error or if the end of file was reached, the function returns the value of the predefined macro **EOF** (-1).

The **ferror** function must be used to establish if an error occurred.

In order to check if the end of file was reached, the **feof** function must be called.

char *fgets(char *str,unsigned int len,FIL *fp)

reads from a file maximum **len-1** characters to the char array pointed by **str**.

The read process stops if a new-line '\n' character is encountered or the end of file was reached. The new-line character is also saved in the char string.

The string is automatically NULL terminated after the read process is stopped.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns the same pointer as **str**.

If the end of file was encountered and no characters were read, a NULL pointer is returned.

The same happens in case of file access error.

The **ferror** function must be used to establish if an error occurred.

In order to check if the end of file was reached, the **feof** function must be called.

int fputc(char k,FIL* fp)

writes the character **k** to a file.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value which represents the same character as **k**, the MSB being 0.

In case of error the function returns the value of the predefined macro **EOF** (-1).

int fputs(char *str,FIL* fp)

writes to a file the NULL terminated char string, stored in RAM, pointed by **str**.

The terminating NULL character is not written to the file.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value (1).

In case of error the function returns the value of the predefined macro **EOF** (-1).

int fputsf(char flash *str,FIL* fp)

writes to a file the NULL terminated char string, stored in FLASH memory, pointed by **str**.

The terminating NULL character is not written to the file.

The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value (1).

In case of error the function returns the value of the predefined macro **EOF** (-1).

int fprintf(FIL *fp, char flash *fmtstr,...)

this function is identical to **printf** except that the formatted text is written to a file. The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value: the number of written characters.
In case of error the function returns the value of the predefined macro **EOF** (-1).

int fvprintf(FIL *fp, char flash *fmtstr, va_list argptr)

this function is identical to **vprintf** except that the formatted text is written to a file. The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value: the number of written characters.
In case of error the function returns the value of the predefined macro **EOF** (-1).

int fscanf(FIL *fp, char flash *fmtstr,...)

this function is identical to **scanf** except that the formatted text is read from a file. The **fp** pointer must point to a **FIL** type structure, defined in the **ff.h** header file, that was previously initialized using the **f_open** function.

On success the function returns a positive value: the number of read entries.
In case of error the function returns the value of the predefined macro **EOF** (-1).

5.3 Standard Library Functions

The prototypes for these functions are placed in the file **stdlib.h**, located in the `.INC` subdirectory. This file must be **#include -d** before using the functions.

unsigned char cabs(signed char x)

returns the absolute value of the byte x.

unsigned int abs(int x)

returns the absolute value of the integer x.

unsigned long labs(long int x)

returns the absolute value of the long integer x.

float fabs(float x)

returns the absolute value of the floating point number x.

int atoi(char *str)

converts the string str to integer.

long int atol(char *str)

converts the string str to long integer.

void itoa(int n, char *str)

converts the integer n to characters in string str.

void ltoa(long int n, char *str)

converts the long integer n to characters in string str.

void ftoa(float n, unsigned char decimals, char *str)

converts the floating point number n to characters in string str. The number is represented with a specified number of decimals.

void ftoe(float n, unsigned char decimals, char *str)

converts the floating point number n to characters in string str. The number is represented as a mantissa with a specified number of decimals and an integer power of 10 exponent (e.g. 12.35e-5).

float atof(char *str)

converts the characters from string str to floating point.

int rand (void)

generates a pseudo-random number between 0 and 32767.

void srand(int seed)

sets the starting value seed used by the pseudo-random number generator in the **rand** function.

void *malloc(unsigned int size)

allocates a memory block in the heap, with the length of size bytes.
On success the function returns a pointer to the start of the memory block, the block being filled with zeroes.

Notes:

- The allocated memory block occupies **size+4** bytes in the heap.
- An additional 4 bytes of heap are also used by the dynamic memory allocation functions.

This must be taken into account when specifying the **Heap size** in the **Project|Configure|C Compiler|Code Generation** menu (total size of allocated blocks + 4 bytes).

If there wasn't enough contiguous free memory in the heap to allocate, the function returns a null pointer.

void *calloc(unsigned int num, unsigned int size)

allocates a memory block in the heap for an array of num elements, each element having the size length.

On success the function returns a pointer to the start of the memory block, the block being filled with zeroes.

If there wasn't enough contiguous free memory in the heap to allocate, the function returns a null pointer.

void *realloc(void *ptr, unsigned int size)

changes the size of a memory block allocated in the heap.

The ptr pointer must point to a block of memory previously allocated in the heap.

The size argument specifies the new size of the memory block.

On success the function returns a pointer to the start of the newly allocated memory block, the contents of the previously allocated block being copied to the newly allocated one.

If the newly allocated memory block is larger in size than the old one, the size difference is not filled with zeroes.

If there wasn't enough contiguous free memory in the heap to allocate, the function returns a null pointer.

void free(void *ptr)

frees a memory block allocated in the heap by the malloc, calloc or realloc functions and pointed by the ptr pointer.

After being freed, the memory block is available for new allocation.

If ptr is null then it is ignored.

5.4 Mathematical Functions

The prototypes for these functions are placed in the file **math.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the functions.

signed char cmax(signed char a, signed char b)

returns the maximum value of bytes a and b.

int max(int a, int b)

returns the maximum value of integers a and b.

long int lmax(long int a, long int b)

returns the maximum value of long integers a and b.

float fmax(float a, float b)

returns the maximum value of floating point numbers a and b.

signed char cmin(signed char a, signed char b)

returns the minimum value of bytes a and b.

int min(int a, int b)

returns the minimum value of integers a and b.

long int lmin(long int a, long int b)

returns the minimum value of long integers a and b.

float fmin(float a, float b)

returns the minimum value of floating point numbers a and b.

signed char csign(signed char x)

returns -1, 0 or 1 if the byte x is negative, zero or positive.

signed char sign(int x)

returns -1, 0 or 1 if the integer x is negative, zero or positive

signed char lsign(long int x)

returns -1, 0 or 1 if the long integer x is negative, zero or positive.

signed char fsign(float x)

returns -1, 0 or 1 if the floating point number x is negative, zero or positive.

unsigned char isqrt(unsigned int x)

returns the square root of the unsigned integer x.

unsigned int lsqrt(unsigned long x)

returns the square root of the unsigned long integer x.

float sqrt(float x)

returns the square root of the positive floating point number x.

float floor(float x)

returns the smallest integer value of the floating point number x.

float ceil(float x)

returns the largest integer value of the floating point number x.

float fmod(float x, float y)

returns the remainder of x divided by y.

float modf(float x, float *ipart)

splits the floating point number x into integer and fractional components. The fractional part of x is returned as a signed floating point number. The integer part is stored as floating point number at ipart.

float ldexp(float x, int expn)

returns $x * 2^{\text{expn}}$.

float frexp(float x, int *expn)

returns the mantissa and exponent of the floating point number x.

float exp(float x)

returns e^x .

float log(float x)

returns the natural logarithm of the floating point number x.

float log10(float x)

returns the base 10 logarithm of the floating point number x.

float pow(float x, float y)

returns x^y .

float sin(float x)

returns the sine of the floating point number x, where the angle is expressed in radians.

float cos(float x)

returns the cosine of the floating point number x, where the angle is expressed in radians.

float tan(float x)

returns the tangent of the floating point number x, where the angle is expressed in radians.

float sinh(float x)

returns the hyperbolic sine of the floating point number x, where the angle is expressed in radians.

float cosh(float x)

returns the hyperbolic cosine of the floating point number x, where the angle is expressed in radians.

float tanh(float x)

returns the hyperbolic tangent of the floating point number x, where the angle is expressed in radians.

float asin(float x)

returns the arc sine of the floating point number x (in the range $-\pi/2$ to $\pi/2$).
x must be in the range -1 to 1.

float acos(float x)

returns the arc cosine of the floating point number x (in the range 0 to π).
x must be in the range -1 to 1.

float atan(float x)

returns the arc tangent of the floating point number x (in the range $-\pi/2$ to $\pi/2$).

float atan2(float y, float x)

returns the arc tangent of the floating point numbers y/x (in the range $-\pi$ to π).

5.4.1 64-bit Integer Mathematical Functions

The **64-bit Integer Mathematical Functions** are intended to be used instead of the standard C mathematical functions that access the 64-bit **long long** integer data type, which is currently not supported by CodeVisionAVR.

The above mentioned functions are declared in the **math64.h** header file, which must be **#include-d** in the C program modules where these are referenced.

The 64-bit integers are stored in the following structure data types, defined in the **math64.h** header file:

```
/* Signed 64-bit integer type */
typedef struct
{
    unsigned long lo;
    long hi;
} long64_t;

/* Unsigned 64-bit integer type */
typedef struct
{
    unsigned long lo;
    unsigned long hi;
} ulong64_t;
```

The **long64_t**, respectively **ulong64_t**, data types should be used instead of the standard C **long long**, respectively **unsigned long long** types.

The value ranges are:

- -9223372036854775808 to 9223372036854775807 for the **long64_t** type
- 0 to 18446744073709551615 for the **ulong64_t** type.

The **__INIT64(n)** macro is defined in **math64.h**, in order to be able to initialize during declaration a **long64_t** or **ulong64_t** variable, with a numeral **n**.

Example:

```
/* Define the 64-bit signed integer variable alfa and
   assign the value -1000000000000000000 to it */
long64_t alfa=__INIT64(-1000000000000000000LL);

/* Define the 64-bit unsigned integer variable beta and
   assign the value 5000000000000000000 to it */
ulong64_t beta=__INIT64(5000000000000000000ULL);
```

Note: the **LL**, respectively **ULL**, suffixes are used to specify that the numerals must be considered as 64-bit signed, respectively unsigned, integers.

The **__EQU64(x,n)** macro is defined in **math64.h**, in order to assign a numeral **n** to a **x long64_t** or **ulong64_t** variable in the program body.

Example:

```
#include <math64.h>

/* Declare the 64-bit global variables */
long64_t a;
ulong64_t b;
```

```
void main(void)
{
/* Assign the numeral -1000000000000000000 to a */
__EQU64(a,-1000000000000000000LL);

/* Assign the numeral 5000000000000000000 to b */
__EQU64(b,5000000000000000000ULL);
}
```

Assigning **long64_t** or **ulong64_t** variables between them, follows the standard C syntax.
Example:

```
#include <math64.h>

void main(void)
{
/* Declare the 64-bit local variables */
long64_t a=__INIT64(1000000000000000000LL);
long64_t b;

b=a;
}
```

Assigning a 8-bit, 16-bit or 32-bit value to a **long64_t**, respectively **ulong64_t**, variable must be performed using the **tolong64**, respectively **tolong64u**, functions defined in **math64.h**:

long64_t tolong64(long x)

returns the 32-bit long integer **x** promoted to a signed 64-bit integer.

ulong64_t tolong64u(unsigned long x)

returns the 32-bit unsigned long integer **x** promoted to an unsigned 64-bit integer.

Example:

```
#include <math64.h>

void main(void)
{
long64_t a;
ulong64_t b;

long c=-12345678L;
unsigned long d=12345678UL;

a=tolong64(c); /* a=-12345678 */
b=tolong64u(d); /* b=12345678 */
}
```

Truncating a **long64_t** or **ulong64_t** to a 8-bit, 16-bit or 32-bit value can be performed by simply accessing the **lo** member of the structure.

Example:

```
#include <math64.h>

void main(void)
{
    long64_t a=__INIT64(-12345678LL);
    ulong64_t b=__INIT64(12345678ULL);
    long64_t c=__INIT64(0xABCD00000000LL);

    long d;
    unsigned long e;
    long f;

    d=a.lo; /* c=-12345678 */
    e=b.lo; /* d=12345678 */
    f=c.lo; /* f=0 */
}
```

The rest of the functions defined in the **math64.h** header are:

long64_t add64(long64_t x, long64_t y)

returns the 64-bit signed result of the **x + y** operation.

Example:

```
#include <math64.h>

void main(void)
{
    long64_t a=__INIT64(-10000000000000000LL);
    long64_t b=__INIT64(8);
    long64_t c;

    c=add64(a,b); /* c= -9999999999999992 */
}
```

long64_t sub64(long64_t x, long64_t y)

returns the 64-bit signed result of the **x - y** operation.

long64_t mul64(long64_t x, long64_t y)

returns the 64-bit signed result of the **x * y** operation.

ulong64_t mul64u(ulong64_t x, ulong64_t y)

returns the 64-bit unsigned result of the **x * y** operation.

long64_t div64(long64_t x, long64_t y)

returns the 64-bit signed result of the x / y operation.

ulong64_t div64u(ulong64_t x, ulong64_t y)

returns the 64-bit unsigned result of the x / y operation.

long64_t mod64(long64_t x, long64_t y)

returns the 64-bit signed result of the $x \% y$ operation.

ulong64_t mod64u(ulong64_t x, ulong64_t y)

returns the 64-bit unsigned result of the $x \% y$ operation.

ulong64_t or64(ulong64_t x, ulong64_t y)

returns the 64-bit unsigned result of the $x | y$ operation.

ulong64_t and64(ulong64_t x, ulong64_t y)

returns the 64-bit unsigned result of the $x \& y$ operation.

ulong64_t xor64(ulong64_t x, ulong64_t y)

returns the 64-bit unsigned result of the $x \wedge y$ operation.

long64_t neg64(long64_t x)

returns the 64-bit signed result of the $-x$ operation.

ulong64_t abs64(long64_t x)

returns the 64-bit unsigned absolute value of x .

signed char sign64(long64_t x)

returns -1, 0 or 1 if the value of the 64-bit signed integer x is **negative**, **zero** or **positive**.

ulong64_t com64(ulong64_t x)

returns the 64-bit unsigned result of the $\sim x$ operation.

ulong64_t not64(ulong64_t x)

returns the 64-bit unsigned result of the $!x$ operation.

signed char cmp64(long64_t x, long64_t y)

compares two 64-bit signed integers **x** and **y**.
Returns **1** for **x > y**, **0** for **x == y**, **-1** for **x < y**.

signed char cmp64u(ulong64_t x, ulong64_t y)

compares two 64-bit unsigned integers **x** and **y**.
Returns **1** for **x > y**, **0** for **x == y**, **-1** for **x < y**.

void asr64(long64_t *x, unsigned char n)

performs an arithmetic shift right by **n** bits, on the 64-bit signed integer pointed by **x**.

Example:

```
#include <math64.h>

void main(void)
{
    long64_t a=__INIT64(-8000000000000000LL);

    asr64(&a,2); /* *a=*a>>2 -> a=-2000000000000000 */
}
```

void lsr64(ulong64_t *x, unsigned char n)

performs a logic shift right by **n** bits, on the 64-bit unsigned integer pointed by **x**.

void lsl64(ulong64_t *x, unsigned char n)

performs a logic shift left by **n** bits, on the 64-bit unsigned integer pointed by **x**.

Example:

```
#include <math64.h>

void main(void)
{
    ulong64_t a=__INIT64(8000000000000000LL);

    lsl64(&a,2); /* *a=*a<<2 -> a=32000000000000000 */
}
```

void inc64(long64_t *x)

increments a 64-bit signed integer pointed by **x**.

Example:

```
#include <math64.h>

void main(void)
{
    long64_t a=__INIT64(-8000000000000000LL);

    inc64(&a); /* *a=*a+1 -> a=-7999999999999999 */
}
```

void dec64(long64_t *x)

decrements a 64-bit signed integer pointed by **x**.

unsigned long sqrt64(ulong64_t x)

returns the square root of a 64-bit unsigned integer **x**.

long64_t atol64(char *str)

converts the NULL terminated char string pointed by **str**, containing the decimal representation of a signed number, to a 64-bit signed integer.

Note: The function skips past preceding white space characters and converts the numeral as long as decimal digits are present.

Example:

```
#include <math64.h>

char buffer[]=" -8000000000000000 ";

void main(void)
{
    long64_t a;

    a=atol64(buffer); /* a=-8000000000000000 */
}
```

ulong64_t xtol64(char *str)

converts the NULL terminated char string pointed by **str**, containing the hexadecimal representation of an unsigned number, to a 64-bit unsigned integer.

Note: The function skips past preceding white space characters and converts the numeral as long as hexadecimal digits are present.

Example:

```
#include <math64.h>

char buffer[]=" ABCD1234567890H ";
```

```
void main(void)
{
    long64_t a;

    a=xtol64(buffer); /* a=0xABCD1234567890 */
}
```

void ltoa64(long64_t x, char *str)

converts the 64-bit signed integer **x** to characters in the NULL terminated char string **str**, in decimal representation.

Note: The char buffer pointed by **str** must have at least 21 characters, so that it can hold the largest converted decimal 64-bit value, including the '-' sign and the NULL string terminator.

Example:

```
#include <io.h>
#include <stdio.h>
#include <math64.h>

char buffer[32];

void main(void)
{
    long64_t a=__INIT64(-8000000000000000LL);
    long64_t b=__INIT64(8);

    /* USART initialization for the ATmega328P chip clocked at 16 MHz
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 @ 16 MHz */
    UCSR0A=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
            (0<<UPE0) | (0<<U2X0) | (0<<MPCM0);
    UCSR0B=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
            (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSR0C=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
            (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRR0H=0x00;
    UBRR0L=0x67;

    /* Store the result of a+b in decimal format to the buffer */
    ltoa64(sum64(a,b),buffer); /* buffer="-9999999999999992" */

    /* Output the buffer contents using the USART */
    printf("a + b = %s\r\n",buffer);
}
```

void ltox64(ulong64_t x, char *str)

converts the 64-bit unsigned integer **x** to characters in the NULL terminated char string **str**, in hexadecimal representation.

Note: The char buffer pointed by **str** must have at least 17 characters, so that it can hold the largest converted hexadecimal 64-bit value, including the NULL string terminator.

void printl64(long64_t x)

outputs the 64-bit signed integer **x** in decimal format, using the **putchar** Standard C Input/Output function.

Example:

```
#include <io.h>
#include <stdio.h>
#include <math64.h>

void main(void)
{
    long64_t a=__INIT64(-8000000000000000LL);
    long64_t b=__INIT64(8);

    /* USART initialization for the ATmega328P chip clocked at 16 MHz
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 @ 16 MHz */
    UCSR0A=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
        (0<<UPE0) | (0<<U2X0) | (0<<MPCM0);
    UCSR0B=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
        (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSR0C=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
        (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRR0H=0x00;
    UBRR0L=0x67;

    printf("a + b = ");

    /* Output the result of a+b in decimal format using the USART */
    printl64(sum64(a,b));

    printf("\r\n");
}
```

void printx64(ulong64_t x)

outputs the 64-bit unsigned integer **x** in hexadecimal format, using the **putchar** Standard C Input/Output function.

Note: Additional information on the usage of the **64-bit Integer Mathematical Functions** can be found in the example program supplied with the compiler and located in the **\Examples\AVR\64-Bit Math** subdirectory of the CodeVisionAVR installation.

5.5 String Functions

The prototypes for these functions are placed in the file **string.h**, located in the `.INC` subdirectory. This file must be **#include -d** before using the functions.

The string manipulation functions were extended to handle strings located both in RAM and FLASH memories.

char *strcat(char *str1, char *str2)

concatenate the string str2 to the end of the string str1.

char *strcatf(char *str1, char flash *str2)

concatenate the string str2, located in FLASH, to the end of the string str1.

char *strncat(char *str1, char *str2, unsigned char n)

concatenate maximum n characters of the string str2 to the end of the string str1.
Returns a pointer to the string str1.

char *strncatf(char *str1, char flash *str2, unsigned char n)

concatenate maximum n characters of the string str2, located in FLASH, to the end of the string str1.
Returns a pointer to the string str1.

char *strchr(char *str, char c)

returns a pointer to the first occurrence of the character c in the string str, else a NULL pointer.

char *strchrh(char *str, char c)

returns a pointer to the first occurrence of the character c in the string str, else a NULL pointer.

char *strrchr(flash char *str, char c)

returns a pointer to the last occurrence of the character c in the string str located in FLASH memory, else a NULL pointer.

flash char *strrchrf(flash char *str, char c)

returns a pointer to the last occurrence of the character c in the string str located in FLASH memory, else a NULL pointer.

signed char strpos(char *str, char c)

for the TINY memory model.

int strpos(char *str, char c)

for the SMALL memory model.

returns the index to first occurrence of the character c in the string str, else -1.

signed char strrpos(char *str, char c)

for the TINY memory model.

int strrpos(char *str, char c)

for the SMALL memory model.

returns the index to the last occurrence of the character c in the string str, else -1.

signed char strcmp(char *str1, char *str2)

compares the string str1 with the string str2.

Returns <0, 0, >0 according to str1<str2, str1=str2, str1>str2.

signed char strcmpf(char *str1, char flash *str2)

compares the string str1, located in RAM, with the string str2, located in FLASH.

Returns <0, 0, >0 according to str1<str2, str1=str2, str1>str2.

signed char strncmp(char *str1, char *str2, unsigned char n)

compares at most n characters of the string str1 with the string str2.

Returns <0, 0, >0 according to str1<str2, str1=str2, str1>str2.

signed char strncmpf(char *str1, char flash *str2, unsigned char n)

compares at most n characters of the string str1, located in RAM, with the string str2, located in FLASH.

Returns <0, 0, >0 according to str1<str2, str1=str2, str1>str2.

char *strcpy(char *dest, char *src)

copies the string src to the string dest.

char *strcpyf(char *dest, char flash *src)

copies the string src, located in FLASH, to the string dest, located in RAM.

Returns a pointer to the string dest.

char *strncpy(char *dest, char *src, unsigned char n)

copies at most n characters from the string src to the string dest.

Returns a pointer to the string dest.

If there is no null character among the first n characters of src, then dest will not be null terminated.

If n is less then the length of src, then the remainder of dest will be padded with nulls.

char *strncpyf(char *dest, char flash *src, unsigned char n)

copies at most n characters from the string src, located in FLASH, to the string dest, located in SRAM.

Returns a pointer to the string dest.

If there is no null character among the first n characters of src, then dest will not be null terminated.

If n is less then the length of src, then the remainder of dest will be padded with nulls.

unsigned char strcpy(char *dest, char *src, unsigned char n)

copies at most n characters from the string src to the string dest, ensuring that it will be always null terminated, even if the src string was truncated to fit.

If n is less then the length of src, then the remainder of dest after the null terminator, will not be padded with nulls.

The function returns the size of the src string.

unsigned char strcpyf(char *dest, char flash *src, unsigned char n)

copies at most n characters from the string src, located in FLASH, to the string dest located in SRAM, ensuring that it will be always null terminated, even if the src string was truncated to fit.

If n is less then the length of src, then the remainder of dest after the null terminator, will not be padded with nulls.

The function returns the size of the src string.

unsigned char strspn(char *str, char *set)

returns the index of the first character, from the string str, that doesn't match a character from the string set.

If all characters from set are in str returns the length of str.

unsigned char strspnf(char *str, char flash *set)

returns the index of the first character, from the string str, located in RAM, that doesn't match a character from the string set, located in FLASH.

If all characters from set are in str returns the length of str.

unsigned char strcspn(char *str, char *set)

searches the string str for the first occurrence of a character from the string set.

If there is a match returns, the index of the character in str.

If there are no matching characters, returns the length of str.

unsigned char strcspnf(char *str, char flash *set)

searches the string str for the first occurrence of a character from the string set, located in FLASH.

If there is a match, returns the index of the character in str.

If there are no matching characters, returns the length of str.

char *strpbrk(char *str, char *set)

searches the string str for the first occurrence of a char from the string set.

If there is a match, returns a pointer to the character in str.

If there are no matching characters, returns a NULL pointer.

char *strpbrkf(char *str, char flash *set)

searches the string str, located in RAM, for the first occurrence of a char from the string set, located in FLASH.

If there is a match, returns a pointer to the character in str.

If there are no matching characters, returns a NULL pointer.

char *strrpbkr(char *str, char *set)

searches the string str for the last occurrence of a character from the string set.

If there is a match, returns a pointer to the character in str.

If there are no matching characters, returns a NULL pointer.

char *strrbrkf(char *str, char flash *set)

searches the string str, located in RAM, for the last occurrence of a character from the string set, located in FLASH.

If there is a match, returns a pointer to the character in str.

If there are no matching characters, returns a NULL pointer.

char *strstr(char *str1, char *str2)

searches the string str1 for the first occurrence of the string str2.

If there is a match, returns a pointer to the character in str1 where str2 begins.

If there is no match, returns a NULL pointer.

char *strstrf(char *str1, char flash *str2)

searches the string str1, located in RAM, for the first occurrence of the string str2, located in FLASH.

If there is a match, returns a pointer to the character in str1 where str2 begins.

If there is no match, returns a NULL pointer.

char *strtok(char *str1, char flash *str2)

scans the string str1, located in RAM, for the first token not contained in the string str2, located in FLASH.

The function considers the string str1 as consisting of a sequence of text tokens, separated by spans of one or more characters from the string str2.

The first call to strtok, with the pointer to str1 being different from NULL, returns a pointer to the first character of the first token in str1. Also a NULL character will be written in str1, immediately after the returned token.

Subsequent calls to strtok, with NULL as the first parameter, will work through the string str1 until no more tokens remain. When there are no more tokens, strtok will return a NULL pointer.

unsigned char strlen(char *str)

for the TINY memory model.

returns the length of the string str (in the range 0..255), excluding the null terminator.

unsigned int strlen(char *str)

for the SMALL memory model.

returns the length of the string str (in the range 0..65535), excluding the null terminator.

unsigned int strlenf(char flash *str)

returns the length of the string str located in FLASH, excluding the null terminator.

void *memcpy(void *dest,void *src, unsigned char n)

for the TINY memory model.

void *memcpy(void *dest,void *src, unsigned int n)

for the SMALL memory model.

Copies n bytes from src to dest. dest must not overlap src, else use **memmove**.

Returns a pointer to dest.

void *memcpyf(void *dest,void flash *src, unsigned char n)

for the TINY memory model.

void *memcpyf(void *dest,void flash *src, unsigned int n)

for the SMALL memory model.

Copies n bytes from src, located in FLASH, to dest. Returns a pointer to dest.

void *memccpy(void *dest,void *src, char c, unsigned char n)

for the TINY memory model.

void *memccpy(void *dest,void *src, char c, unsigned int n)

for the SMALL memory model.

Copies at most n bytes from src to dest, until the character c is copied.

dest must not overlap src.

Returns a NULL pointer if the last copied character was c or a pointer to dest+n+1.

void *memmove(void *dest,void *src, unsigned char n)

for the TINY memory model.

void *memmove(void *dest,void *src, unsigned int n)

for the SMALL memory model.

Copies n bytes from src to dest. dest may overlap src.

Returns a pointer to dest.

void *memchr(void *buf, unsigned char c, unsigned char n)

for the TINY memory model.

void *memchr(void *buf, unsigned char c, unsigned int n)

for the SMALL memory model.

Scans n bytes from buf for byte c.

Returns a pointer to c if found or a NULL pointer if not found.

signed char memcmp(void *buf1,void *buf2, unsigned char n)

for the TINY memory model.

signed char memcmp(void *buf1,void *buf2, unsigned int n)

for the SMALL memory model.

Compares at most n bytes of buf1 with buf2.

Returns <0, 0, >0 according to buf1<buf2, buf1=buf2, buf1>buf2.

signed char memcmppf(void *buf1,void flash *buf2, unsigned char n)

for the TINY memory model.

signed char memcmppf(void *buf1,void flash *buf2, unsigned int n)

for the SMALL memory model.

Compares at most n bytes of buf1, located in RAM, with buf2, located in FLASH.
Returns <0, 0, >0 according to buf1<buf2, buf1=buf2, buf1>buf2.

void *memset(void *buf, unsigned char c, unsigned char n)

for the TINY memory model.

void *memset(void *buf, unsigned char c, unsigned int n)

for the SMALL memory model.

Sets n bytes from buf with byte c. Returns a pointer to buf.

5.6 Variable Length Argument Lists Macros

These macros are defined in the file **stdarg.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the macros.

void va_start(argptr, previous_par)

This macro, when used in a function with a variable length argument list, initializes the **argptr** pointer of **va_list** type, for subsequent use by the **va_arg** and **va_end** macros.

The **previous_par** argument must be the name of the function argument immediately preceding the optional arguments.

The **va_start** macro must be called prior to any access using the **va_arg** macro.

type va_arg(argptr, type)

This macro is used to extract successive arguments from the variable length argument list referenced by **argptr**.

type specifies the data type of the argument to extract.

The **va_arg** macro can be called only once for each argument. The order of the parameters in the argument list must be observed.

On the first call **va_arg** returns the first argument after the **previous_par** argument specified in the **va_start** macro. Subsequent calls to **va_arg** return the remaining arguments in succession.

void va_end(argptr)

This macro is used to terminate use of the variable length argument list pointer **argptr**, initialized using the **va_start** macro.

Example:

```
#include <stdarg.h>

/* declare a function with a variable number of arguments */
int sum_all(int nsum, ...)
{
    va_list argptr;
    int i, result=0;

    /* initialize argptr */
    va_start(argptr, nsum);

    /* add all the function arguments after nsum */
    for (i=1; i <= nsum; i++)
        /* add each argument */
        result+=va_arg(argptr, int);

    /* terminate the use of argptr */
    va_end(argptr);

    return result;
}

void main(void)
{
    int s;
    /* calculate the sum of 5 arguments */
    s=sum_all(5, 10, 20, 30, 40, 50);
}
```

5.7 Non-local Jump Functions

These functions can execute a non-local goto.

They are usually used to pass control to an error recovery routine.

The prototypes for the non-local jump functions are placed in the file **setjmp.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the functions.

int setjmp(char *env)

This function saves the current CPU state (Y, SP, SREG registers and the current instruction address) in the env variable.

The CPU state can then be restored by subsequently calling the **longjmp** function.

Execution is then resumed immediately after the **setjmp** function call.

The **setjmp** function will return 0 when the current CPU state is saved in the env variable.

If the function returns a value different from 0, it signals that a **longjmp** function was executed.

In this situation the returned value is the one that was passed as the retval argument to the **longjmp** function.

In order to preserve the local variables in the function where setjmp is used, these must be declared with the **volatile** attribute.

void longjmp(char *env, int retval)

This function restores the CPU state that was previously saved in the env variable by a call to **setjmp**.

The retval argument holds the integer non-zero value that will be returned by **setjmp** after the call to **longjmp**. If a 0 value is passed as the retval argument then it will be substituted with 1.

In order to facilitate the usage of these functions, the **setjmp.h** header file also contains the definition of the **jmp_buf** data type, which is used when declaring the env variables.

Example:

```
#include <mega8515.h>
#include <stdio.h>
#include <setjmp.h>

/* declare the variable used to hold the CPU state */
jmp_buf cpu_state;

void foo(void)
{
    printf("Now we will make a long jump to main()\n\r");
    longjmp(cpu_state,1);
}

/* ATmega8515 clock frequency [Hz] */
#define xtal 4000000L

/* Baud rate */
#define baud 9600

void main(void)
{
    /* this local variable will be preserved after a longjmp */
    volatile int i;
    /* this local variable will not be preserved after a longjmp */
    int j;
```

```
/* initialize the USART control register
   TX enabled, no interrupts, 8 data bits */
UCSRA=0x00;
UCSRB=0x08;
UCSRC=0x86;

/* initialize the USART's baud rate */
UBRRH=(xtal/16/ baud-1) >> 8;
UBRRL=(xtal/16/ baud-1) & 0xFF;

if (setjmp(cpu_state)==0)
{
    printf("First call to setjmp\n\r");
    foo();
}
else
    printf("We jumped here from foo()\n\r");
}
```

5.8 BCD Conversion Functions

The prototypes for these functions are placed in the file **bcd.h**, located in the .\INC subdirectory. This file must be **#include -d** before using the functions.

unsigned char bcd2bin(unsigned char n)

Converts the number n from BCD representation to its binary equivalent.

unsigned char bin2bcd(unsigned char n)

Converts the number n from binary representation to its BCD equivalent.
The number n values must be from 0 to 99.

5.9 Gray Code Conversion Functions

The prototypes for these functions are placed in the file **gray.h**, located in the .\INC subdirectory. This file must be **#include -d** before using the functions.

unsigned char gray2binc(unsigned char n)

unsigned int gray2bin(unsigned int n)

unsigned long gray2binl(unsigned long n)

Convert the number n from Gray code representation to its binary equivalent.

unsigned char bin2grayc(unsigned char n)

unsigned int bin2gray(unsigned int n)

unsigned long bin2grayl(unsigned long n)

Convert the number n from binary representation to its Gray code equivalent.

5.10 Memory Access Macros

The memory access macros are defined in the **mem.h** header file, located in the .INC subdirectory. This file must be **#include -d** before using these macros.

pokeb(addr, data)

this macro writes the **unsigned char** data to RAM at address addr.

pokew(addr, data)

this macro writes the **unsigned int** data to RAM at address addr. The LSB is written at address addr and the MSB is written at address addr+1.

peekb(unsigned int addr)

this macro reads an **unsigned char** located in RAM at address addr.

peekw (unsigned int addr)

this macro reads an **unsigned int** located in RAM at address addr. The LSB is read from address addr and the MSB is read from address addr+1.

5.11 Alphanumeric LCD Functions

5.11.1 LCD Functions for displays with up to 2x40 characters

The LCD Functions are intended for easy interfacing between C programs and alphanumeric LCD modules, built with several types of popular display controllers.

The prototypes for these functions are placed in the corresponding header files, located in the .\INC subdirectory:

- **alcd.h** - Hitachi HD44780 or compatible
- **alcd_ks0073.h** - Samsung KS0073
- **alcd_ssd1803.h** - Solomon Systech SSD1803, used in Electronic Assembly's www.lcd-module.de DIP203 display modules.

The appropriate header file must be **#include** -d before using the functions.

The LCD functions do support both the XMEGA and non-XMEGA chips.

The following LCD formats are supported in **alcd.h**: 1x8, 2x12, 3x12, 1x16, 2x16, 2x20, 4x20, 2x24 and 2x40 characters.

The allocation of LCD module signals to the I/O ports must be specified in the **Project|Configure|C Compiler|Libraries|Alphanumeric LCD** menu.

The LCD power supply and contrast control voltage must also be connected according to the module data sheet.

The low level LCD Functions are:

void _lcd_write_data(unsigned char data)

writes the byte data to the LCD instruction register.

This function may be used for modifying the LCD configuration.

Example:

```
/* enables the displaying of the cursor */
_lcd_write_data(0xe);
```

void lcd_write_byte(unsigned char addr, unsigned char data);

writes a byte to the LCD character generator or display RAM.

Example:

```
/* LCD user defined characters
Chip: ATmega8515

Use an 2x16 alphanumeric LCD connected
to the STK600 PORTC header as follows:
```

```
[LCD]    [STK600 PORTC HEADER]
1 GND-   9  GND
2 +5V-  10  VCC
3 VLC-   LCD HEADER Vo
4 RS -   1   PC0
5 RD -   2   PC1
6 EN -   3   PC2
11 D4 -   5   PC4
12 D5 -   6   PC5
```

```
13 D6 - 7   PC6
14 D7 - 8   PC7

The connections must be specified in the
Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */

/* include the LCD driver routines */
#include <alcd.h>

typedef unsigned char byte;

/* table for the user defined character
   arrow that points to the top right corner */
flash byte char0[8]={
0b10000000,
0b10001111,
0b10000011,
0b10000101,
0b10001001,
0b10010000,
0b10100000,
0b11000000};

/* function used to define user characters */
void define_char(byte flash *pc,byte char_code)
{
byte i,a;
a=(char_code<<3) | 0x40;
for (i=0; i<8; i++) lcd_write_byte(a++,*pc++);
}

void main(void)
{
/* initialize the LCD for 2 lines & 16 columns */
lcd_init(16);

/* define user character 0 */
define_char(char0,0);

/* switch to writing in Display RAM */
lcd_gotoxy(0,0);
lcd_putsf("User char 0:");

/* display used defined char 0 */
lcd_putchar(0);

while (1); /* loop forever */
}
```

unsigned char lcd_read_byte(unsigned char addr);

reads a byte from the LCD character generator or display RAM.

The high level LCD Functions are:

void lcd_init(unsigned char lcd_columns)

initializes the LCD module, clears the display and sets the printing character position at row 0 and column 0. The numbers of columns of the LCD must be specified (e.g. 16). No cursor is displayed. This is the first function that must be called before using the other high level LCD Functions.

void lcd_clear(void)

clears the LCD and sets the printing character position at row 0 and column 0.

void lcd_gotoxy(unsigned char x, unsigned char y)

sets the current display position at column x and row y. The row and column numbering starts from 0.

void lcd_putchar(char c)

displays the character c at the current display position.

void lcd_puts(char *str)

displays at the current display position the string str, located in RAM.

void lcd_putsf(char flash *str)

displays at the current display position the string str, located in FLASH.

void lcd_putse(char eeprom *str)

displays at the current display position the string str, located in EEPROM.

int lcd_printfxy(unsigned char x, unsigned char y, char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at specified screen coordinates, according to the format specifiers in the **fmtstr** string.

Parameters:

x specifies the column coordinate of the first displayed character
y specifies the row coordinate of the first displayed character
fmtstr pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

int lcd_printf(char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at current display position, according to the format specifiers in the **fmtstr** string.

Parameters:

fmtstr pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

5.11.2 LCD Functions for displays with 4x40 characters

The LCD Functions are intended for easy interfacing between C programs and alphanumeric LCD modules with 4x40 characters, built with the Hitachi HD44780 chip or equivalent. The prototypes for these functions are placed in the file **lcd4x40.h**, located in the .INC subdirectory. This file must be **#include -d** before using the functions.

The LCD functions do not yet support the XMEGA chips.

Prior to **#include** -ing the **lcd4x40.h** file, you must declare which microcontroller port is used for communication with the LCD module.

Example:

```
/* the LCD module is connected to PORTC */
#asm
    .equ __lcd_port=0x15
#endasm

/* now you can include the LCD Functions */
#include <lcd4x40.h>
```

The LCD module must be connected to the port bits as follows:

[LCD]	[AVR Port]
RS (pin 11) ---	bit 0
RD (pin 10) ---	bit 1
EN1 (pin 9) ----	bit 2
EN2 (pin 15) --	bit 3
DB4 (pin 4) ----	bit 4
DB5 (pin 3) ----	bit 5
DB6 (pin 2) ----	bit 6
DB7 (pin 1) ----	bit 7

You must also connect the LCD power supply and contrast control voltage, according to the data sheet.

The low level LCD Functions are:

void _lcd_ready(void)

waits until the LCD module is ready to receive data.

This function must be called prior to writing data to the LCD with the **_lcd_write_data** function.

void _lcd_write_data(unsigned char data)

writes the byte data to the LCD instruction register.

This function may be used for modifying the LCD configuration.

Prior calling the low level functions **_lcd_ready** and **_lcd_write_data**, the global variable **_en1_msk** must be set to **LCD_EN1**, respectively **LCD_EN2**, to select the upper, respectively lower half, LCD controller.

Example:

```
/* enables the displaying of the cursor on the upper half
   of the LCD */
_en1_msk=LCD_EN1;
_lcd_ready();
_lcd_write_data(0xe);
```

void lcd_write_byte(unsigned char addr, unsigned char data);

writes a byte to the LCD character generator or display RAM.

unsigned char lcd_read_byte(unsigned char addr);

reads a byte from the LCD character generator or display RAM.

The high level LCD Functions are:

unsigned char lcd_init(void)

initializes the LCD module, clears the display and sets the printing character position at row 0 and column 0. No cursor is displayed.

The function returns 1 if the LCD module is detected and 0 if it is not.

This is the first function that must be called before using the other high level LCD Functions.

void lcd_clear(void)

clears the LCD and sets the printing character position at row 0 and column 0.

void lcd_gotoxy(unsigned char x, unsigned char y)

sets the current display position at column x and row y. The row and column numbering starts from 0.

void lcd_putchar(char c)

displays the character c at the current display position.

void lcd_puts(char *str)

displays at the current display position the string str, located in RAM.

void lcd_putsf(char flash *str)

displays at the current display position the string str, located in FLASH.

int lcd_printfxy(unsigned char x, unsigned char y, char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at specified screen coordinates, according to the format specifiers in the **fmtstr** string.

Parameters:

x specifies the column coordinate of the first displayed character

y specifies the row coordinate of the first displayed character

fmtstr pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

int lcd_printf(char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at current display position, according to the format specifiers in the **fmtstr** string.

Parameters:

fmtstr pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

5.11.3 LCD Functions for displays connected in 8 bit memory mapped mode

These LCD Functions are intended for easy interfacing between C programs and alphanumeric LCD modules built with the Hitachi HD44780 chip or equivalent.

The LCD is connected to the AVR external data and address buses as an 8 bit peripheral.

This type of connection is used in the Kanda Systems STK200+ and STK300 development boards.

For the LCD connection, please consult the documentation that came with your development board.

The LCD functions do not yet support the XMEGA chips.

These functions can be used only with AVR chips that allow using external memory devices.

The prototypes for these functions are placed in the file **lcdstk.h**, located in the **.\INC** subdirectory.

This file must be **#include -d** before using the functions.

The following LCD formats are supported in **lcdstk.h**: 1x8, 2x12, 3x12, 1x16, 2x16, 2x20, 4x20, 2x24 and 2x40 characters.

The LCD Functions are:

void _lcd_ready(void)

waits until the LCD module is ready to receive data.

This function must be called prior to writing data to the LCD with the **_LCD_RS0** and **_LCD_RS1** macros.

Example:

```
/* enables the displaying of the cursor */
_lcd_ready();
_LCD_RS0=0xe;
```

The **_LCD_RS0**, respectively **_LCD_RS1**, macros are used for accessing the LCD Instruction Register with RS=0, respectively RS=1.

void lcd_write_byte(unsigned char addr, unsigned char data);

writes a byte to the LCD character generator or display RAM.

Example:

```
/* LCD user defined characters

Chip: ATmegaS8515
Memory Model: SMALL
Data Stack Size: 128 bytes

Use an 2x16 alphanumeric LCD connected
to the STK200+ LCD connector */

/* include the LCD driver routines */
#include <lcdstk.h>

typedef unsigned char byte;
```

```
/* table for the user defined character
   arrow that points to the top right corner */
flash byte char0[8]={
0b10000000,
0b10001111,
0b10000011,
0b10000101,
0b10001001,
0b10010000,
0b10100000,
0b11000000};

/* function used to define user characters */
void define_char(byte flash *pc,byte char_code)
{
byte i,a;
a=(char_code<<3) | 0x40;
for (i=0; i<8; i++) lcd_write_byte(a++,*pc++);
}

void main(void)
{
/* initialize the LCD for 2 lines & 16 columns */
lcd_init(16);

/* define user character 0 */
define_char(char0,0);

/* switch to writing in Display RAM */
lcd_gotoxy(0,0);
lcd_putsf("User char 0:");

/* display used defined char 0 */
lcd_putchar(0);

while (1); /* loop forever */
}
```

unsigned char lcd_read_byte(unsigned char addr);

reads a byte from the LCD character generator or display RAM.

unsigned char lcd_init(unsigned char lcd_columns)

initializes the LCD module, clears the display and sets the printing character position at row 0 and column 0. The numbers of columns of the LCD must be specified (e.g. 16). No cursor is displayed. The function returns 1 if the LCD module is detected and 0 if it is not. This is the first function that must be called before using the other high level LCD Functions.

void lcd_clear(void)

clears the LCD and sets the printing character position at row 0 and column 0.

void lcd_gotoxy(unsigned char x, unsigned char y)

sets the current display position at column x and row y. The row and column numbering starts from 0.

void lcd_putchar(char c)

displays the character **c** at the current display position.

void lcd_puts(char *str)

displays at the current display position the string **str**, located in RAM.

void lcd_putsf(char flash *str)

displays at the current display position the string **str**, located in FLASH.

int lcd_printfxy(unsigned char x, unsigned char y, char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at specified screen coordinates, according to the format specifiers in the **fmtstr** string.

Parameters:

- x** specifies the column coordinate of the first displayed character
- y** specifies the row coordinate of the first displayed character
- fmtstr** pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

int lcd_printf(char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at current display position, according to the format specifiers in the **fmtstr** string.

Parameters:

- fmtstr** pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

5.12 Graphic Display Functions

The Graphic Display Functions are intended for easy interfacing between C programs and graphic LCD, TFT and OLED modules built with a large variety of controllers.

The prototypes for these functions are placed in the file **glcd.h**, located in the `.INC` subdirectory. This file must be **#include -d** before using the functions.

Before using these functions, the type of the graphic display controller, the I/O port signals employed for communication with it and the display resolution must be specified in the **Project|Configure|C Compiler|Libraries|Graphic Display** menu.

The following graphic display controllers are supported:

- Ilitek ILI9225 (for color 176x220 and 220x176 TFT displays)
- Ilitek ILI9325 (equivalent Raydium RM68090) (for color 240x320 and 320x240 TFT displays)
- Ilitek ILI9328 (for color 240x320 and 320x240 TFT displays)
- Ilitek ILI9331 (for color 240x320 and 320x240 TFT displays)
- Ilitek ILI9340 (for color 240x320 and 320x240 TFT displays)
- Ilitek ILI9341 (for color 240x320 and 320x240 TFT displays)
- Samsung KS0108 (equivalent: HD61202)
- Philips PCD8544
- RAiO Technology RA8875 (for color 480x272 and 800x480 TFT displays)
- Epson S1D13700
- Samsung S6D0164 (for color 176x220 and 220x176 TFT displays)
- Samsung S6D1121 (for color 240x320 and 320x240 TFT displays)
- S-MOS Systems SED1520 (equivalents: NJU6450, PT6520)
- Epson SED1335 (equivalent: RA8835)
- Epson SED1530
- Sunplus SPLC501C
- Sino Wealth SH1101A (for 128x64 OLED displays)
- Solomon Systech SSD1289 (for color 240x320 and 320x240 TFT displays)
- Solomon Systech SSD1303 (for 128x64 OLED displays)
- Solomon Systech SSD1306 (for 128x64 OLED displays)
- Solomon Systech SSD1322 (for 128x64, 256x64 OLED displays)
- Solomon Systech SSD1331 (for 96x64 OLED color displays)
- Solomon Systech SSD1332 (for 96x64 OLED color displays)
- Solomon Systech SSD1351 (for 128x96, 128x128 OLED color displays)
- Solomon Systech SSD1963 (for color 320x240, 480x272 and 800x480 TFT displays)
- Solomon Systech SSD2119 (for color 320x240 TFT displays)
- Sitronix ST7565
- Sitronix ST7567
- Sitronix ST7781 (for color 240x320 and 320x240 TFT displays)
- Sitronix ST7789 (for color 240x320 and 320x240 TFT displays)
- Sitronix ST7920
- Toshiba T6963C
- UltraChip UC1608
- UltraChip UC1610
- UltraChip UC1701
- Delcomp XG7100.

Note: The library functions for color TFT displays are supported only for the Advanced or Professional CodeVisionAVR licenses.

The Graphic Display functions do support both the XMEGA and non-XMEGA AVR chips.

The coordinate system employed by these functions has the origin (0,0) in the upper left corner of the display, with the x-coordinates increasing from left to right, and the y-coordinates increasing from top to bottom.

Coordinate clipping is performed, therefore no graphic data will be displayed for invalid coordinates.

The following helper data types are defined in the header file **glcd_types.h**:

- **GLCDX_t** type used for specifying the X horizontal display coordinate
 - **GLCDY_t** type used for specifying the Y vertical display coordinate
 - **GLCDDX_t** type used for specifying a horizontal displacement
 - **GLCDDY_t** type used for specifying a vertical displacement
 - **GLCDRAD_t** type used for specifying a circle radius
 - **GLCDCOL_t** type used for specifying foreground and background display colors
 - **GLCDMEMADDR_t** type used for specifying RAM, EEPROM, FLASH or external memory addresses for bitmap image storage
-
- **GLCDBLOCKMODE_t** enumeration type used for specifying the read/write modes for the **glcd_block** function:

```
typedef enum
{
    GLCD_PUTCOPY, /* copy a bitmap from memory to display
                  *overwriting previous display data */
    GLCD_PUTXOR,  /* copy a bitmap from memory to display
                  *performing a XOR with previous display data */
    GLCD_PUTOR,   /* copy a bitmap from memory to display
                  *performing an OR with previous display data */
    GLCD_PUTNOT,  /* copy a bitmap from memory to display
                  *performing a bit negation */
    GLCD_PUTAND,  /* copy a bitmap from memory to display
                  *performing an AND with previous display data */
    GLCD_PUTTP,   /* used for displaying image in transparent mode */
    GLCD_GET      /* used for storing a block of data from
                  *specified coordinates to memory */
    GLCD_PUTCHAR, /* used internally by the glcd_putchar function */
    GLCD_PUTFILL, /* used internally by the rectangular area fill
                  *function */
    GLCD_CLEARBLOCK, /* used internally by the rectangular area
                  *clear function */
    GLCD_SETBLOCK,  /* used internally by the rectangular area set
                  *function */
} GLCDBLOCKMODE_t;
```

Notes:

- The **GLCD_PUTXOR**, **GLCD_PUTOR**, **GLCD_PUTNOT**, **GLCD_PUTAND** modes are supported only for displays with 2 colors (monochrome).
 - The **GLCD_PUTTP** mode is supported only for displays with more than 2 colors.
-
- **GLCDMEMADDR_t** type used for specifying RAM, EEPROM, FLASH or external memory addresses for bitmap image storage

- **GLCDTEXT_t** structure type used for specifying the text displaying parameters:

```
typedef struct
{
    flash unsigned char *font; /* current font */
    unsigned char horiz;      /* horizontal justification in pixels */
    unsigned char vert;       /* vertical justification in pixels */
    unsigned char transparent:1; /* enable transparent text
                                display mode */
} GLCDTEXT_t;
```

Note: The **transparent** structure member is defined only for displays with more than 2 colors.

- **GLCDLINE_t** structure type used for specifying the line drawing parameters:

```
typedef struct
{
    unsigned char thick; /* line thickness */
    unsigned char pattern; /* bit pattern */
} GLCDLINE_t;
```

- **GLCDPOINT_t** structure type used for specifying point coordinates:

```
typedef struct
{
    GLCDX_t x;
    GLCDY_t y;
} GLCDPOINT_t;
```

- **GLCDFILL_t** structure type used for specifying the fill style parameters:

```
typedef struct
{
    GLCDCOL_t color; /* fill color */

    /* bit pattern for filling a rectangular area */
    unsigned char pattern[_GLCD_FILL_PATTERN_HEIGHT_];
} GLCDFILL_t;
```

- **GLCDARCCOORDS_t** structure type used for specifying the arc coordinates:

```
typedef struct
{
    GLCDX_t x; /* arc x center coordinate */
    GLCDY_t y; /* arc y center coordinate */
    GLCDX_t xstart; /* arc start x coordinate */
    GLCDY_t ystart; /* arc start y coordinate */
    GLCDX_t xend; /* arc end x coordinate */
    GLCDY_t yend; /* arc end y coordinate */
} GLCDARCCOORDS_t;
```

- **GLCDINIT_t** structure type used for specifying various parameters used for initializing the display controller:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */

    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);

    /* pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    /* additional structure members which are specific
       to each display controller... */

} GLCDINIT_t;
```

- **GLCDSTATE_t** structure type used for specifying the graphic display state:

```
typedef struct
{
    GLCDCOL_t fgcolor; /* foreground color */
    GLCDCOL_t bkcolor; /* background color */
    GLCDCOL_t tpcolor; /* transparency color */
    GLCDX_t cx; /* current x horizontal coordinate */
    GLCDY_t cy; /* current y vertical coordinate */
    GLCDTEXT_t text; /* current text display settings */
    GLCDLINE_t line; /* current line display settings */
    GLCDARCCOORDS_t arc; /* coordinates of last displayed arc */
    GLCDFILL_t fill; /* current fill display settings */

    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);

    /* pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
} GLCDSTATE_t;
```

Note: The **tpcolor** transparency color member is available only for displays with more than 2 colors.

- **GLCDMEM_t** enumeration type used for specifying the kind of memory access:

```
typedef enum
{
    GLCD_MEM_RAM, /* RAM access */
    GLCD_MEM_FLASH, /* FLASH access */
    GLCD_MEM_EEPROM, /* EEPROM access */
    GLCD_MEM_EXT /* external memory accessed
                  using special functions */
} GLCDMEM_t;
```

The following macros are defined in the header file **glcd_types.h** :

- **GLCD_LINE_SOLID** solid line pattern
- **GLCD_LINE_DOT_SMALL** small dots line pattern
- **GLCD_LINE_DOT_LARGE** large dots line pattern
- **_GLCD_FILL_PATTERN_WIDTH_** width of the fill pattern measured in pixels
- **_GLCD_MAXCOLOR_** highest color value for a pixel in ON state.

The following macros are predefined by the compiler based on the settings from the **Project|Configure|C Compiler|Libraries|Graphic Display** menu:

- **_GLCD_MAXX_** horizontal display resolution measured in pixels
- **_GLCD_MAXY_** vertical display resolution measured in pixels
- **_GLCD_BYTEY_** signals that the display controller uses vertical byte organization for accessing the display RAM
- **_GLCD_INTERNAL_FONT_WIDTH_** specifies the width of the internal character generator's font, measured in pixels
- **_GLCD_INTERNAL_FONT_HEIGHT_** specifies the height of the internal character generator's font, measured in pixels
- **_GLCD_CTRL_ILI9225_** signals that the display controller type is Ilitek ILI9225
- **_GLCD_CTRL_ILI9325_** signals that the display controller type is Ilitek ILI9325
- **_GLCD_CTRL_ILI9328_** signals that the display controller type is Ilitek ILI9328
- **_GLCD_CTRL_ILI9331_** signals that the display controller type is Ilitek ILI9331
- **_GLCD_CTRL_ILI9340_** signals that the display controller type is Ilitek ILI9340
- **_GLCD_CTRL_ILI9341_** signals that the display controller type is Ilitek ILI9341
- **_GLCD_CTRL_KS0108_** signals that the display controller type is Samsung KS0108
- **_GLCD_CTRL_SED1335_** signals that the display controller type is Epson SED1335
- **_GLCD_CTRL_PCD8544_** signals that the display controller type is Philips PCD8544
- **_GLCD_CTRL_RA8875_** signals that the display controller type is RAiO Technology RA8875
- **_GLCD_CTRL_SED1520_** signals that the display controller type is S-MOS Systems SED1520
- **_GLCD_CTRL_SED1530_** signals that the display controller type is Epson SED1520
- **_GLCD_CTRL_S1D13700_** signals that the display controller type is Epson S1D13700
- **_GLCD_CTRL_S6D0164_** signals that the display controller type is Samsung S6D0164
- **_GLCD_CTRL_S6D1121_** signals that the display controller type is Samsung S6D1121
- **_GLCD_CTRL_ST7565_** signals that the display controller type is Sitronix ST7565
- **_GLCD_CTRL_ST7567_** signals that the display controller type is Sitronix ST7567
- **_GLCD_CTRL_ST7781_** signals that the display controller type is Sitronix ST7781
- **_GLCD_CTRL_ST7789_** signals that the display controller type is Sitronix ST7789
- **_GLCD_CTRL_ST7920_** signals that the display controller type is Sitronix ST7920
- **_GLCD_CTRL_SPLC501_** signals that the display controller type is Sunplus SPLC501C
- **_GLCD_CTRL_SSD1289_** signals that the display controller type is Solomon Systech SSD1289
- **_GLCD_CTRL_SSD1303_** signals that the display controller type is Solomon Systech SSD1303 or the equivalent Sino Wealth SH1101A
- **_GLCD_CTRL_SSD1306_** signals that the display controller type is Solomon Systech SSD1306
- **_GLCD_CTRL_SSD1322_** signals that the display controller type is Solomon Systech SSD1322
- **_GLCD_CTRL_SSD1331_** signals that the display controller type is Solomon Systech SSD1331
- **_GLCD_CTRL_SSD1332_** signals that the display controller type is Solomon Systech SSD1332
- **_GLCD_CTRL_SSD1351_** signals that the display controller type is Solomon Systech SSD1351
- **_GLCD_CTRL_SSD1963_** signals that the display controller type is Solomon Systech SSD1963
- **_GLCD_CTRL_SSD2119_** signals that the display controller type is Solomon Systech SSD2119
- **_GLCD_CTRL_T6963_** signals that the display controller type is Toshiba T6963C
- **_GLCD_CTRL_UC1608_** signals that the display controller type is UltraChip UC1608
- **_GLCD_CTRL_UC1610_** signals that the display controller type is UltraChip UC1610
- **_GLCD_CTRL_UC1701_** signals that the display controller type is UltraChip UC1701
- **_GLCD_CTRL_XG7100_** signals that the display controller type is Delcomp XG7100.

CodeVisionAVR

Note: The header file **glcd_types.h** is automatically *#include*-d by **glcd.h**, so there is no need to *#include* it directly. The same applies to the header file **graphics.h** where the high level graphic display functions are declared.

The following high level graphic display functions are available:

bool glcd_init(GLCDINIT_t *init_data)

initializes the graphic display controller and performs the following initializations of the graphic system:

- clears the display
- sets the current plot coordinates to (0,0)
- sets the current font used for displaying text as specified by the **font** member of the structure pointed by **init_data**
- sets the current background color to 0
- sets the current foreground color to **_GLCD_MAXCOLOR_**
- sets the current transparency color to 0 (for displays with more than 2 colors)
- sets the current text horizontal justification to 1 pixel
- sets the current text vertical justification to 1 pixel
- sets the current line width to 1 pixel
- sets the transparent text mode display to OFF for LCDs with more than 2 colors
- sets the current line pattern to solid line
- sets the current line color to **_GLCD_MAXCOLOR_**
- sets the current fill pattern to solid
- sets the current fill color to **_GLCD_MAXCOLOR_**
- sets the pointers to the external memory read and write functions.

Parameter:

init_data points to a **GLCDINIT_t** structure that specifies various parameters used for initializing the display controller, including the font used for displaying text. If the **font** member of the structure pointed by **init_data** is NULL, then the internal character generator (if present) of the display controller will be used for displaying text.

In this situation the horizontal and vertical text justification settings will have no effect, the text will be aligned to character cell boundaries specific to the controller.

If **init_data** is NULL, then the default settings for the specific display controller will be used, including the internal character generator, if present.

Return values:

true on success, **false** in case of error.

Note: A 5x7 pixel font is supplied as standard with CodeVisionAVR.

In order to use this font, the **font5x7.h** header file must be *#include*-d and the **GLCDINIT_t** structure member **font** must be initialized with the **font5x7** array address, when **glcd_init** is called.

Additional fonts can be created using the LCD Vision font editor, supplied with the Advanced version of CodeVisionAVR.

Example:

```
/* Include the graphic display driver functions.  
   The display controller type and connections must be specified in  
   the Project|Configure|C Compiler|Libraries|Graphic Display menu. */  
#include <glcd.h>
```

```
/* Include the font definition */
#include <font5x7.h>

/* Function used for reading image data from external memory */
unsigned char read_ext_memory(GLCDMEMADDR_t addr)
{
    unsigned char data;
    /* Place your code here ... */

    return data;
}

/* Function used for writing image data to external memory */
void write_ext_memory(GLCDMEMADDR_t addr, unsigned char data)
{
    /* Place your code here ... */

}

void main(void)
{
    GLCDINIT_t init;

    /* Specify the current font */
    init.font=font5x7;

    /* Specify the function used for reading data from external memory.
       If not used, set value to NULL */
    init.readxmem=read_ext_memory;

    /* Specify the function used for writing data to external memory.
       If not used, set value to NULL */
    init.writexmem=write_ext_memory;

    /* Initialize the display controller and graphics */
    glcd_init(&init);

    /* Follows the rest of the code ... */
}
```

void glcd_display(bool on)

Turns display on/off.

Parameter:

on specifies display on/off state.

void glcd_setcolor(GLCDCOL_t foreground_color)

Sets the current foreground color that will be used for displaying text and graphics.

Parameter:

foreground_color specifies the foreground color.

void glcd_setbkcolor(GLCDCOL_t background_color)

Sets the current background color that will be used for displaying text and graphics.

Parameter:

background_color specifies the background color.

void glcd_settpcolor(GLCDCOL_t transparent_color)

Sets the transparency color for image displaying in transparent mode.

Parameter:

transparent_color specifies the transparency color.

When an image pixel with this color must be displayed in transparent mode **GLCD_PUTTP**, the background color at the pixel coordinates will be used instead.

Note: This function is available only for displays with more than 2 colors.

GLCDCOL_t glcd_getcolor(void)

Returns the display's current foreground color.

GLCDCOL_t glcd_getbkcolor(void)

Returns the display's current background color.

GLCDCOL_t glcd_gettpcolor(void)

Returns the current transparency color for image displaying in transparent mode.

When an image pixel with this color must be displayed in transparent mode **GLCD_PUTTP**, the background color at the pixel coordinates will be used instead.

Note: This function is available only for displays with more than 2 colors.

GLCDCOL_t glcd_getmaxcolor(void)

Returns the highest color value for a pixel in ON state.

GLCDX_t glcd_getmaxx(void)

Returns the maximum X horizontal coordinate value.

GLCDY_t glcd_getmaxy(void)

Returns the maximum Y horizontal coordinate value.

void glcd_clear(void)

Clears the display by setting it's color to the current background color.

void glcd_putpixel(GLCDX_t x, GLCDY_t y, GLCDCOL_t color)

Sets the color of the pixel at specified coordinates.

Note: The current pixel plot coordinates are not affected by this function.

Parameters:

x specifies the horizontal pixel coordinate

y specifies the vertical pixel coordinate

color specifies the color that must be assigned to the pixel.

void glcd_setpixel(GLCDX_t x, GLCDY_t y)

Sets the color of the pixel at specified coordinates to the current foreground color.

Note: The current pixel plot position coordinates are not affected by this function.

Parameters:

x specifies the horizontal pixel coordinate

y specifies the vertical pixel coordinate.

void glcd_clrpixel(GLCDX_t x, GLCDY_t y)

Sets the color of the pixel at specified coordinates to the current background color.

Note: The current pixel plot position coordinates are not affected by this function.

Parameters:

x specifies the horizontal pixel coordinate

y specifies the vertical pixel coordinate.

GLCDCOL_t glcd_getpixel(GLCDX_t x, GLCDY_t y)

Returns the color of the pixel at specified coordinates. If the pixel coordinates are outside the display area, the returned color will be 0.

Note: The current pixel plot position coordinates are not affected by this function.

Parameters:

x specifies the horizontal pixel coordinate

y specifies the vertical pixel coordinate.

void glcd_moveto(GLCDX_t x, GLCDY_t y)

Moves the current pixel plot position to the specified coordinates.

Parameters:

x specifies the horizontal pixel coordinate

y specifies the vertical pixel coordinate.

void glcd_moverel(GLCDDX_t dx, GLCDDY_t dy)

Moves the current pixel plot position to a new relative position.

Parameters:

dx specifies the horizontal displacement relative to the current pixel plot position
dy specifies the vertical displacement relative to the current pixel plot position.

GLCDX_t glcd_getx(void)

Returns the value of the current pixel plot position horizontal coordinate.

GLCDY_t glcd_gety(void)

Returns the value of the current pixel plot position vertical coordinate.

void glcd_setfont(flash unsigned char *font_name)

Specifies the current font used for displaying text.

Parameters:

font_name points to an array located in FLASH memory, that holds the font definition.

void glcd_settextjustify(unsigned char horiz, unsigned char vert)

Sets the horizontal and vertical text justification values.

Parameters:

horiz specifies the horizontal spacing between displayed characters, measured in pixels
vert specifies the vertical spacing between displayed characters, measured in pixels.

unsigned char glcd_charwidth(char c)

Returns the width (in pixels) of a character for the current font, including the horizontal justification.

Parameter:

c specifies the code of the character for which the width must be returned.

unsigned char glcd_textheight(void)

Returns the text height (in pixels) for the current font, including the vertical justification.

GLCDX_t glcd_textwidth(char *str)

Returns the text width (in pixels) of a NULL terminated literal char string located in RAM for the current font, including the horizontal justification.

Parameter:

str pointer to the literal char string.

GLCDX_t glcd_textwidthf(flash char *str)

Returns the text width (in pixels) of a NULL terminated literal char string located in FLASH for the current font, including the horizontal justification.

Parameter:

str pointer to the literal char string.

GLCDX_t glcd_textwidth(eeprom char *str)

Returns the text width (in pixels) of a NULL terminated literal char string located in EEPROM for the current font, including the horizontal justification.

Parameter:

str pointer to the literal char string.

void glcd_boxsize(char *str, GLCDX_t *width, GLCDY_t *height)

Returns the width and height (in pixels) of the rectangular screen area needed to display a NULL terminated literal char string, containing multiple lines of text terminated with the '\n' character, for the current font including the horizontal and vertical justifications. The width of the area will be the displayed size of the longest line of text.

Parameters:

str pointer to the literal char string

width pointer to a **GLCDX_t** type variable that will hold the horizontal size of the area

height pointer to a **GLCDY_t** type variable that will hold the vertical size of the area.

void glcd_boxsizef(flash char *str, GLCDX_t *width, GLCDY_t *height)

Returns the width and height (in pixels) of the rectangular screen area needed to display a NULL terminated literal char string located in FLASH memory, containing multiple lines of text terminated with the '\n' character, for the current font including the horizontal and vertical justifications. The width of the area will be the displayed size of the longest line of text.

Parameters:

str pointer to the literal char string

width pointer to a **GLCDX_t** type variable that will hold the horizontal size of the area

height pointer to a **GLCDY_t** type variable that will hold the vertical size of the area.

void glcd_boxsizee(eeprom char *str, GLCDX_t *width, GLCDY_t *height)

Returns the width and height (in pixels) of the rectangular screen area needed to display a NULL terminated literal char string located in EEPROM, containing multiple lines of text terminated with the '\n' character, for the current font including the horizontal and vertical justifications. The width of the area will be the displayed size of the longest line of text.

Parameters:

str pointer to the literal char string
width pointer to a **GLCDX_t** type variable that will hold the horizontal size of the area
height pointer to a **GLCDY_t** type variable that will hold the vertical size of the area.

void glcd_transparent(bool on)

Controls displaying text in transparent mode.
If this mode is enabled, the background color of the area where the character is displayed is preserved, otherwise the color specified by **glcd_setbkcolor** is used.

Parameter:

on enables or disables displaying text in transparent mode.

Note: The **glcd_transparent** function is defined only for displays with more than 2 colors.

void glcd_putcharxy(GLCDX_t x, GLCDY_t y, char c)

Displays a character using the current font at the specified coordinates.
After the character is displayed, the current horizontal pixel plot coordinate is increased to the next display position by the width of the character + horizontal text justification.
If the new horizontal pixel plot coordinate will result outside the right display margin, then the new horizontal coordinate will be set to 0 and the vertical pixel plot coordinate will be increased by the height of the font + vertical text justification.

Parameters:

x specifies the horizontal coordinate of the left top corner of the displayed character
y specifies the vertical coordinate of the left top corner of the displayed character
c specifies the code of the character that must be displayed.

void glcd_putchar(char c)

Displays a character using the current font at the current pixel plot position.

Parameter:

c specifies the code of the character that must be displayed.

void glcd_outtextxy(GLCDX_t x, GLCDY_t y, char *str)

Displays a NULL terminated literal char string located in RAM at the specified coordinates.
The new display position will be located at the end of the displayed text.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character
y specifies the vertical coordinate of the left top corner of the first displayed character
str pointer to the literal char string.

void glcd_outtextxyf(GLCDX_t x, GLCDY_t y, flash char *str)

Displays a NULL terminated literal char string located in FLASH at the specified coordinates.
The new display position will be located at the end of the displayed text.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character
y specifies the vertical coordinate of the left top corner of the first displayed character
str pointer to the literal char string.

void glcd_outtextxye(GLCDX_t x, GLCDY_t y, eeprom char *str)

Displays a NULL terminated literal char string located in EEPROM at the specified coordinates.
The new display position will be located at the end of the displayed text.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character
y specifies the vertical coordinate of the left top corner of the first displayed character
str pointer to the literal char string.

void glcd_outtext(char *str)

Displays a NULL terminated literal char string located in RAM at the current display position.
The new display position will be located at the end of the displayed text.

Parameter:

str pointer to the literal char string.

void glcd_outtextf(char *str)

Displays a NULL terminated literal char string located in FLASH at the current display position.
The new display position will be located at the end of the displayed text.

Parameter:

str pointer to the literal char string.

void glcd_outtexte(char *str)

Displays a NULL terminated literal char string located in EEPROM at the current display position.

The new display position will be located at the end of the displayed text.

Parameter:

str pointer to the literal char string.

void glcd_outtextoffs(GLCDX_t x, GLCDY_t y, char *str)

Displays a NULL terminated character string located in RAM, containing multiple lines of text terminated with the '\n' character, starting from the specified x, y coordinates.

The start of the text lines will have an offset of x pixels from the left edge of the screen.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character in a line of text

y specifies the vertical coordinate of the left top corner of the first displayed character

str pointer to the literal char string.

void glcd_outtextoffsf(GLCDX_t x, GLCDY_t y, flash char *str)

Displays a NULL terminated character string located in FLASH memory, containing multiple lines of text terminated with the '\n' character, starting from the specified x, y coordinates.

The start of the text lines will have an offset of x pixels from the left edge of the screen.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character in a line of text

y specifies the vertical coordinate of the left top corner of the first displayed character

str pointer to the literal char string.

void glcd_outtextoffse(GLCDX_t x, GLCDY_t y, eeprom char *str)

Displays a NULL terminated character string located in EEPROM, containing multiple lines of text terminated with the '\n' character, starting from the specified x, y coordinates.

The start of the text lines will have an offset of x pixels from the left edge of the screen.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character in a line of text

y specifies the vertical coordinate of the left top corner of the first displayed character

str pointer to the literal char string.

int glcd_printfxy(GLCDX_t x, GLCDY_t y, char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at specified screen coordinates, according to the format specifiers in the **fmtstr** string.

Parameters:

x specifies the horizontal coordinate of the left top corner of the first displayed character
y specifies the vertical coordinate of the left top corner of the first displayed character
fmtstr pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

int glcd_printf(char flash *fmtstr [, arg1, arg2, ...])

outputs formatted text, at current display position, according to the format specifiers in the **fmtstr** string.

Parameters:

fmtstr pointer to the format specifier string, located in FLASH memory.

Return value: the number of displayed characters.

The supported format specifiers are identical to those of the **printf** Standard C Input/Output Function.

**void glcd_block(GLCDX_t left, GLCDY_t top, GLCDX_t width, GLCDY_t height,
GLCDMEM_t memt, GLCDMEMADDR_t addr, GLCDBLOCKMODE_t mode)**

Writes/reads a block of bytes to/from a rectangular graphics display area at specified coordinates.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangular display area
top specifies the vertical coordinate of the left top corner of the rectangular display area
width specifies the horizontal size of the rectangular display area
height specifies the vertical size of the rectangular display area
memt specifies the memory type to/from which the data will be written/read.
It may take one of the following values:

• GLCD_MEM_RAM	RAM access
• GLCD_MEM_FLASH	FLASH access
• GLCD_MEM_EEPROM	EEPROM access
• GLCD_MEM_EXT	external memory accessed using special functions.

addr specifies the memory address to/from which the data will be written/read
mode specifies the operation to be performed:

• GLCD_PUTCOPY	copy a bitmap from memory to display overwriting previous display data

• GLCD_PUTTP	copy a bitmap from memory to display overwriting previous display data using transparent mode (when an image pixel with the current transparency color must be displayed, the background color at the pixel coordinates will be used instead)
• GLCD_PUTXOR	copy a bitmap from memory to display performing a XOR with previous display data
• GLCD_PUTOR	copy a bitmap from memory to display performing an OR with previous display data
• GLCD_PUTNOT	copy a bitmap from memory to display performing a bit negation
• GLCD_PUTAND	copy a bitmap from memory to display performing an AND with previous display data
• GLCD_GET	read a block of data from specified coordinates.

Notes:

- The **glcd_block** function doesn't access the text overlay display, if present.
- The **GLCD_PUTXOR**, **GLCD_PUTOR**, **GLCD_PUTNOT**, **GLCD_PUTAND** modes are supported only for displays with 2 colors (monochrome).
- The **GLCD_PUTTP** mode is supported only for displays with more than 2 colors.

unsigned long glcd_imagesize(GLCDX_t width, GLCDY_t height)

Returns the memory size in bytes needed to store a rectangular bitmap image.

Parameters:

width specifies the horizontal size of the rectangular display area
height specifies the vertical size of the rectangular display area.

Return values:

image size or 0 if the **width** or **height** values are not valid.

unsigned long glcd_putimage(GLCDX_t left, GLCDY_t top, unsigned char *pimg, GLCDBLOCKMODE_t mode)

Displays a bitmap image located in RAM at specified coordinates.

Parameters:

left specifies the horizontal coordinate of the left top corner of the image
top specifies the vertical coordinate of the left top corner of the image
pimg pointer to the image data, which is located in RAM
mode specifies how the display operation must be performed:

• GLCD_PUTCOPY	copy a bitmap from memory to display overwriting previous display data
• GLCD_PUTTP	copy a bitmap from memory to display overwriting previous display data using transparent mode (when an image pixel with the current transparency color must be displayed, the background color at the pixel coordinates will be used instead)

• GLCD_PUTXOR	copy a bitmap from memory to display performing a XOR with previous display data
• GLCD_PUTOR	copy a bitmap from memory to display performing an OR with previous display data
• GLCD_PUTNOT	copy a bitmap from memory to display performing a bit negation
• GLCD_PUTAND	copy a bitmap from memory to display performing an AND with previous display data.

Return values:

image size or 0 if the coordinate values are not valid.

Notes:

- The **GLCD_PUTXOR**, **GLCD_PUTOR**, **GLCD_PUTNOT**, **GLCD_PUTAND** modes are supported only for displays with 2 colors (monochrome).
- The **GLCD_PUTTP** mode is supported only for displays with more than 2 colors.

unsigned long glcd_putimagef(GLCDX_t left, GLCDY_t top, flash unsigned char *pimg, GLCDBLOCKMODE_t mode)

Displays a bitmap image located in FLASH at specified coordinates.

Parameters:

left specifies the horizontal coordinate of the left top corner of the image

top specifies the vertical coordinate of the left top corner of the image

pimg pointer to the image data, which is located in FLASH

mode specifies how the display operation must be performed:

• GLCD_PUTCOPY	copy a bitmap from memory to display overwriting previous display data
• GLCD_PUTTP	copy a bitmap from memory to display overwriting previous display data using transparent mode (when an image pixel with the current transparency color must be displayed, the background color at the pixel coordinates will be used instead)
• GLCD_PUTXOR	copy a bitmap from memory to display performing a XOR with previous display data
• GLCD_PUTOR	copy a bitmap from memory to display performing an OR with previous display data
• GLCD_PUTNOT	copy a bitmap from memory to display performing a bit negation
• GLCD_PUTAND	copy a bitmap from memory to display performing an AND with previous display data.

Return values:

image size or 0 if the coordinate values are not valid.

Notes:

- The **GLCD_PUTXOR**, **GLCD_PUTOR**, **GLCD_PUTNOT**, **GLCD_PUTAND** modes are supported only for displays with 2 colors (monochrome).
- The **GLCD_PUTTP** mode is supported only for displays with more than 2 colors.

unsigned long glcd_putimagee(GLCDX_t left, GLCDY_t top, eeprom unsigned char *pimg, GLCDBLOCKMODE_t mode)

Displays a bitmap image located in EEPROM at specified coordinates.

Parameters:

left specifies the horizontal coordinate of the left top corner of the image

top specifies the vertical coordinate of the left top corner of the image

pimg pointer to the image data, which is located in EEPROM

mode specifies how the display operation must be performed:

- **GLCD_PUTCOPY** copy a bitmap from memory to display
overwriting previous display data
- **GLCD_PUTTP** copy a bitmap from memory to display
overwriting previous display data using transparent
mode (when an image pixel with the current
transparency color must be displayed, the
background color at the pixel coordinates will be used
instead)
- **GLCD_PUTXOR** copy a bitmap from memory to display
performing a XOR with previous display data
- **GLCD_PUTOR** copy a bitmap from memory to display
performing an OR with previous display data
- **GLCD_PUTNOT** copy a bitmap from memory to display
performing a bit negation
- **GLCD_PUTAND** copy a bitmap from memory to display
performing an AND with previous display data.

Return values:

image size or 0 if the coordinate values are not valid.

Notes:

- The **GLCD_PUTXOR**, **GLCD_PUTOR**, **GLCD_PUTNOT**, **GLCD_PUTAND** modes are supported only for displays with 2 colors (monochrome).
- The **GLCD_PUTTP** mode is supported only for displays with more than 2 colors.

unsigned long glcd_putimagex(GLCDX_t left, GLCDY_t top, GLCDMEMADDR_t addr, GLCDBLOCKMODE_t mode)

Displays a bitmap image located in external memory at specified coordinates.

Note: External memory read must be implemented through an user defined function, specified during initialization by **glcd_init**.

Parameters:

left specifies the horizontal coordinate of the left top corner of the image

top specifies the vertical coordinate of the left top corner of the image

addr specifies the external memory address from which the image will be read

mode specifies how the display operation must be performed:

- **GLCD_PUTCOPY** copy a bitmap from memory to display overwriting previous display data
- **GLCD_PUTTP** copy a bitmap from memory to display overwriting previous display data using transparent mode (when an image pixel with the current transparency color must be displayed, the background color at the pixel coordinates will be used instead)
- **GLCD_PUTXOR** copy a bitmap from memory to display performing a XOR with previous display data
- **GLCD_PUTOR** copy a bitmap from memory to display performing an OR with previous display data
- **GLCD_PUTNOT** copy a bitmap from memory to display performing a bit negation
- **GLCD_PUTAND** copy a bitmap from memory to display performing an AND with previous display data.

Return values:

image size or 0 if the coordinate values are not valid.

Notes:

- The **GLCD_PUTXOR**, **GLCD_PUTOR**, **GLCD_PUTNOT**, **GLCD_PUTAND** modes are supported only for displays with 2 colors (monochrome).
- The **GLCD_PUTTP** mode is supported only for displays with more than 2 colors.

unsigned long glcd_getimage(GLCDX_t left, GLCDY_t top, GLCDX_t width, GLCDY_t height, unsigned char *pimg)

Saves a rectangular display area to RAM as a bitmapped image.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangular display area

top specifies the vertical coordinate of the left top corner of the rectangular display area

width specifies the horizontal size of the rectangular display area

height specifies the vertical size of the rectangular display area

pimg points to the byte array that will hold the image data.

Return values:

image size or 0 if the coordinate values are not valid.

unsigned long glcd_getimagee(GLCDX_t left, GLCDY_t top, GLCDX_t width, GLCDY_t height, eeprom unsigned char *pimg)

Saves a rectangular display area to EEPROM as a bitmapped image.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangular display area
top specifies the vertical coordinate of the left top corner of the rectangular display area
width specifies the horizontal size of the rectangular display area
height specifies the vertical size of the rectangular display area
pimg points to the byte array that will hold the image data.

Return values:

image size or 0 if the coordinate values are not valid.

unsigned long glcd_getimagex(GLCDX_t left, GLCDY_t top, GLCDX_t width, GLCDY_t height, GLCDMEMADDR_t addr)

Saves a rectangular display area to external memory as a bitmapped image.

Note: External memory write must be implemented through an user defined function, specified during initialization by **glcd_init**.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangular display area
top specifies the vertical coordinate of the left top corner of the rectangular display area
width specifies the horizontal size of the rectangular display area
height specifies the vertical size of the rectangular display area
addr specifies the external memory address to which the image will be written.

Return values:

image size or 0 if the coordinate values are not valid.

void glcd_setlinestyle(unsigned char thickness, unsigned char bit_pattern)

Sets the current line displaying style.

Parameters:

thickness specifies the thickness of the lines to be drawn on the display, measured in pixels
bit_pattern specifies the pattern of the eight successive pixels of the lines to be drawn.
There are the following predefined patterns:

- **GLCD_LINE_SOLID** solid line pattern
- **GLCD_LINE_DOT_SMALL** small dots line pattern
- **GLCD_LINE_DOT_LARGE** large dots line pattern.

void glcd_setlinethick(unsigned char thickness)

Sets the current line thickness.

Parameter:

thickness specifies the thickness of the lines to be drawn on the display, measured in pixels.

unsigned char glcd_getlinethick(void)

Returns current line thickness setting, measured in pixels.

unsigned char glcd_getlinepattern(void)

Returns current line bit pattern setting.

void glcd_line(GLCDX_t x0, GLCDY_t y0, GLCDX_t x1, GLCDY_t y1)

Draws a line with the current foreground color, thickness and bit pattern. The current pixel plot position will be updated to the line's ending point coordinates.

Parameters:

x0 specifies the line's starting point horizontal coordinate

y0 specifies the line's starting point vertical coordinate

x1 specifies the line's ending point horizontal coordinate

y1 specifies the line's ending point vertical coordinate.

void glcd_lineto(GLCDX_t x, GLCDY_t y)

Draws a line from the current pixel plot position to a new position using the current foreground color, thickness and bit pattern. The current pixel plot position will be updated to the line's ending point coordinates.

Parameters:

x specifies the line's ending point horizontal coordinate

y specifies the line's ending point vertical coordinate.

void glcd_linerel(GLCDDX_t dx, GLCDDY_t dy)

Draws a line from the current pixel plot position to a new relative position using the current foreground color, thickness and bit pattern. The current pixel plot position will be updated to the line's ending point coordinates.

Parameters:

dx specifies the horizontal displacement of the line's ending point relative to the current pixel plot position

dy specifies the vertical displacement of the line's ending point relative to the current pixel plot position.

```
void glcd_triangle(GLCDX_t x0, GLCDY_t y0, GLCDX_t x1, GLCDY_t y1,  
                  GLCDX_t x2, GLCDY_t y2)
```

Draws a triangle with the current foreground color, line thickness and bit pattern.
The current pixel plot position will be updated to the third point of the triangle.

Parameters:

x0 specifies the horizontal coordinate of the first point of the triangle
y0 specifies the vertical coordinate of the first point of the triangle
x1 specifies the horizontal coordinate of the second point of the triangle
y1 specifies the vertical coordinate of the second point of the triangle
x2 specifies the horizontal coordinate of the third point of the triangle
y2 specifies the vertical coordinate of the third point of the triangle.

```
void glcd_filltriangle(GLCDX_t x0, GLCDY_t y0, GLCDX_t x1, GLCDY_t y1,  
                      GLCDX_t x2, GLCDY_t y2)
```

Draws a triangle filled with the current fill color.
The current pixel plot position will be updated to the third point of the triangle.

Parameters:

x0 specifies the horizontal coordinate of the first point of the triangle
y0 specifies the vertical coordinate of the first point of the triangle
x1 specifies the horizontal coordinate of the second point of the triangle
y1 specifies the vertical coordinate of the second point of the triangle
x2 specifies the horizontal coordinate of the third point of the triangle
y2 specifies the vertical coordinate of the third point of the triangle.

```
void glcd_rectangle(GLCDX_t left, GLCDY_t top, GLCDX_t right, GLCDY_t bottom)
```

Draws a rectangle with the current foreground color, line thickness and bit pattern, using absolute coordinates.
The current pixel plot position will be updated to the left top corner of the rectangle.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangle
top specifies the vertical coordinate of the left top corner of the rectangle
right specifies the horizontal coordinate of the right bottom corner of the rectangle
bottom specifies the vertical coordinate of the right bottom corner of the rectangle.

```
void glcd_rectrel(GLCDX_t left, GLCDY_t top, GLCDDX_t width, GLCDDY_t height)
```

Draws a rectangle with the current foreground color, line thickness and bit pattern, using relative coordinates.
The current pixel plot position will be updated to the left top corner of the rectangle.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangle
top specifies the vertical coordinate of the left top corner of the rectangle
width specifies the horizontal size of the rectangle
height specifies the vertical size of the rectangle.

```
void glcd_rectround(GLCDX_t left, GLCDY_t top, GLCDDX_t width, GLCDDY_t height,  
                   GLCDRAD_t radius)
```

Draws a rectangle with rounded corners, using the current foreground color and line thickness.

The current pixel plot position will be updated to the left top corner of the rectangle.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangle

top specifies the vertical coordinate of the left top corner of the rectangle

width specifies the horizontal size of the rectangle

height specifies the vertical size of the rectangle

radius specifies the radius of each corner's circle arc.

```
void glcd_fillrectround(GLCDX_t left, GLCDY_t top, GLCDDX_t width, GLCDDY_t height,  
                       GLCDRAD_t radius)
```

Draws a rectangle with rounded corners, filled using the current fill color.

The current pixel plot position will be updated to the left top corner of the rectangle.

Parameters:

left specifies the horizontal coordinate of the left top corner of the rectangle

top specifies the vertical coordinate of the left top corner of the rectangle

width specifies the horizontal size of the rectangle

height specifies the vertical size of the rectangle

radius specifies the radius of each corner's circle arc.

```
void glcd_drawpoly(unsigned char npoints, flash GLCDPOINT_t *polypoints)
```

Draws a polygon using the current foreground color, line thickness and bit pattern.

The current pixel plot position will be updated to the ending point of the last line of the polygon.

Parameters:

npoints specifies the number of points of the polygon

polypoints points to a an array of polygon point coordinates located in FLASH.

Example:

```
/* Include the graphic display driver functions.  
   The display controller type and connections must be specified in  
   the Project|Configure|C Compiler|Libraries|Graphic Display menu. */  
#include <glcd.h>  
  
/* Array located in FLASH that holds the hexagon point coordinates.  
   The coordinate of the last point must match the ones of the  
   first point, so that the polygon will be closed.  
   So there will be 6+1=7 points for a hexagon. */  
flash GLCDPOINT_t hexagon[7]=  
{ {40,0}, {57,10}, {57,30}, {40,40}, {23,30}, {23,10}, {40,0} };  
  
void main(void)  
{  
    GLCDINIT_t init;
```

```
/* We will not display any text, so there's need for a font */
init.font=NULL;

/* No need for reading data from external memory */
init.readxmem=NULL;

/* No need for writing data to external memory */
init.writexmem=NULL;

/* Initialize the display controller and graphics */
glcd_init(&init);

/* Draw the hexagon */
glcd_drawpoly(7,hexagon);

/* Stop here */
while (1);
}
```

void glcd_circle(GLCDX_t x, GLCDY_t y, GLCDRAD_t radius)

Draws a circle at specified center coordinates using the current foreground color and line thickness.

Parameters:

x specifies the horizontal coordinate of the circle's center
y specifies the vertical coordinate of the circle's center
radius specifies the circle's radius.

void glcd_arc(GLCDX_t x, GLCDY_t y, unsigned short start_angle, unsigned short end_angle, GLCDRAD_t radius)

Draws an arc of a circle at specified center coordinates using the current foreground color and line thickness.
The angles are measured in degrees, starting from the three o'clock position counter-clockwise.

Parameters:

x specifies the horizontal coordinate of the circle's center
y specifies the vertical coordinate of the circle's center
start_angle specifies the arc's starting angle
end_angle specifies the arc's ending angle
radius specifies the circle's radius.

void glcd_getarccoords(GLCDARCCOORDS_t *arccoords)

Fills a **GLCDARCCOORDS_t** type structure with information about the last call to the **glcd_arc** function.

Parameter:

arccoords points to a **GLCDARCCOORDS_t** type structure.

void glcd_ellipse(GLCDX_t x, GLCDY_t y, GLCDX_t radiusx, GLCDY_t radiusy)

Draws an ellipse at specified center coordinates using the current line color and thickness.

Parameters:

x ellipse's center horizontal coordinate
y ellipse's center vertical coordinate
radiusx ellipse's horizontal radius
radiusy ellipse's vertical radius.

void glcd_fillellipse(GLCDX_t x, GLCDY_t y, radiusx, GLCDY_t radiusy)

Draws an ellipse at specified center coordinates using the current fill color.

Parameters:

x ellipse's center horizontal coordinate
y ellipse's center vertical coordinate
radiusx ellipse's horizontal radius
radiusy ellipse's vertical radius.

void glcd_setfill(unsigned char *pattern, GLCDCOL_t color)

Sets an user defined 8x8 pixel fill pattern from RAM, used by the **glcd_bar** and **glcd_barrel** functions, and the fill color.

Parameters:

pattern points to an 8 byte array that holds the fill pattern
color specifies the current color used by the filling functions.

void glcd_setfillf(flash unsigned char *pattern, GLCDCOL_t color)

Sets an user defined 8x8 pixel fill pattern from FLASH, used by the **glcd_bar** and **glcd_barrel** functions, and the fill color.

Parameters:

pattern points to an 8 byte array that holds the fill pattern
color specifies the current color used by the filling functions.

void glcd_setfille(eeprom unsigned char *pattern, GLCDCOL_t color)

Sets an user defined 8x8 pixel fill pattern from EEPROM, used by the **glcd_bar** and **glcd_barrel** functions, and the fill color.

Parameters:

pattern points to an 8 byte array that holds the fill pattern
color specifies the current color used by the filling functions.

void glcd_setfillcolor(GLCDCOL_t color)

Sets the fill color.

Parameters:

color specifies the current color used by the filling functions.

GLCDCOL_t glcd_getfillcolor(void)

Returns the current fill color used by the filling functions.

void glcd_bar(GLCDX_t left, GLCDY_t top, GLCDX_t right, GLCDY_t bottom)

Draws a filled-in rectangular bar, using absolute coordinates, without drawing an outline.
The bar is filled using the current fill pattern and fill color.

Parameters:

left specifies the horizontal coordinate of the left top corner of the bar

top specifies the vertical coordinate of the left top corner of the bar

right specifies the horizontal coordinate of the right bottom corner of the bar

bottom specifies the vertical coordinate of the right bottom corner of the bar.

void glcd_barrel(GLCDX_t left, GLCDY_t top, GLCDDX_t width, GLCDDY_t height)

Draws a filled-in rectangular bar, using relative coordinates, without drawing an outline.
The bar is filled using the current fill pattern and fill color.

Parameters:

left specifies the horizontal coordinate of the left top corner of the bar

top specifies the vertical coordinate of the left top corner of the bar

width specifies the horizontal size of the bar

height specifies the vertical size of the bar.

void glcd_floodfill(GLCDX_t x, GLCDY_t y, GLCDCOL_t border)

Fills a closed polygon or area with the current fill color.

Parameters:

x specifies the horizontal coordinate of a point inside the area to be filled

y specifies the vertical coordinate of a point inside the area to be filled

border specifies the color of the border of the area to be filled, where the fill process must stop.

void glcd_fillcircle(GLCDX_t x, GLCDY_t y, GLCDRAD_t radius)

Draws and fills a circle at specified center coordinates using the current fill color.

Parameters:

x specifies the horizontal coordinate of the circle's center
y specifies the vertical coordinate of the circle's center
radius specifies the circle's radius.

**void glcd_pieslice(GLCDX_t x, GLCDY_t y, unsigned short start_angle,
 unsigned short end_angle, GLCDRAD_t radius)**

Draws a pie slice at specified center coordinates using the current foreground color and line thickness. After that the pie slice is filled with the current fill color.
The angles are measured starting from from 3 o'clock counter-clockwise.

Parameters:

x specifies the horizontal coordinate of the circle's center
y specifies the vertical coordinate of the circle's center
start_angle specifies the arc's starting angle
end_angle specifies the arc's ending angle
radius specifies the circle's radius.

5.12.1 Graphic LCD Functions Specific to the ILI9225 Controller

The ILI9225 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit parallel interface mode with 256 or 64k colors.

Both 176x220 (portrait) and 220x176 (landscape) display modes are supported.

In order to take full advantage of the ILI9225 controller's features, the following specific functions, declared in the **glcd_ili9225.h** header file, were implemented:

void ili9225_wrcmd(unsigned char cmd)

Writes a command to the ILI9225 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_ili9225.h** header file:

```
/* ILI9225 command register definitions */
#define ILI9225_CMD_RD_DRIVER_CODE 0x00 /* Read driver code */
#define ILI9225_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define ILI9225_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform control */
/*
#define ILI9225_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define ILI9225_CMD_DISPLAY_CONTROL 0x07 /* Display control register */
#define ILI9225_CMD_BLANK_PERIOD_CONTROL1 0x08 /* Blank period control register 1 */
#define ILI9225_CMD_FRAME_CYCLE_CONTROL 0x0b /* Frame cycle control register */
#define ILI9225_CMD_EXT_IF_CONTROL 0x0c /* External display interface control register */
#define ILI9225_CMD_START_OSC 0x0f /* Start oscillator register */
#define ILI9225_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define ILI9225_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define ILI9225_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define ILI9225_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define ILI9225_CMD_POWER_CONTROL5 0x14 /* Power control 5 register */
#define ILI9225_CMD_VCI_RECYCLING 0x15 /* VCI recycling period setting register */
#define ILI9225_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define ILI9225_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define ILI9225_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define ILI9225_CMD_SOFTWARE_RESET 0x28 /* Software reset register */
#define ILI9225_CMD_GATE_SCAN 0x30 /* Gate scan position register */
#define ILI9225_CMD_VERT_SCROLL_CONTROL1_END 0x31 /* Vertical scroll control 1 end addr. */
#define ILI9225_CMD_VERT_SCROLL_CONTROL1_START 0x32 /* Vertical scroll control 1 start addr. */
#define ILI9225_CMD_VERT_SCROLL_CONTROL2 0x33 /* Vertical scroll control 2 */
#define ILI9225_CMD_SCREEN_DRIVING_POS_END 0x34 /* Partial Screen end driving position */
#define ILI9225_CMD_SCREEN_DRIVING_POS_START 0x35 /* Partial Screen start driving position */
```

```
#define ILI9225_CMD_HORIZ_RAM_ADDR_END 0x36 /* Address of horizontal end  
window position */  
#define ILI9225_CMD_HORIZ_RAM_ADDR_START 0x37 /* Address of horizontal  
start window position */  
#define ILI9225_CMD_VERT_RAM_ADDR_END 0x38 /* Address of vertical end  
window position */  
#define ILI9225_CMD_VERT_RAM_ADDR_START 0x39 /* Address of vertical start  
window position */  
  
#define ILI9225_CMD_GAMMA_CONTROL1 0x50 /* Gamma control 1 */  
#define ILI9225_CMD_GAMMA_CONTROL2 0x51 /* Gamma control 2 */  
#define ILI9225_CMD_GAMMA_CONTROL3 0x52 /* Gamma control 3 */  
#define ILI9225_CMD_GAMMA_CONTROL4 0x53 /* Gamma control 4 */  
#define ILI9225_CMD_GAMMA_CONTROL5 0x54 /* Gamma control 5 */  
#define ILI9225_CMD_GAMMA_CONTROL6 0x55 /* Gamma control 6 */  
#define ILI9225_CMD_GAMMA_CONTROL7 0x56 /* Gamma control 7 */  
#define ILI9225_CMD_GAMMA_CONTROL8 0x57 /* Gamma control 8 */  
#define ILI9225_CMD_GAMMA_CONTROL9 0x58 /* Gamma control 9 */  
#define ILI9225_CMD_GAMMA_CONTROL10 0x59 /* Gamma control 10 */  
#define ILI9225_CMD_NVM_PROG 0x60 /* NV Memory data programming */  
#define ILI9225_CMD_NVM_CTRL 0x61 /* NV Memory control */  
#define ILI9225_CMD_NVM_STATUS 0x62 /* NV Memory status */  
#define ILI9225_CMD_NVM_PROT_KEY 0x63 /* NV Memory protection key */  
#define ILI9225_CMD_ID_CODE 0x65 /* ID code */  
#define ILI9225_CMD_SPI_RW_CTRL 0x66 /* SPI read/write control */
```

A detailed description of the above mentioned command registers can be found in the ILI9225 datasheet.

void ili9225_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the ILI9225 controller.

Parameters:

index command register index
data to be written.

unsigned short ili9225_rdreg(unsigned char index)

Reads the contents of a command register of the ILI9225 controller.

Parameters:

index command register index.

void ili9225_wrdata(unsigned short data)

Writes data to the ILI9225 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short ili9225_rddata(void)

Reads data from the ILI9225 controller's Graphic Display RAM.

The **glcd_ili9225.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ILI9225 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
order to the display RAM */
                                /* =0 -> RGB, =1 ->BGR */
    unsigned char lcd_type:1; /* LCD type =0 normally black, =1
normally white */
    unsigned char vcil:4; /* VCI1 voltage */
    unsigned char vcoml:7; /* VCOML=GVDD*(0.534+0.006*(vcoml-15)) [V]
*/
    unsigned char vcomh:7; /* VCOMH=GVDD*(0.4015+0.0055*vcomh) [V] */
    unsigned char gamma_voltage:7; /* GVDD=2.50+gamma_voltage*0.02 [V]
*/

    /* pointer to an array located in FLASH memory
    which contains gamma control adjustment
    values for registers 1..10 */
    flash unsigned short *gamma_control;
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ILI9225_REVX_NORM 0 /* No horizontal reverse */
#define ILI9225_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ILI9225_REVY_NORM 0 /* No vertical reverse */
#define ILI9225_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ILI9225_CL_BITS_RGB 0 /* Write color bits to display RAM in RGB
order */
#define ILI9225_CL_BITS_BGR 1 /* Write color bits to display RAM in BGR
order */

/* Initialization values for lcd_type */
#define ILI9225_LCD_TYPE_BLACK 0
#define ILI9225_LCD_TYPE_WHITE 1
```

```
/* Initialization values for vci1 */
#define ILI9225_VCI1_1_35V 0 /* VCI1=1.35V */
#define ILI9225_VCI1_1_75V 1 /* VCI1=1.75V */
#define ILI9225_VCI1_2_07V 2 /* VCI1=2.07V */
#define ILI9225_VCI1_2_16V 3 /* VCI1=2.16V */
#define ILI9225_VCI1_2_25V 4 /* VCI1=2.25V */
#define ILI9225_VCI1_2_34V 5 /* VCI1=2.34V */
#define ILI9225_VCI1_2_43V 6 /* VCI1=2.43V */
#define ILI9225_VCI1_2_52V 7 /* VCI1=2.52V */
#define ILI9225_VCI1_2_58V 8 /* VCI1=2.58V */
#define ILI9225_VCI1_2_64V 9 /* VCI1=2.64V */
#define ILI9225_VCI1_2_70V 10 /* VCI1=2.70V */
#define ILI9225_VCI1_2_76V 11 /* VCI1=2.76V */
#define ILI9225_VCI1_2_82V 12 /* VCI1=2.82V */
#define ILI9225_VCI1_2_88V 13 /* VCI1=2.88V */
#define ILI9225_VCI1_2_94V 14 /* VCI1=2.94V */
#define ILI9225_VCI1_3_00V 15 /* VCI1=3.00V */

/* Default value for reverse_x */
#define ILI9225_DEFAULT_REVX ILI9225_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ILI9225_DEFAULT_REVY ILI9225_REVY_NORM /* No vertical reverse */
/* Default value for cl_bits_order
   (color bits writing order to display RAM) */
#define ILI9225_DEFAULT_CL_BITS ILI9225_CL_BITS_RGB /* write in RGB
                                                    order */

/* Default value for lcd_type */
#define ILI9225_DEFAULT_LCD_TYPE ILI9225_LCD_TYPE_WHITE
/* Default value for vci1 */
#define ILI9225_DEFAULT_VCI1 ILI9225_VCI1_2_58V
/* Default value for vcoml */
#define ILI9225_DEFAULT_VCOML 0x58
/* Default value for vcomh */
#define ILI9225_DEFAULT_VCOMH 0x50
/* Default value for gamma_voltage */
#define ILI9225_DEFAULT_GAMMA_VOLTAGE 0x65
/* Use the default initialization values, stored in the library,
   for the gamma control registers */
#define ILI9225_DEFAULT_GAMMA 0
```

The following colors are redefined in the **glcd_ili9225.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
```

GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE

The ILI9225 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ili9225.h** header file is automatically #included when the main **glcd.h** header file is #included. Therefore there is no need to explicitly #include **glcd_ili9225.h**.
- The **..\EXAMPLES\Graphic Displays\ILI9225** directory contains fully functional code samples that may be used as references for ILI9225 initialization and usage.

5.12.2 Graphic LCD Functions Specific to the ILI9325 and RM68090 Controllers

The ILI9325 (equivalent Raydium RM68090) library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes with 256 or 64k colors. To obtain higher display speed, the 16 bit interface mode is recommended. Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ILI9325 controller's features, the following specific functions, declared in the **glcd_ili9325.h** header file, were implemented:

void ili9325_wrcmd(unsigned char cmd)

Writes a command to the ILI9325 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_ili9325.h** header file:

```
/* ILI9325 command register definitions */
#define ILI9325_CMD_OSC 0x00 /* Oscillator register */
#define ILI9325_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define ILI9325_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform control */
/*
#define ILI9325_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define ILI9325_RESIZE_CONTROL 0x04 /* Resizing control register */
#define ILI9325_CMD_DISPLAY_CONTROL1 0x07 /* Display control register 1 */
#define ILI9325_CMD_DISPLAY_CONTROL2 0x08 /* Display control register 2 */
#define ILI9325_CMD_DISPLAY_CONTROL3 0x09 /* Display control register 3 */
#define ILI9325_CMD_DISPLAY_CONTROL4 0x0a /* Display control register 4 */
#define ILI9325_CMD_RGB_IF_CONTROL1 0x0c /* RGB display interface control */
register 1 */
#define ILI9325_FRAME_MARKER_POS 0x0d /* Frame marker position */
#define ILI9325_CMD_RGB_IF_CONTROL2 0x0f /* RGB display interface control */
register 2 */
#define ILI9325_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define ILI9325_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define ILI9325_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define ILI9325_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define ILI9325_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define ILI9325_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define ILI9325_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define ILI9325_CMD_POWER_CONTROL7 0x29 /* Power control 7 register */
#define ILI9325_CMD_FRAME_RATE 0x2b /* Frame rate frequency control */
register */

#define ILI9325_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define ILI9325_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define ILI9325_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define ILI9325_CMD_GAMMA_CONTROL4 0x35 /* Gamma control 4 */
#define ILI9325_CMD_GAMMA_CONTROL5 0x36 /* Gamma control 5 */
#define ILI9325_CMD_GAMMA_CONTROL6 0x37 /* Gamma control 6 */
#define ILI9325_CMD_GAMMA_CONTROL7 0x38 /* Gamma control 7 */
#define ILI9325_CMD_GAMMA_CONTROL8 0x39 /* Gamma control 8 */
#define ILI9325_CMD_GAMMA_CONTROL9 0x3c /* Gamma control 9 */
```



```
#define ILI9325_CMD_GAMMA_CONTROL10 0x3d /* Gamma control 10 */
#define ILI9325_CMD_HORIZ_RAM_ADDR_START 0x50 /* Address of horizontal
start window positions */
#define ILI9325_CMD_HORIZ_RAM_ADDR_END 0x51 /* Address of horizontal end
window positions */
#define ILI9325_CMD_VERT_RAM_ADDR_START 0x52 /* Address of vertical start
window positions */
#define ILI9325_CMD_VERT_RAM_ADDR_END 0x53 /* Address of vertical end
window positions */
#define ILI9325_CMD_DRIVER_OUT_CONTROL2 0x60 /* Driver output control */
#define ILI9325_CMD_BASE_IMG_DISPLAY_CONTROL 0x61 /* Base image display
control */
#define ILI9325_CMD_VERT_SCROLL_CONTROL 0x6a /* Vertical scroll control */
#define ILI9325_CMD_PARTIAL_IMG1_DISPLAY_POS 0x80 /* Partial image 1
display position */
#define ILI9325_CMD_PARTIAL_IMG1_START_LINE 0x81 /* Partial image 1 display
start line */
#define ILI9325_CMD_PARTIAL_IMG1_END_LINE 0x82 /* Partial image 1 display
end line */
#define ILI9325_CMD_PARTIAL_IMG2_DISPLAY_POS 0x83 /* Partial image 2
display position */
#define ILI9325_CMD_PARTIAL_IMG2_START_LINE 0x84 /* Partial image 2 display
start line */
#define ILI9325_CMD_PARTIAL_IMG2_END_LINE 0x85 /* Partial image 2 display
end line */
#define ILI9325_CMD_PANEL_IF_CONTROL1 0x90 /* Panel interface control 1 */
#define ILI9325_CMD_PANEL_IF_CONTROL2 0x92 /* Panel interface control 2 */
#define ILI9325_CMD_PANEL_IF_CONTROL4 0x95 /* Panel interface control 4 */
#define ILI9325_CMD_OTP_VCM_PROG_CONTROL 0xA1 /* OTP VCM programming
control */
#define ILI9325_CMD_OTP_VCM_STATUS_ENABLE 0xA2 /* OTP VCM status and enable
*/
#define ILI9325_CMD_OTP_PGM_ID_KEY 0xA5 /* OTP programming ID key */
```

A detailed description of the above mentioned command registers can be found in the ILI9325 datasheet.

void ili9325_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the ILI9325 controller.

Parameters:

index command register index
data to be written.

unsigned short ili9325_rdreg(unsigned char index)

Reads the contents of a command register of the ILI9325 controller.

Parameters:

index command register index.

void ili9325_wldata(unsigned short data)

Writes data to the ILI9325 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short ili9325_rddata(void)

Reads data from the ILI9325 controller's Graphic Display RAM.

The **glcd_ili9325.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ILI9325 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */

    /* power control registers bits */
    unsigned char stepup_factor:3; /* step-up factor of the step-up
                                     circuit, see BT0..BT2 bits in
                                     the datasheet */

    unsigned char stepup_freq1:3; /* controls the frequency for the
                                     step-up circuit 1 */
    unsigned char stepup_freq2:3; /* controls the frequency for the
                                     step-up circuit 2 */

    unsigned char crt_source:3; /* adjusts the amount of current
                                   from the constant current source
                                   in the internal op. amplifier
                                   circuit (AP0..AP2 bits) */

    unsigned char vreglout:4; /* adjusts the VREG1OUT voltage */
    unsigned char vcom:5; /* adjusts the amplitude of the Vcom
                           alternating drive voltage based on
                           VREG1OUT voltage */

    unsigned char vcomh:6; /* adjusts the amplitude of the VcomH
                           voltage based on VREG1OUT voltage
                           VcomH=VREG1OUT*(vcomh*0.005+0.685) [V] */

    unsigned char frame_freq:4; /* LCD frame frequency */
}
```

```
/* positive gamma control registers bits */
unsigned char kp00:3; /* KP00..KP02 positive gamma micro adj. */
unsigned char kp10:3; /* KP10..KP12 positive gamma micro adj. */
unsigned char kp20:3; /* KP20..KP22 positive gamma micro adj. */
unsigned char kp30:3; /* KP30..KP32 positive gamma micro adj. */
unsigned char kp40:3; /* KP40..KP42 positive gamma micro adj. */
unsigned char kp50:3; /* KP50..KP52 positive gamma micro adj. */
unsigned char rp00:3; /* RP00..RP02 positive gamma gradient
adj. */
unsigned char rp10:3; /* RP10..RP12 positive gamma gradient
adj. */
unsigned char vrp00:4; /* VRP00..VRP03 positive gamma amplification
adj. */
unsigned char vrp10:5; /* VRP10..VRP14 positive gamma amplification
adj. */

/* negative gamma control registers bits */
unsigned char kn00:3; /* KN00..KN02 negative gamma micro adj. */
unsigned char kn10:3; /* KN10..KN12 negative gamma micro adj. */
unsigned char kn20:3; /* KN20..KN22 positive gamma micro adj. */
unsigned char kn30:3; /* KN30..KN32 positive gamma micro adj. */
unsigned char kn40:3; /* KN40..KN42 negative gamma micro adj. */
unsigned char kn50:3; /* KN50..KN52 negative gamma micro adj. */
unsigned char rn00:3; /* RN00..RN02 negative gamma gradient
adj. */
unsigned char rn10:3; /* RN10..RN12 negative gamma gradient
adj. */
unsigned char vrn00:4; /* VRN00..VRN03 negative gamma amplification
adj. */
unsigned char vrn10:5; /* VRN10..VRN14 negative gamma
amplification adj. */

} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ILI9325_REVX_NORM 0 /* No horizontal reverse */
#define ILI9325_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ILI9325_REVY_NORM 0 /* No vertical reverse */
#define ILI9325_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ILI9325_CL_BITS_RGB 0 /* Write color bits to display RAM
in RGB order */
#define ILI9325_CL_BITS_BGR 1 /* Write color bits to display RAM
in BGR order */

/* Initialization values for the VREG1OUT voltage */
#define ILI9325_VREG1OUT_4V000 8 /* 4.000 V */
#define ILI9325_VREG1OUT_4V125 9 /* 4.125 V */
#define ILI9325_VREG1OUT_4V250 10 /* 4.250 V */
#define ILI9325_VREG1OUT_4V375 11 /* 4.375 V */
#define ILI9325_VREG1OUT_4V500 12 /* 4.500 V */
#define ILI9325_VREG1OUT_4V625 13 /* 4.625 V */
#define ILI9325_VREG1OUT_4V750 14 /* 4.750 V */
#define ILI9325_VREG1OUT_4V875 15 /* 4.875 V */
#define ILI9325_VREG1OUT_5V000 1 /* 5.000 V */
#define ILI9325_VREG1OUT_5V125 2 /* 5.125 V */
```

```
#define ILI9325_VREG1OUT_5V250 3 /* 5.250 V */
#define ILI9325_VREG1OUT_5V500 4 /* 5.500 V */
#define ILI9325_VREG1OUT_5V750 5 /* 5.750 V */
#define ILI9325_VREG1OUT_6V000 6 /* 6.000 V */

/* Initialization values for the Vcom voltage */
#define ILI9325_VCOM_0_70 0 /* Vcom=VREG1OUT*0.70 */
#define ILI9325_VCOM_0_72 1 /* Vcom=VREG1OUT*0.72 */
#define ILI9325_VCOM_0_74 2 /* Vcom=VREG1OUT*0.74 */
#define ILI9325_VCOM_0_76 3 /* Vcom=VREG1OUT*0.76 */
#define ILI9325_VCOM_0_78 4 /* Vcom=VREG1OUT*0.78 */
#define ILI9325_VCOM_0_80 5 /* Vcom=VREG1OUT*0.80 */
#define ILI9325_VCOM_0_82 6 /* Vcom=VREG1OUT*0.82 */
#define ILI9325_VCOM_0_84 7 /* Vcom=VREG1OUT*0.84 */
#define ILI9325_VCOM_0_86 8 /* Vcom=VREG1OUT*0.86 */
#define ILI9325_VCOM_0_88 9 /* Vcom=VREG1OUT*0.88 */
#define ILI9325_VCOM_0_90 10 /* Vcom=VREG1OUT*0.90 */
#define ILI9325_VCOM_0_92 11 /* Vcom=VREG1OUT*0.92 */
#define ILI9325_VCOM_0_94 12 /* Vcom=VREG1OUT*0.94 */
#define ILI9325_VCOM_0_96 13 /* Vcom=VREG1OUT*0.96 */
#define ILI9325_VCOM_0_98 14 /* Vcom=VREG1OUT*0.98 */
#define ILI9325_VCOM_1_00 15 /* Vcom=VREG1OUT*1.00 */
#define ILI9325_VCOM_1_02 0x14 /* Vcom=VREG1OUT*1.02 */
#define ILI9325_VCOM_1_04 0x15 /* Vcom=VREG1OUT*1.04 */
#define ILI9325_VCOM_1_06 0x16 /* Vcom=VREG1OUT*1.06 */
#define ILI9325_VCOM_1_08 0x17 /* Vcom=VREG1OUT*1.08 */
#define ILI9325_VCOM_1_10 0x18 /* Vcom=VREG1OUT*1.10 */
#define ILI9325_VCOM_1_12 0x19 /* Vcom=VREG1OUT*1.12 */
#define ILI9325_VCOM_1_14 0x1A /* Vcom=VREG1OUT*1.14 */
#define ILI9325_VCOM_1_16 0x1B /* Vcom=VREG1OUT*1.16 */
#define ILI9325_VCOM_1_18 0x1C /* Vcom=VREG1OUT*1.18 */
#define ILI9325_VCOM_1_20 0x1D /* Vcom=VREG1OUT*1.20 */
#define ILI9325_VCOM_1_22 0x1E /* Vcom=VREG1OUT*1.22 */
#define ILI9325_VCOM_1_24 0x1F /* Vcom=VREG1OUT*1.24 */

/* Initialization value for VcomH
   VcomH=VREG1OUT*(VREG1OUT_MULT1000/1000)
   VREG1OUT_MULT1000=685..1000 */
#define ILI9325_VCOMH(VREG1OUT_MULT1000) ((VREG1OUT_MULT1000-685)/5)

/* Initialization values for stepup_freq1 */
#define ILI9325_STEPUP1_FOSC 0 /* FDCDC1=Fosc */
#define ILI9325_STEPUP1_FOSC2 1 /* FDCDC1=Fosc/2 */
#define ILI9325_STEPUP1_FOSC4 2 /* FDCDC1=Fosc/4 */
#define ILI9325_STEPUP1_FOSC8 3 /* FDCDC1=Fosc/8 */
#define ILI9325_STEPUP1_FOSC16 4 /* FDCDC1=Fosc/16 */
#define ILI9325_STEPUP1_FOSC32 5 /* FDCDC1=Fosc/32 */
#define ILI9325_STEPUP1_FOSC64 6 /* FDCDC1=Fosc/64 */
#define ILI9325_STEPUP1_HALT 7 /* Halt step-up circuit 1 */

/* Initialization values for stepup_freq2 */
#define ILI9325_STEPUP2_FOSC4 0 /* FDCDC2=Fosc/4 */
#define ILI9325_STEPUP2_FOSC8 1 /* FDCDC2=Fosc/8 */
#define ILI9325_STEPUP2_FOSC16 2 /* FDCDC2=Fosc/16 */
#define ILI9325_STEPUP2_FOSC32 3 /* FDCDC2=Fosc/32 */
#define ILI9325_STEPUP2_FOSC64 4 /* FDCDC2=Fosc/64 */
#define ILI9325_STEPUP2_FOSC128 5 /* FDCDC2=Fosc/128 */
#define ILI9325_STEPUP2_FOSC256 6 /* FDCDC2=Fosc/256 */
#define ILI9325_STEPUP2_HALT 7 /* Halt step-up circuit 2 */
```

```
/* Initialization values for frame_freq */
#define ILI9325_FRAME40 0 /* 40Hz */
#define ILI9325_FRAME43 1 /* 43Hz */
#define ILI9325_FRAME45 2 /* 45Hz */
#define ILI9325_FRAME48 3 /* 48Hz */
#define ILI9325_FRAME51 4 /* 51Hz */
#define ILI9325_FRAME55 5 /* 55Hz */
#define ILI9325_FRAME59 6 /* 59Hz */
#define ILI9325_FRAME64 7 /* 64Hz */
#define ILI9325_FRAME70 8 /* 70Hz */
#define ILI9325_FRAME77 9 /* 77Hz */
#define ILI9325_FRAME85 10 /* 85Hz */
#define ILI9325_FRAME96 11 /* 96Hz */
#define ILI9325_FRAME110 12 /* 110Hz */
#define ILI9325_FRAME128 13 /* 128Hz */

/* Default value for reverse_x */
#define ILI9325_DEFAULT_REVX ILI9325_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ILI9325_DEFAULT_REVY ILI9325_REVY_NORM /* No vertical reverse */

/* Default value for cl_bits_order
   (color bits writing order to display RAM),
   write in RGB order */
#define ILI9325_DEFAULT_CL_BITS ILI9325_CL_BITS_RGB

/* Power control 1 BT0..BT2 step-up factor of the step-up circuit
   DDVDH=Vci1*2, VCL=-Vci1, VGH=Vci1*6, VGL=-Vci1*3 */
#define ILI9325_DEFAULT_STEPUP_FACTOR 2
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the
   internal op. amplifier circuit */
#define ILI9325_DEFAULT_CRT_SOURCE 2
/* Power control 2 DC00..DC02 step-up circuit 1 frequency */
#define ILI9325_DEFAULT_STEPUP1_FREQ ILI9325_STEPUP1_FOSC4
/* Power control 2 DC10..DC12 step-up circuit 2 frequency */
#define ILI9325_DEFAULT_STEPUP2_FREQ ILI9325_STEPUP2_FOSC128
/* Default value for VREG1OUT voltage */
#define ILI9325_DEFAULT_VREG1OUT ILI9325_VREG1OUT_4V000
/* Default value for Vcom alternating drive voltage */
#define ILI9325_DEFAULT_VCOM ILI9325_VCOM_0_94
/* Default value for VcomH voltage
   VcomH=VREG1OUT*0.835 */
#define ILI9325_DEFAULT_VCOMH ILI9325_VCOMH(835)
/* Default value for LCD frame frequency */
#define ILI9325_DEFAULT_FRAME_FREQ ILI9325_FRAME96

/* Default initialization values for the gamma control register bits */
/* KP00..KP02 positive gamma micro adj. */
#define ILI9325_DEFAULT_KP00 7
/* KP10..KP12 positive gamma micro adj. */
#define ILI9325_DEFAULT_KP10 7
/* KP20..KP22 positive gamma micro adj. */
#define ILI9325_DEFAULT_KP20 4
/* KP30..KP32 positive gamma micro adj. */
#define ILI9325_DEFAULT_KP30 2
/* KP40..KP42 positive gamma micro adj. */
#define ILI9325_DEFAULT_KP40 4
```

```
/* KP50..KP52 positive gamma micro adj. */
#define ILI9325_DEFAULT_KP50 2
/* RP00..RP02 positive gamma gradient adj. */
#define ILI9325_DEFAULT_RP00 2
/* RP10..RP12 positive gamma gradient adj. */
#define ILI9325_DEFAULT_RP10 5
/* VRP00..VRP03 positive gamma amplification adj. */
#define ILI9325_DEFAULT_VRP00 2
/* VRP10..VRP14 positive gamma amplification adj. */
#define ILI9325_DEFAULT_VRP10 3
/* KN00..KN02 negative gamma micro adj. */
#define ILI9325_DEFAULT_KN00 7
/* KN10..KN12 negative gamma micro adj. */
#define ILI9325_DEFAULT_KN10 5
/* KN20..KN22 positive gamma micro adj. */
#define ILI9325_DEFAULT_KN20 4
/* KN30..KN32 positive gamma micro adj. */
#define ILI9325_DEFAULT_KN30 2
/* KN40..KN42 negative gamma micro adj. */
#define ILI9325_DEFAULT_KN40 4
/* KN50..KN52 negative gamma micro adj. */
#define ILI9325_DEFAULT_KN50 2
/* RN00..RN02 negative gamma gradient adj. */
#define ILI9325_DEFAULT_RN00 2
/* RN10..RN12 negative gamma gradient adj. */
#define ILI9325_DEFAULT_RN10 5
/* VRN00..VRN03 negative gamma amplification adj. */
#define ILI9325_DEFAULT_VRN00 2
/* VRN10..VRN14 negative gamma amplification adj. */
#define ILI9325_DEFAULT_VRN10 3
```

The following colors are redefined in the **glcd_ili9325.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ILI9325 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ili9325.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ili9325.h**.
- The **..\EXAMPLES\Graphic Displays\ILI9325** directory contains fully functional code samples that may be used as references for ILI9325 initialization and usage.

5.12.3 Graphic LCD Functions Specific to the ILI9328 Controller

The ILI9328 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ILI9328 controller's features, the following specific functions, declared in the **glcd_ili9328.h** header file, were implemented:

void ili9328_wrcmd(unsigned char cmd)

Writes a command to the ILI9328 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_ili9328.h** header file:

```
/* ILI9328 command register definitions */
#define ILI9328_CMD_OSC 0x00 /* Oscillator register */
#define ILI9328_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define ILI9328_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform control */
#define ILI9328_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define ILI9328_RESIZE_CONTROL 0x04 /* Resizing control register */
#define ILI9328_CMD_DISPLAY_CONTROL1 0x07 /* Display control register 1 */
#define ILI9328_CMD_DISPLAY_CONTROL2 0x08 /* Display control register 2 */
#define ILI9328_CMD_DISPLAY_CONTROL3 0x09 /* Display control register 3 */
#define ILI9328_CMD_DISPLAY_CONTROL4 0x0a /* Display control register 4 */
#define ILI9328_CMD_RGB_IF_CONTROL1 0x0c /* RGB display interface control register 1 */
#define ILI9328_FRAME_MARKER_POS 0x0d /* Frame marker position */
#define ILI9328_CMD_RGB_IF_CONTROL2 0x0f /* RGB display interface control register 2 */
#define ILI9328_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define ILI9328_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define ILI9328_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define ILI9328_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define ILI9328_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define ILI9328_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define ILI9328_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define ILI9328_CMD_POWER_CONTROL7 0x29 /* Power control 7 register */
#define ILI9328_CMD_FRAME_RATE 0x2b /* Frame rate frequency control register */
#define ILI9328_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define ILI9328_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define ILI9328_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define ILI9328_CMD_GAMMA_CONTROL4 0x35 /* Gamma control 4 */
#define ILI9328_CMD_GAMMA_CONTROL5 0x36 /* Gamma control 5 */
#define ILI9328_CMD_GAMMA_CONTROL6 0x37 /* Gamma control 6 */
#define ILI9328_CMD_GAMMA_CONTROL7 0x38 /* Gamma control 7 */
#define ILI9328_CMD_GAMMA_CONTROL8 0x39 /* Gamma control 8 */
#define ILI9328_CMD_GAMMA_CONTROL9 0x3c /* Gamma control 9 */
#define ILI9328_CMD_GAMMA_CONTROL10 0x3d /* Gamma control 10 */
```



```
#define ILI9328_CMD_HORIZ_RAM_ADDR_START 0x50 /* Address of horizontal
start window positions */
#define ILI9328_CMD_HORIZ_RAM_ADDR_END 0x51 /* Address of horizontal end
window positions */
#define ILI9328_CMD_VERT_RAM_ADDR_START 0x52 /* Address of vertical start
window positions */
#define ILI9328_CMD_VERT_RAM_ADDR_END 0x53 /* Address of vertical end
window positions */
#define ILI9328_CMD_DRIVER_OUT_CONTROL2 0x60 /* Driver output control */
#define ILI9328_CMD_BASE_IMG_DISPLAY_CONTROL 0x61 /* Base image display
control */
#define ILI9328_CMD_VERT_SCROLL_CONTROL 0x6a /* Vertical scroll control */
#define ILI9328_CMD_PARTIAL_IMG1_DISPLAY_POS 0x80 /* Partial image 1
display position */
#define ILI9328_CMD_PARTIAL_IMG1_START_LINE 0x81 /* Partial image 1 display
start line */
#define ILI9328_CMD_PARTIAL_IMG1_END_LINE 0x82 /* Partial image 1 display
end line */
#define ILI9328_CMD_PARTIAL_IMG2_DISPLAY_POS 0x83 /* Partial image 2
display position */
#define ILI9328_CMD_PARTIAL_IMG2_START_LINE 0x84 /* Partial image 2 display
start line */
#define ILI9328_CMD_PARTIAL_IMG2_END_LINE 0x85 /* Partial image 2 display
end line */
#define ILI9328_CMD_PANEL_IF_CONTROL1 0x90 /* Panel interface control 1 */
#define ILI9328_CMD_PANEL_IF_CONTROL2 0x92 /* Panel interface control 2 */
#define ILI9328_CMD_PANEL_IF_CONTROL4 0x95 /* Panel interface control 4 */
#define ILI9328_CMD_OTP_VCM_PROG_CONTROL 0xA1 /* OTP VCM programming
control */
#define ILI9328_CMD_OTP_VCM_STATUS_ENABLE 0xA2 /* OTP VCM status and enable
*/
#define ILI9328_CMD_OTP_PGM_ID_KEY 0xA5 /* OTP programming ID key */
```

A detailed description of the above mentioned command registers can be found in the ILI9328 datasheet.

void ili9328_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the ILI9328 controller.

Parameters:

index command register index
data to be written.

unsigned short ili9328_rdreg(unsigned char index)

Reads the contents of a command register of the ILI9328 controller.

Parameters:

index command register index.

void ili9328_wrddata(unsigned short data)

Writes data to the ILI9328 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short ili9328_rddata(void)

Reads data from the ILI9328 controller's Graphic Display RAM.

The **glcd_ili9328.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ILI9328 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */

    /* power control registers bits */
    unsigned char stepup_factor:3; /* step-up factor of the step-up
                                     circuit, see BT0..BT2 bits in
                                     the datasheet */

    unsigned char stepup_freq1:3; /* controls the frequency for the
                                     step-up circuit 1 */
    unsigned char stepup_freq2:3; /* controls the frequency for the
                                     step-up circuit 2 */

    unsigned char crt_source:3; /* adjusts the amount of current
                                   from the constant current source
                                   in the internal op. amplifier
                                   circuit (AP0..AP2 bits) */

    unsigned char vreg1out:4; /* adjusts the VREG1OUT voltage */
    unsigned char vcom:5; /* adjusts the amplitude of the Vcom
                            alternating drive voltage based on
                            VREG1OUT voltage */

    unsigned char vcomh:6; /* adjusts the amplitude of the VcomH
                             voltage based on VREG1OUT voltage
                             VcomH=VREG1OUT*(vcomh*0.005+0.685) [V] */

    unsigned char frame_freq:4; /* LCD frame frequency */
}
```

```
/* positive gamma control registers bits */
unsigned char kp00:3; /* KP00..KP02 positive gamma micro adj. */
unsigned char kp10:3; /* KP10..KP12 positive gamma micro adj. */
unsigned char kp20:3; /* KP20..KP22 positive gamma micro adj. */
unsigned char kp30:3; /* KP30..KP32 positive gamma micro adj. */
unsigned char kp40:3; /* KP40..KP42 positive gamma micro adj. */
unsigned char kp50:3; /* KP50..KP52 positive gamma micro adj. */
unsigned char rp00:3; /* RP00..RP02 positive gamma gradient
adj. */
unsigned char rp10:3; /* RP10..RP12 positive gamma gradient
adj. */
unsigned char vrp00:4; /* VRP00..VRP03 positive gamma amplification
adj. */
unsigned char vrp10:5; /* VRP10..VRP14 positive gamma amplification
adj. */

/* negative gamma control registers bits */
unsigned char kn00:3; /* KN00..KN02 negative gamma micro adj. */
unsigned char kn10:3; /* KN10..KN12 negative gamma micro adj. */
unsigned char kn20:3; /* KN20..KN22 positive gamma micro adj. */
unsigned char kn30:3; /* KN30..KN32 positive gamma micro adj. */
unsigned char kn40:3; /* KN40..KN42 negative gamma micro adj. */
unsigned char kn50:3; /* KN50..KN52 negative gamma micro adj. */
unsigned char rn00:3; /* RN00..RN02 negative gamma gradient
adj. */
unsigned char rn10:3; /* RN10..RN12 negative gamma gradient
adj. */
unsigned char vrn00:4; /* VRN00..VRN03 negative gamma amplification
adj. */
unsigned char vrn10:5; /* VRN10..VRN14 negative gamma
amplification adj. */

} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ILI9328_REVX_NORM 0 /* No horizontal reverse */
#define ILI9328_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ILI9328_REVY_NORM 0 /* No vertical reverse */
#define ILI9328_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ILI9328_CL_BITS_RGB 0 /* Write color bits to display RAM
in RGB order */
#define ILI9328_CL_BITS_BGR 1 /* Write color bits to display RAM
in BGR order */

/* Initialization values for the VREG1OUT voltage */
#define ILI9328_VREG1OUT_4V000 8 /* 4.000 V */
#define ILI9328_VREG1OUT_4V125 9 /* 4.125 V */
#define ILI9328_VREG1OUT_4V250 10 /* 4.250 V */
#define ILI9328_VREG1OUT_4V375 11 /* 4.375 V */
#define ILI9328_VREG1OUT_4V500 12 /* 4.500 V */
#define ILI9328_VREG1OUT_4V625 13 /* 4.625 V */
#define ILI9328_VREG1OUT_4V750 14 /* 4.750 V */
#define ILI9328_VREG1OUT_4V875 15 /* 4.875 V */
#define ILI9328_VREG1OUT_5V000 1 /* 5.000 V */
#define ILI9328_VREG1OUT_5V125 2 /* 5.125 V */
```

```
#define ILI9328_VREG1OUT_5V250 3 /* 5.250 V */
#define ILI9328_VREG1OUT_5V500 4 /* 5.500 V */
#define ILI9328_VREG1OUT_5V750 5 /* 5.750 V */
#define ILI9328_VREG1OUT_6V000 6 /* 6.000 V */

/* Initialization values for the Vcom voltage */
#define ILI9328_VCOM_0_70 0 /* Vcom=VREG1OUT*0.70 */
#define ILI9328_VCOM_0_72 1 /* Vcom=VREG1OUT*0.72 */
#define ILI9328_VCOM_0_74 2 /* Vcom=VREG1OUT*0.74 */
#define ILI9328_VCOM_0_76 3 /* Vcom=VREG1OUT*0.76 */
#define ILI9328_VCOM_0_78 4 /* Vcom=VREG1OUT*0.78 */
#define ILI9328_VCOM_0_80 5 /* Vcom=VREG1OUT*0.80 */
#define ILI9328_VCOM_0_82 6 /* Vcom=VREG1OUT*0.82 */
#define ILI9328_VCOM_0_84 7 /* Vcom=VREG1OUT*0.84 */
#define ILI9328_VCOM_0_86 8 /* Vcom=VREG1OUT*0.86 */
#define ILI9328_VCOM_0_88 9 /* Vcom=VREG1OUT*0.88 */
#define ILI9328_VCOM_0_90 10 /* Vcom=VREG1OUT*0.90 */
#define ILI9328_VCOM_0_92 11 /* Vcom=VREG1OUT*0.92 */
#define ILI9328_VCOM_0_94 12 /* Vcom=VREG1OUT*0.94 */
#define ILI9328_VCOM_0_96 13 /* Vcom=VREG1OUT*0.96 */
#define ILI9328_VCOM_0_98 14 /* Vcom=VREG1OUT*0.98 */
#define ILI9328_VCOM_1_00 15 /* Vcom=VREG1OUT*1.00 */
#define ILI9328_VCOM_1_02 0x14 /* Vcom=VREG1OUT*1.02 */
#define ILI9328_VCOM_1_04 0x15 /* Vcom=VREG1OUT*1.04 */
#define ILI9328_VCOM_1_06 0x16 /* Vcom=VREG1OUT*1.06 */
#define ILI9328_VCOM_1_08 0x17 /* Vcom=VREG1OUT*1.08 */
#define ILI9328_VCOM_1_10 0x18 /* Vcom=VREG1OUT*1.10 */
#define ILI9328_VCOM_1_12 0x19 /* Vcom=VREG1OUT*1.12 */
#define ILI9328_VCOM_1_14 0x1A /* Vcom=VREG1OUT*1.14 */
#define ILI9328_VCOM_1_16 0x1B /* Vcom=VREG1OUT*1.16 */
#define ILI9328_VCOM_1_18 0x1C /* Vcom=VREG1OUT*1.18 */
#define ILI9328_VCOM_1_20 0x1D /* Vcom=VREG1OUT*1.20 */
#define ILI9328_VCOM_1_22 0x1E /* Vcom=VREG1OUT*1.22 */
#define ILI9328_VCOM_1_24 0x1F /* Vcom=VREG1OUT*1.24 */

/* Initialization value for VcomH
   VcomH=VREG1OUT*(VREG1OUT_MULT1000/1000)
   VREG1OUT_MULT1000=685..1000 */
#define ILI9328_VCOMH(VREG1OUT_MULT1000) ((VREG1OUT_MULT1000-685)/5)

/* Initialization values for stepup_freq1 */
#define ILI9328_STEPUP1_FOSC 0 /* FDCDC1=Fosc */
#define ILI9328_STEPUP1_FOSC2 1 /* FDCDC1=Fosc/2 */
#define ILI9328_STEPUP1_FOSC4 2 /* FDCDC1=Fosc/4 */
#define ILI9328_STEPUP1_FOSC8 3 /* FDCDC1=Fosc/8 */
#define ILI9328_STEPUP1_FOSC16 4 /* FDCDC1=Fosc/16 */
#define ILI9328_STEPUP1_FOSC32 5 /* FDCDC1=Fosc/32 */
#define ILI9328_STEPUP1_FOSC64 6 /* FDCDC1=Fosc/64 */
#define ILI9328_STEPUP1_HALT 7 /* Halt step-up circuit 1 */

/* Initialization values for stepup_freq2 */
#define ILI9328_STEPUP2_FOSC4 0 /* FDCDC2=Fosc/4 */
#define ILI9328_STEPUP2_FOSC8 1 /* FDCDC2=Fosc/8 */
#define ILI9328_STEPUP2_FOSC16 2 /* FDCDC2=Fosc/16 */
#define ILI9328_STEPUP2_FOSC32 3 /* FDCDC2=Fosc/32 */
#define ILI9328_STEPUP2_FOSC64 4 /* FDCDC2=Fosc/64 */
#define ILI9328_STEPUP2_FOSC128 5 /* FDCDC2=Fosc/128 */
#define ILI9328_STEPUP2_FOSC256 6 /* FDCDC2=Fosc/256 */
#define ILI9328_STEPUP2_HALT 7 /* Halt step-up circuit 2 */
```

```
/* Initialization values for frame_freq */
#define ILI9328_FRAME40 0 /* 40Hz */
#define ILI9328_FRAME43 1 /* 43Hz */
#define ILI9328_FRAME45 2 /* 45Hz */
#define ILI9328_FRAME48 3 /* 48Hz */
#define ILI9328_FRAME51 4 /* 51Hz */
#define ILI9328_FRAME55 5 /* 55Hz */
#define ILI9328_FRAME59 6 /* 59Hz */
#define ILI9328_FRAME64 7 /* 64Hz */
#define ILI9328_FRAME70 8 /* 70Hz */
#define ILI9328_FRAME77 9 /* 77Hz */
#define ILI9328_FRAME85 10 /* 85Hz */
#define ILI9328_FRAME96 11 /* 96Hz */
#define ILI9328_FRAME110 12 /* 110Hz */
#define ILI9328_FRAME128 13 /* 128Hz */

/* Default value for reverse_x */
#define ILI9328_DEFAULT_REVX ILI9328_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ILI9328_DEFAULT_REVY ILI9328_REVY_NORM /* No vertical reverse */

/* Default value for cl_bits_order
   (color bits writing order to display RAM),
   write in RGB order */
#define ILI9328_DEFAULT_CL_BITS ILI9328_CL_BITS_RGB

/* Power control 1 BT0..BT2 step-up factor of the step-up circuit
   DDVDH=Vci1*2, VCL=-Vci1, VGH=Vci1*6, VGL=-Vci1*3 */
#define ILI9328_DEFAULT_STEPUP_FACTOR 2
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the
   internal op. amplifier circuit */
#define ILI9328_DEFAULT_CRT_SOURCE 2
/* Power control 2 DC00..DC02 step-up circuit 1 frequency */
#define ILI9328_DEFAULT_STEPUP1_FREQ ILI9328_STEPUP1_FOSC4
/* Power control 2 DC10..DC12 step-up circuit 2 frequency */
#define ILI9328_DEFAULT_STEPUP2_FREQ ILI9328_STEPUP2_FOSC128
/* Default value for VREG1OUT voltage */
#define ILI9328_DEFAULT_VREG1OUT ILI9328_VREG1OUT_4V000
/* Default value for Vcom alternating drive voltage */
#define ILI9328_DEFAULT_VCOM ILI9328_VCOM_0_94
/* Default value for VcomH voltage
   VcomH=VREG1OUT*0.835 */
#define ILI9328_DEFAULT_VCOMH ILI9328_VCOMH(835)
/* Default value for LCD frame frequency */
#define ILI9328_DEFAULT_FRAME_FREQ ILI9328_FRAME96

/* Default initialization values for the gamma control register bits */
/* KP00..KP02 positive gamma micro adj. */
#define ILI9328_DEFAULT_KP00 7
/* KP10..KP12 positive gamma micro adj. */
#define ILI9328_DEFAULT_KP10 7
/* KP20..KP22 positive gamma micro adj. */
#define ILI9328_DEFAULT_KP20 4
/* KP30..KP32 positive gamma micro adj. */
#define ILI9328_DEFAULT_KP30 2
/* KP40..KP42 positive gamma micro adj. */
#define ILI9328_DEFAULT_KP40 4
```

```
/* KP50..KP52 positive gamma micro adj. */
#define ILI9328_DEFAULT_KP50 2
/* RP00..RP02 positive gamma gradient adj. */
#define ILI9328_DEFAULT_RP00 2
/* RP10..RP12 positive gamma gradient adj. */
#define ILI9328_DEFAULT_RP10 5
/* VRP00..VRP03 positive gamma amplification adj. */
#define ILI9328_DEFAULT_VRP00 2
/* VRP10..VRP14 positive gamma amplification adj. */
#define ILI9328_DEFAULT_VRP10 3
/* KN00..KN02 negative gamma micro adj. */
#define ILI9328_DEFAULT_KN00 7
/* KN10..KN12 negative gamma micro adj. */
#define ILI9328_DEFAULT_KN10 5
/* KN20..KN22 positive gamma micro adj. */
#define ILI9328_DEFAULT_KN20 4
/* KN30..KN32 positive gamma micro adj. */
#define ILI9328_DEFAULT_KN30 2
/* KN40..KN42 negative gamma micro adj. */
#define ILI9328_DEFAULT_KN40 4
/* KN50..KN52 negative gamma micro adj. */
#define ILI9328_DEFAULT_KN50 2
/* RN00..RN02 negative gamma gradient adj. */
#define ILI9328_DEFAULT_RN00 2
/* RN10..RN12 negative gamma gradient adj. */
#define ILI9328_DEFAULT_RN10 5
/* VRN00..VRN03 negative gamma amplification adj. */
#define ILI9328_DEFAULT_VRN00 2
/* VRN10..VRN14 negative gamma amplification adj. */
#define ILI9328_DEFAULT_VRN10 3
```

The following colors are redefined in the **glcd_ili9328.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ILI9328 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ili9328.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ili9328.h**.
- The **..\EXAMPLES\Graphic Displays\ILI9328** directory contains fully functional code samples that may be used as references for ILI9328 initialization and usage.

5.12.4 Graphic LCD Functions Specific to the ILI9331 Controller

The ILI9331 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ILI9331 controller's features, the following specific functions, declared in the **glcd_ili9331.h** header file, were implemented:

void ili9331_wrcmd(unsigned char cmd)

Writes a command to the ILI9331 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_ili9331.h** header file:

```
/* ILI9331 command register definitions */
#define ILI9331_CMD_OSC 0x00 /* Oscillator register */
#define ILI9331_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define ILI9331_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform control */
#define ILI9331_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define ILI9331_RESIZE_CONTROL 0x04 /* Resizing control register */
#define ILI9331_CMD_DISPLAY_CONTROL1 0x07 /* Display control register 1 */
#define ILI9331_CMD_DISPLAY_CONTROL2 0x08 /* Display control register 2 */
#define ILI9331_CMD_DISPLAY_CONTROL3 0x09 /* Display control register 3 */
#define ILI9331_CMD_DISPLAY_CONTROL4 0x0a /* Display control register 4 */
#define ILI9331_CMD_RGB_IF_CONTROL1 0x0c /* RGB display interface control register 1 */
#define ILI9331_FRAME_MARKER_POS 0x0d /* Frame marker position */
#define ILI9331_CMD_RGB_IF_CONTROL2 0x0f /* RGB display interface control register 2 */
#define ILI9331_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define ILI9331_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define ILI9331_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define ILI9331_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define ILI9331_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define ILI9331_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define ILI9331_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define ILI9331_CMD_POWER_CONTROL7 0x29 /* Power control 7 register */
#define ILI9331_CMD_FRAME_RATE 0x2b /* Frame rate frequency control register */
#define ILI9331_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define ILI9331_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define ILI9331_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define ILI9331_CMD_GAMMA_CONTROL4 0x35 /* Gamma control 4 */
#define ILI9331_CMD_GAMMA_CONTROL5 0x36 /* Gamma control 5 */
#define ILI9331_CMD_GAMMA_CONTROL6 0x37 /* Gamma control 6 */
#define ILI9331_CMD_GAMMA_CONTROL7 0x38 /* Gamma control 7 */
#define ILI9331_CMD_GAMMA_CONTROL8 0x39 /* Gamma control 8 */
#define ILI9331_CMD_GAMMA_CONTROL9 0x3c /* Gamma control 9 */
#define ILI9331_CMD_GAMMA_CONTROL10 0x3d /* Gamma control 10 */
```



```
#define ILI9331_CMD_HORIZ_RAM_ADDR_START 0x50 /* Address of horizontal
start window positions */
#define ILI9331_CMD_HORIZ_RAM_ADDR_END 0x51 /* Address of horizontal end
window positions */
#define ILI9331_CMD_VERT_RAM_ADDR_START 0x52 /* Address of vertical start
window positions */
#define ILI9331_CMD_VERT_RAM_ADDR_END 0x53 /* Address of vertical end
window positions */
#define ILI9331_CMD_DRIVER_OUT_CONTROL2 0x60 /* Driver output control */
#define ILI9331_CMD_BASE_IMG_DISPLAY_CONTROL 0x61 /* Base image display
control */
#define ILI9331_CMD_VERT_SCROLL_CONTROL 0x6a /* Vertical scroll control */
#define ILI9331_CMD_PARTIAL_IMG1_DISPLAY_POS 0x80 /* Partial image 1
display position */
#define ILI9331_CMD_PARTIAL_IMG1_START_LINE 0x81 /* Partial image 1 display
start line */
#define ILI9331_CMD_PARTIAL_IMG1_END_LINE 0x82 /* Partial image 1 display
end line */
#define ILI9331_CMD_PARTIAL_IMG2_DISPLAY_POS 0x83 /* Partial image 2
display position */
#define ILI9331_CMD_PARTIAL_IMG2_START_LINE 0x84 /* Partial image 2 display
start line */
#define ILI9331_CMD_PARTIAL_IMG2_END_LINE 0x85 /* Partial image 2 display
end line */
#define ILI9331_CMD_PANEL_IF_CONTROL1 0x90 /* Panel interface control 1 */
#define ILI9331_CMD_PANEL_IF_CONTROL2 0x92 /* Panel interface control 2 */
#define ILI9331_CMD_PANEL_IF_CONTROL4 0x95 /* Panel interface control 4 */
#define ILI9331_CMD_OTP_VCM_PROG_CONTROL 0xA1 /* OTP VCM programming
control */
#define ILI9331_CMD_OTP_VCM_STATUS_ENABLE 0xA2 /* OTP VCM status and enable
*/
#define ILI9331_CMD_OTP_PGM_ID_KEY 0xA5 /* OTP programming ID key */
#define ILI9331_CMD_WR_DISP_BRIGHTNESS 0xB1 /* Write display brightness */
#define ILI9331_CMD_RD_DISP_BRIGHTNESS 0xB2 /* Read display brightness */
#define ILI9331_CMD_WR_CTRL_DISPLAY 0xB3 /* Write CTRL display value */
#define ILI9331_CMD_RD_CTRL_DISPLAY 0xB4 /* Read CTRL display value */
#define ILI9331_CMD_WR_CABC 0xB5 /* Write Content Adaptive Brightness
Control value */
#define ILI9331_CMD_RD_CABC 0xB6 /* Read Content Adaptive Brightness
Control value */
#define ILI9331_CMD_WR_CABC_MIN_BRIGHTNESS 0xBE /* Write CABC minimum
brightness */
#define ILI9331_CMD_RD_CABC_MIN_BRIGHTNESS 0xBF /* Read CABC minimum
brightness */
#define ILI9331_CMD_CABC_CTRL1 0xC8 /* CABC control 1 */
#define ILI9331_CMD_CABC_CTRL2 0xC9 /* CABC control 2 */
#define ILI9331_CMD_CABC_CTRL3 0xCA /* CABC control 3 */
```

A detailed description of the above mentioned command registers can be found in the ILI9331 datasheet.

void ili9331_wrrreg(unsigned char index, unsigned short data)

Writes data to a command register of the ILI9331 controller.

Parameters:

index command register index
data to be written.

unsigned short ili9331_rdreg(unsigned char index)

Reads the contents of a command register of the ILI9331 controller.

Parameters:

index command register index.

void ili9331_wrdata(unsigned short data)

Writes data to the ILI9331 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short ili9331_rddata(void)

Reads data from the ILI9331 controller's Graphic Display RAM.

The **glcd_ili9331.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ILI9331 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */

    /* power control registers bits */
    unsigned char stepup_factor:3; /* step-up factor of the step-up
                                     circuit, see BT0..BT2 bits in
                                     the datasheet */
    unsigned char stepup_freq1:3; /* controls the frequency for the
                                     step-up circuit 1 */
    unsigned char stepup_freq2:3; /* controls the frequency for the
                                     step-up circuit 2 */
    unsigned char crt_source:3; /* adjusts the amount of current
                                   from the constant current source
                                   in the internal op. amplifier
                                   circuit (AP0..AP2 bits) */
    unsigned char vreg1out:4; /* adjusts the VREG1OUT voltage */
    unsigned char vcom:5; /* adjusts the amplitude of the Vcom
                             alternating drive voltage based on
                             VREG1OUT voltage */
    unsigned char vcomh:6; /* adjusts the amplitude of the VcomH
                             voltage based on VREG1OUT voltage
                             VcomH=VREG1OUT*(vcomh*0.005+0.685) [V] */
};
```

```
unsigned char frame_freq:4; /* LCD frame frequency */
/* positive gamma control registers bits */
unsigned char kp00:3; /* KP00..KP02 positive gamma micro adj. */
unsigned char kp10:3; /* KP10..KP12 positive gamma micro adj. */
unsigned char kp20:3; /* KP20..KP22 positive gamma micro adj. */
unsigned char kp30:3; /* KP30..KP32 positive gamma micro adj. */
unsigned char kp40:3; /* KP40..KP42 positive gamma micro adj. */
unsigned char kp50:3; /* KP50..KP52 positive gamma micro adj. */
unsigned char rp00:3; /* RP00..RP02 positive gamma gradient
adj. */
unsigned char rp10:3; /* RP10..RP12 positive gamma gradient
adj. */
unsigned char vrp00:4; /* VRP00..VRP03 positive gamma amplification
adj. */
unsigned char vrp10:5; /* VRP10..VRP14 positive gamma amplification
adj. */
/* negative gamma control registers bits */
unsigned char kn00:3; /* KN00..KN02 negative gamma micro adj. */
unsigned char kn10:3; /* KN10..KN12 negative gamma micro adj. */
unsigned char kn20:3; /* KN20..KN22 positive gamma micro adj. */
unsigned char kn30:3; /* KN30..KN32 positive gamma micro adj. */
unsigned char kn40:3; /* KN40..KN42 negative gamma micro adj. */
unsigned char kn50:3; /* KN50..KN52 negative gamma micro adj. */
unsigned char rn00:3; /* RN00..RN02 negative gamma gradient
adj. */
unsigned char rn10:3; /* RN10..RN12 negative gamma gradient
adj. */
unsigned char vrn00:4; /* VRN00..VRN03 negative gamma amplification
adj. */
unsigned char vrn10:5; /* VRN10..VRN14 negative gamma
amplification adj. */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ILI9331_REVX_NORM 0 /* No horizontal reverse */
#define ILI9331_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ILI9331_REVY_NORM 0 /* No vertical reverse */
#define ILI9331_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ILI9331_CL_BITS_RGB 0 /* Write color bits to display RAM
in RGB order */
#define ILI9331_CL_BITS_BGR 1 /* Write color bits to display RAM
in BGR order */

/* Initialization values for the VREG1OUT voltage */
#define ILI9331_VREG1OUT_4V000 8 /* 4.000 V */
#define ILI9331_VREG1OUT_4V125 9 /* 4.125 V */
#define ILI9331_VREG1OUT_4V250 10 /* 4.250 V */
#define ILI9331_VREG1OUT_4V375 11 /* 4.375 V */
#define ILI9331_VREG1OUT_4V500 12 /* 4.500 V */
#define ILI9331_VREG1OUT_4V625 13 /* 4.625 V */
#define ILI9331_VREG1OUT_4V750 14 /* 4.750 V */
#define ILI9331_VREG1OUT_4V875 15 /* 4.875 V */
#define ILI9331_VREG1OUT_5V000 1 /* 5.000 V */
#define ILI9331_VREG1OUT_5V125 2 /* 5.125 V */
```

```
#define ILI9331_VREG1OUT_5V250 3 /* 5.250 V */
#define ILI9331_VREG1OUT_5V500 4 /* 5.500 V */
#define ILI9331_VREG1OUT_5V750 5 /* 5.750 V */
#define ILI9331_VREG1OUT_6V000 6 /* 6.000 V */

/* Initialization values for the Vcom voltage */
#define ILI9331_VCOM_0_70 0 /* Vcom=VREG1OUT*0.70 */
#define ILI9331_VCOM_0_72 1 /* Vcom=VREG1OUT*0.72 */
#define ILI9331_VCOM_0_74 2 /* Vcom=VREG1OUT*0.74 */
#define ILI9331_VCOM_0_76 3 /* Vcom=VREG1OUT*0.76 */
#define ILI9331_VCOM_0_78 4 /* Vcom=VREG1OUT*0.78 */
#define ILI9331_VCOM_0_80 5 /* Vcom=VREG1OUT*0.80 */
#define ILI9331_VCOM_0_82 6 /* Vcom=VREG1OUT*0.82 */
#define ILI9331_VCOM_0_84 7 /* Vcom=VREG1OUT*0.84 */
#define ILI9331_VCOM_0_86 8 /* Vcom=VREG1OUT*0.86 */
#define ILI9331_VCOM_0_88 9 /* Vcom=VREG1OUT*0.88 */
#define ILI9331_VCOM_0_90 10 /* Vcom=VREG1OUT*0.90 */
#define ILI9331_VCOM_0_92 11 /* Vcom=VREG1OUT*0.92 */
#define ILI9331_VCOM_0_94 12 /* Vcom=VREG1OUT*0.94 */
#define ILI9331_VCOM_0_96 13 /* Vcom=VREG1OUT*0.96 */
#define ILI9331_VCOM_0_98 14 /* Vcom=VREG1OUT*0.98 */
#define ILI9331_VCOM_1_00 15 /* Vcom=VREG1OUT*1.00 */
#define ILI9331_VCOM_1_02 0x14 /* Vcom=VREG1OUT*1.02 */
#define ILI9331_VCOM_1_04 0x15 /* Vcom=VREG1OUT*1.04 */
#define ILI9331_VCOM_1_06 0x16 /* Vcom=VREG1OUT*1.06 */
#define ILI9331_VCOM_1_08 0x17 /* Vcom=VREG1OUT*1.08 */
#define ILI9331_VCOM_1_10 0x18 /* Vcom=VREG1OUT*1.10 */
#define ILI9331_VCOM_1_12 0x19 /* Vcom=VREG1OUT*1.12 */
#define ILI9331_VCOM_1_14 0x1A /* Vcom=VREG1OUT*1.14 */
#define ILI9331_VCOM_1_16 0x1B /* Vcom=VREG1OUT*1.16 */
#define ILI9331_VCOM_1_18 0x1C /* Vcom=VREG1OUT*1.18 */
#define ILI9331_VCOM_1_20 0x1D /* Vcom=VREG1OUT*1.20 */
#define ILI9331_VCOM_1_22 0x1E /* Vcom=VREG1OUT*1.22 */
#define ILI9331_VCOM_1_24 0x1F /* Vcom=VREG1OUT*1.24 */

/* Initialization value for VcomH
   VcomH=VREG1OUT*(VREG1OUT_MULT1000/1000)
   VREG1OUT_MULT1000=685..1000 */
#define ILI9331_VCOMH(VREG1OUT_MULT1000) ((VREG1OUT_MULT1000-685)/5)

/* Initialization values for stepup_freq1 */
#define ILI9331_STEPUP1_FOSC 0 /* FDCDC1=Fosc */
#define ILI9331_STEPUP1_FOSC2 1 /* FDCDC1=Fosc/2 */
#define ILI9331_STEPUP1_FOSC4 2 /* FDCDC1=Fosc/4 */
#define ILI9331_STEPUP1_FOSC8 3 /* FDCDC1=Fosc/8 */
#define ILI9331_STEPUP1_FOSC16 4 /* FDCDC1=Fosc/16 */
#define ILI9331_STEPUP1_FOSC32 5 /* FDCDC1=Fosc/32 */
#define ILI9331_STEPUP1_FOSC64 6 /* FDCDC1=Fosc/64 */
#define ILI9331_STEPUP1_HALT 7 /* Halt step-up circuit 1 */

/* Initialization values for stepup_freq2 */
#define ILI9331_STEPUP2_FOSC4 0 /* FDCDC2=Fosc/4 */
#define ILI9331_STEPUP2_FOSC8 1 /* FDCDC2=Fosc/8 */
#define ILI9331_STEPUP2_FOSC16 2 /* FDCDC2=Fosc/16 */
#define ILI9331_STEPUP2_FOSC32 3 /* FDCDC2=Fosc/32 */
#define ILI9331_STEPUP2_FOSC64 4 /* FDCDC2=Fosc/64 */
#define ILI9331_STEPUP2_FOSC128 5 /* FDCDC2=Fosc/128 */
#define ILI9331_STEPUP2_FOSC256 6 /* FDCDC2=Fosc/256 */
#define ILI9331_STEPUP2_HALT 7 /* Halt step-up circuit 2 */
```

```
/* Initialization values for frame_freq */
#define ILI9331_FRAME40 0 /* 40Hz */
#define ILI9331_FRAME43 1 /* 43Hz */
#define ILI9331_FRAME45 2 /* 45Hz */
#define ILI9331_FRAME48 3 /* 48Hz */
#define ILI9331_FRAME51 4 /* 51Hz */
#define ILI9331_FRAME55 5 /* 55Hz */
#define ILI9331_FRAME59 6 /* 59Hz */
#define ILI9331_FRAME64 7 /* 64Hz */
#define ILI9331_FRAME70 8 /* 70Hz */
#define ILI9331_FRAME77 9 /* 77Hz */
#define ILI9331_FRAME85 10 /* 85Hz */
#define ILI9331_FRAME96 11 /* 96Hz */
#define ILI9331_FRAME110 12 /* 110Hz */
#define ILI9331_FRAME128 13 /* 128Hz */

/* Default value for reverse_x */
#define ILI9331_DEFAULT_REVX ILI9331_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ILI9331_DEFAULT_REVY ILI9331_REVY_NORM /* No vertical reverse */

/* Default value for cl_bits_order
   (color bits writing order to display RAM),
   write in RGB order */
#define ILI9331_DEFAULT_CL_BITS ILI9331_CL_BITS_RGB

/* Power control 1 BT0..BT2 step-up factor of the step-up circuit
   DDVDH=Vci1*2, VCL=-Vci1, VGH=Vci1*6, VGL=-Vci1*3 */
#define ILI9331_DEFAULT_STEPUP_FACTOR 2
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the
   internal op. amplifier circuit */
#define ILI9331_DEFAULT_CRT_SOURCE 2
/* Power control 2 DC00..DC02 step-up circuit 1 frequency */
#define ILI9331_DEFAULT_STEPUP1_FREQ ILI9331_STEPUP1_FOSC4
/* Power control 2 DC10..DC12 step-up circuit 2 frequency */
#define ILI9331_DEFAULT_STEPUP2_FREQ ILI9331_STEPUP2_FOSC128
/* Default value for VREG1OUT voltage */
#define ILI9331_DEFAULT_VREG1OUT ILI9331_VREG1OUT_4V000
/* Default value for Vcom alternating drive voltage */
#define ILI9331_DEFAULT_VCOM ILI9331_VCOM_0_94
/* Default value for VcomH voltage
   VcomH=VREG1OUT*0.835 */
#define ILI9331_DEFAULT_VCOMH ILI9331_VCOMH(835)
/* Default value for LCD frame frequency */
#define ILI9331_DEFAULT_FRAME_FREQ ILI9331_FRAME96

/* Default initialization values for the gamma control register bits */
/* KP00..KP02 positive gamma micro adj. */
#define ILI9331_DEFAULT_KP00 7
/* KP10..KP12 positive gamma micro adj. */
#define ILI9331_DEFAULT_KP10 7
/* KP20..KP22 positive gamma micro adj. */
#define ILI9331_DEFAULT_KP20 4
/* KP30..KP32 positive gamma micro adj. */
#define ILI9331_DEFAULT_KP30 2
/* KP40..KP42 positive gamma micro adj. */
#define ILI9331_DEFAULT_KP40 4
```

```
/* KP50..KP52 positive gamma micro adj. */
#define ILI9331_DEFAULT_KP50 2
/* RP00..RP02 positive gamma gradient adj. */
#define ILI9331_DEFAULT_RP00 2
/* RP10..RP12 positive gamma gradient adj. */
#define ILI9331_DEFAULT_RP10 5
/* VRP00..VRP03 positive gamma amplification adj. */
#define ILI9331_DEFAULT_VRP00 2
/* VRP10..VRP14 positive gamma amplification adj. */
#define ILI9331_DEFAULT_VRP10 3
/* KN00..KN02 negative gamma micro adj. */
#define ILI9331_DEFAULT_KN00 7
/* KN10..KN12 negative gamma micro adj. */
#define ILI9331_DEFAULT_KN10 5
/* KN20..KN22 positive gamma micro adj. */
#define ILI9331_DEFAULT_KN20 4
/* KN30..KN32 positive gamma micro adj. */
#define ILI9331_DEFAULT_KN30 2
/* KN40..KN42 negative gamma micro adj. */
#define ILI9331_DEFAULT_KN40 4
/* KN50..KN52 negative gamma micro adj. */
#define ILI9331_DEFAULT_KN50 2
/* RN00..RN02 negative gamma gradient adj. */
#define ILI9331_DEFAULT_RN00 2
/* RN10..RN12 negative gamma gradient adj. */
#define ILI9331_DEFAULT_RN10 5
/* VRN00..VRN03 negative gamma amplification adj. */
#define ILI9331_DEFAULT_VRN00 2
/* VRN10..VRN14 negative gamma amplification adj. */
#define ILI9331_DEFAULT_VRN10 3
```

The following colors are redefined in the **glcd_ili9331.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ILI9331 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ili9331.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ili9331.h**.
- The **..\EXAMPLES\Graphic Displays\ILI9331** directory contains fully functional code samples that may be used as references for ILI9331 initialization and usage.

5.12.5 Graphic LCD Functions Specific to the ILI9340 Controller

The ILI9340 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8/16 bit parallel interface and SPI serial modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ILI9340 controller's features, the following specific functions, declared in the **glcd_ili9340.h** header file, were implemented:

void ili9340_wrcmd(unsigned char cmd)

Writes a command to the ILI9340 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ili9340.h** header file:

```
#define ILI9340_CMD_NOP 0x00 /* No operation */
#define ILI9340_CMD_SOFT_RESET 0x01 /* Software reset */
#define ILI9340_CMD_GET_DISPLAY_ID 0x04 /* Get display identification
                                         information:
                                         LCD module manufacturer ID,
                                         module/driver version ID,
                                         module/driver ID */
#define ILI9340_CMD_GET_DISPLAY_STATUS 0x09 /* Get display status */
#define ILI9340_CMD_GET_PWR_MODE 0x0A /* Get the current power mode */
#define ILI9340_CMD_GET_MADCTL 0x0B /* Get the Memory Address Control
                                     status bits: MX, MY, MH, MV, ML */
#define ILI9340_CMD_GET_PIXEL_FORMAT 0x0C /* Get the display pixel
                                             format */
#define ILI9340_CMD_GET_DISPLAY_MODE 0x0D /* Returns the display image
                                             mode status */
#define ILI9340_CMD_GET_SIGNAL_MODE 0x0E /* Get the current display signal
                                             mode from the peripheral */
#define ILI9340_CMD_GET_SELF_DIAGNOSTIC 0x0F /* Returns the display
                                                self-diagnostic result */
#define ILI9340_CMD_ENT_SLEEP 0x10 /* Enter sleep mode */
#define ILI9340_CMD_EXIT_SLEEP 0x11 /* Exit from sleep mode */
#define ILI9340_CMD_ENT_PARTIAL_MODE 0x12 /* Enter partial display mode */
#define ILI9340_CMD_ENT_NORMAL_MODE 0x13 /* Enter normal display mode */
#define ILI9340_CMD_EXIT_INVERT_MODE 0x20 /* Exit from inverted display
                                             mode */
#define ILI9340_CMD_ENT_INVERT_MODE 0x21 /* Enter inverted display mode */
#define ILI9340_CMD_SET_GAMMA 0x26 /* Selects the gamma curve used by the
                                     display device */
#define ILI9340_CMD_BLANK_DISPLAY 0x28 /* Set display off, without clearing
                                         the frame buffer */
#define ILI9340_CMD_ON_DISPLAY 0x29 /* Set display on */
#define ILI9340_CMD_SET_COLUMN_ADDR 0x2A /* Set the column extent of the
                                             frame buffer accessed with the
                                             ILI9340_CMD_RD_MEM_CONT and
                                             ILI9340_CMD_WR_MEM_CONT
                                             commands */
```



```
#define ILI9340_CMD_SET_PAGE_ADDR 0x2B /* Set the page extent of the frame
                                         buffer accessed with the
                                         ILI9340_CMD_RD_MEM_CONT and
                                         ILI9340_CMD_WR_MEM_CONT
                                         Commands */
#define ILI9340_CMD_WR_MEM_START 0x2C /* Transfer image information from uC
                                         to ILI9340 starting with the
                                         location specified by
                                         ILI9340_CMD_SET_COLUMN_ADDR and
                                         ILI9340_CMD_SET_PAGE_ADDR */
#define ILI9340_CMD_COLOR_SET 0x2D /* Used to define the look-up table for
                                         16-bit to 18-bit color depth
                                         conversion */
#define ILI9340_CMD_RD_MEM_START 0x2E /* Transfer image information from
                                         ILI9340 to uC starting with the
                                         location specified by
                                         ILI9340_CMD_SET_COLUMN_ADDR and
                                         ILI9340_CMD_SET_PAGE_ADDR */
#define ILI9340_CMD_SET_PARTIAL_AREA 0x30 /* Defines the partial display
                                         mode area */
#define ILI9340_CMD_SET_SCROLL_AREA 0x33 /* Defines the vertical scrolling
                                         and fixed areas */
#define ILI9340_CMD_SET_TEAR_OFF 0x34 /* Disable sending synchronization
                                         information from the display */
#define ILI9340_CMD_SET_TEAR_ON 0x35 /* Enable sending synchronization
                                         information from the display */
#define ILI9340_CMD_SET_ADDR_MODE 0x36 /* Set read order from uC to frame
                                         buffer and from frame buffer to
                                         the display panel */
#define ILI9340_CMD_SET_SCROLL_START 0x37 /* Set the start of the vertical
                                         scrolling area in the frame
                                         buffer */
#define ILI9340_CMD_EXIT_IDLE_MODE 0x38 /* Exit idle mode */
#define ILI9340_CMD_ENT_IDLE_MODE 0x39 /* Enter idle mode */
#define ILI9340_CMD_SET_PIXEL_FORMAT 0x3A /* Set pixel format */
#define ILI9340_CMD_WR_MEM_CONT 0x3C /* Transfer image data from uC to
                                         ILI9340 continuing from the
                                         last ILI9340_CMD_WR_MEM_START or
                                         ILI9340_CMD_WR_MEM_CONT */
#define ILI9340_CMD_RD_MEM_CONT 0x3E /* Transfer image data from ILI9340 to
                                         uC continuing from the
                                         last ILI9340_CMD_RD_MEM_START or
                                         ILI9340_CMD_RD_MEM_CONT */
#define ILI9340_CMD_SET_TEAR_SCANLINE 0x44 /* Enable sending the TE signal
                                         to the uC when the display
                                         refresh reaches the provided
                                         scan line */
#define ILI9340_CMD_GET_TEAR_SCANLINE 0x45 /* Get the current scan line */
#define ILI9340_CMD_SET_BRIGHTNESS 0x51 /* Set display brightness */
#define ILI9340_CMD_GET_BRIGHTNESS 0x52 /* Get the display brightness */
#define ILI9340_CMD_SET_CTRL_DISPLAY 0x53 /* Set the brightness control
                                         block, display dimming and
                                         backlight */
#define ILI9340_CMD_GET_CTRL_DISPLAY 0x54 /* Get the brightness control
                                         block, display dimming and
                                         backlight status */
```

```
#define ILI9340_CMD_SET_CONTENT_ADAPTIVE_BRIGHTNESS 0x55 /* Set the
                                                         parameters for
                                                         the content
                                                         adaptive
                                                         brightness */
#define ILI9340_CMD_GET_CONTENT_ADAPTIVE_BRIGHTNESS 0x56 /* Get the
                                                         parameters for
                                                         the content
                                                         adaptive
                                                         brightness */
#define ILI9340_CMD_SET_CABC_MIN_BRIGHTNESS 0x5E /* Set the minimum display
                                                         brightness for
                                                         the content adaptive
                                                         brightness function */
#define ILI9340_CMD_GET_CABC_MIN_BRIGHTNESS 0x5F /* Get the minimum display
                                                         brightness for
                                                         the content adaptive
                                                         brightness function */
#define ILI9340_CMD_SET_RGB_INTF 0xB0 /* Set the operation status of the
                                         display interface */
#define ILI9340_CMD_SET_FRAME_RATE_NORMAL 0xB1 /* Set frame rate control
                                                         parameters in normal
                                                         mode/full colors */
#define ILI9340_CMD_SET_FRAME_RATE_IDLE 0xB2 /* Set frame rate control
                                                         parameters in
                                                         idle mode/8 colors */
#define ILI9340_CMD_SET_FRAME_RATE_PARTIAL 0xB3 /* Set frame rate control
                                                         parameters in
                                                         partial mode/full colors
                                                         */
#define ILI9340_CMD_SET_DISPLAY_INVERSION 0xB4 /* Set display inversion
                                                         mode parameters */
#define ILI9340_CMD_SET_BLANKING_PORCH 0xB5 /* Set blanking porch
                                                         parameters */
#define ILI9340_CMD_SET_DISPLAY_FUNTION_CTRL 0xB6 /* Set display scan
                                                         parameters, shift
                                                         direction, LCD type */
#define ILI9340_CMD_SET_ENTRY_MODE 0xB7 /* Set standby mode, low voltage
                                         detection control, output level
                                         of gate driver parameters. */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL1 0xB8 /* Set the grayscale data in
                                                         user interface image mode
                                                         */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL2 0xB9 /* Set the grayscale data in
                                                         still picture image mode
                                                         */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL3 0xBA /* Set the grayscale data in
                                                         user icon image mode */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL4 0xBB /* Set the minimum limit of
                                                         grayscale threshold value
                                                         */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL5 0xBC /* Set the transition time of
                                                         brightness level */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL7 0xBE /* Set the frequency of the
                                                         PWM_OUT output */
#define ILI9340_CMD_SET_BACKLIGHT_CTRL8 0xBF /* Set the polarity of the
                                                         LEDPWM signal and
                                                         controls the LEDON pin */
```

```
#define ILI9340_CMD_SET_POWER_CTRL1 0xC0 /* Set GVDD level */
#define ILI9340_CMD_SET_POWER_CTRL2 0xC1 /* Set the step-up circuits
factor */
#define ILI9340_CMD_SET_POWER_CTRL3 0xC2 /* Selects the operating frequency
of the step-up
circuits 1, 2, 3, 4 for normal
mode */
#define ILI9340_CMD_SET_POWER_CTRL4 0xC3 /* Selects the operating frequency
of the step-up
circuits 1, 2, 3, 4 for idle
mode */
#define ILI9340_CMD_SET_POWER_CTRL5 0xC4 /* Selects the operating frequency
of the step-up
circuits 1, 2, 3, 4 for partial
mode */
#define ILI9340_CMD_SET_VCOM_CTRL1 0xC5 /* Set the VCOML and VCOMH
voltages */
#define ILI9340_CMD_SET_VCOM_CTRL2 0xC7 /* Set the VCOM offset voltage */
#define ILI9340_CMD_NVM_WRITE 0xD0 /* Write data to non-volatile
memory */
#define ILI9340_CMD_NVM_PROTECTION 0xD1 /* Enable writing to non-volatile
memory */
#define ILI9340_CMD_GET_NVM_STATUS 0xD2 /* Read the non-volatile memory
status */
#define ILI9340_CMD_GET_ID4 0xD3 /* Get the IC device code */
#define ILI9340_CMD_SET_POSITIVE_GAMMA_CORRECTION 0xE0 /* Set positive
gamma correction
control
parameters */
#define ILI9340_CMD_SET_NEGATIVE_GAMMA_CORRECTION 0xE1 /* Set negative
gamma correction
control
parameters */
#define ILI9340_CMD_SET_DIGITAL_GAMMA_CTRL1 0xE2 /* Set macro adjustments
for red and blue gamma
curves */
#define ILI9340_CMD_SET_DIGITAL_GAMMA_CTRL2 0xE3 /* Set micro adjustments
for red and blue gamma
curves */
#define ILI9340_CMD_SET_INTERFACE_CTRL 0xF6 /* Set interface parameters:
data transfer method,
memory write control,
LSB/MSB first, display
operation mode, GDRAM
interface, RGB interface,
65k color mode format */
```

void ili9340_wrdata(unsigned char data)

Writes data byte(s) to the ILI9340 controller after a command was issued using the **ili9340_wrcmd** function.

Parameter:

data to be sent to the controller.

unsigned char ili9340_rddata(void)

Reads result data byte(s) from the ILI9340 controller after a command was issued using the **ili9340_wrcmd** function.

Note: When used immediately after **ili9340_wrcmd**, this function must be called twice. The result of the first call is a dummy read and it is not valid.

void ili9340_wrdram(GLCDCOL_t color)

Writes color data for 1 pixel to the ILI9340 controller's display RAM.

Parameter:

color data to be sent to the controller.

Note: Before calling this function a **ILI9340_CMD_WR_MEM_START** or **ILI9340_CMD_WR_MEM_CONT** command must be issued to the controller using the **ili9340_wrcmd** function.

GLCDCOL_t ili9340_rddram(void)

Reads color data for 1 pixel from the ILI9340 controller's display RAM.

Note: Before calling this function a **ILI9340_CMD_RD_MEM_START** or **ILI9340_CMD_RD_MEM_CONT** command must be issued to the controller using the **ili9340_wrcmd** function.

void ili9340_sleep(bool on)

Puts the ILI9340 controller in sleep mode or exit from sleep mode.

Parameter:

on when **true** puts the controller in sleep mode, when **false** exits the sleep mode.

Notes:

- A delay of minimum 120ms must be present after exiting the sleep mode and entering sleep mode again.

The **glcd_ili9340.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ILI9340 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */
    unsigned char vrh:6; /* set VRH=3.0+(vrh-3)*0.05 [V] */
    unsigned char vcil:4; /* set VCIL=2.30+vcil*0.05 [V] */
    unsigned char vcoml:7; /* set VCOML=-2.5+vcoml*0.025 [V] */
    unsigned char vcomh:7; /* set VCOMH=2.7+vcomh*0.025 [V] */
    unsigned char vcom_offset:7; /* set VCOM offset=VM+vcom_offset-64
                                   */
    unsigned char lcd_type:1; /* LCD type =0 normally black,
                               =1 normally white */
    unsigned char scan_mode:1; /* set vertical scan mode
                               =0 interlaced,
                               =1 non-interlaced */
    unsigned char frame_rate:5; /* set vertical frame rate 61..119Hz */
    unsigned char gamma_curve:2; /* selects the gamma curve used by
                                   the device */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ILI9340_REVX_NORM 0 /* No horizontal reverse */
#define ILI9340_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ILI9340_REVY_NORM 0 /* No vertical reverse */
#define ILI9340_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ILI9340_CL_BITS_RGB 0 /* RGB */
#define ILI9340_CL_BITS_BGR 1 /* BGR */

/* Initialization values for scan_mode */
#define ILI9340_SCAN_INTERLACED 0
#define ILI9340_SCAN_NON_INTERLACED 1

/* Initialization values for lcd_type */
#define ILI9340_LCD_TYPE_BLACK 0
#define ILI9340_LCD_TYPE_WHITE 1
```

```
/* Initialization values for frame_rate */
#define ILI9340_FRAME_RATE_61 0x1F /* 61Hz */
#define ILI9340_FRAME_RATE_63 0x1E /* 63Hz */
#define ILI9340_FRAME_RATE_65 0x1D /* 65Hz */
#define ILI9340_FRAME_RATE_68 0x1C /* 68Hz */
#define ILI9340_FRAME_RATE_70 0x1B /* 70Hz */
#define ILI9340_FRAME_RATE_73 0x1A /* 73Hz */
#define ILI9340_FRAME_RATE_76 0x19 /* 76Hz */
#define ILI9340_FRAME_RATE_79 0x18 /* 79Hz */
#define ILI9340_FRAME_RATE_83 0x17 /* 83Hz */
#define ILI9340_FRAME_RATE_86 0x16 /* 86Hz */
#define ILI9340_FRAME_RATE_90 0x15 /* 90Hz */
#define ILI9340_FRAME_RATE_95 0x14 /* 95Hz */
#define ILI9340_FRAME_RATE_100 0x13 /* 100Hz */
#define ILI9340_FRAME_RATE_106 0x12 /* 106Hz */
#define ILI9340_FRAME_RATE_112 0x11 /* 112Hz */
#define ILI9340_FRAME_RATE_119 0x10 /* 119Hz */

/* Initialization values for gamma_curve */
#define ILI9340_GAMMA_CURVE1_0 0 /* Gamma curve  $y=x^{1.0}$  */
#define ILI9340_GAMMA_CURVE1_8 1 /* Gamma curve  $y=x^{1.8}$  */
#define ILI9340_GAMMA_CURVE2_2 2 /* Gamma curve  $y=x^{2.2}$  */
#define ILI9340_GAMMA_CURVE2_5 3 /* Gamma curve  $y=x^{2.5}$  */

/* Default initialization values for GLCDINIT_t */
/* Default value for reverse_x */
#define ILI9340_DEFAULT_REVX ILI9340_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ILI9340_DEFAULT_REVY ILI9340_REVY_NORM /* No vertical reverse */
/* Default value for cl_bits_order */
/* write in RGB order */
#define ILI9340_DEFAULT_CL_BITS ILI9340_CL_BITS_RGB

/* Default value for vrh */
#define ILI9340_DEFAULT_VRH 0x26
/* Default value for vcil */
#define ILI9340_DEFAULT_VCI1 0x04
/* Default value for vcoml */
#define ILI9340_DEFAULT_VCOML 0x40
/* Default value for vcomh */
#define ILI9340_DEFAULT_VCOMH 0x34
/* Default value for vcom_offset */
#define ILI9340_DEFAULT_VCOM_OFFSET 0x40
/* Default value for lcd_type */
#define ILI9340_DEFAULT_LCD_TYPE ILI9340_LCD_TYPE_WHITE
/* Default value for scan_mode */
#define ILI9340_DEFAULT_SCAN_MODE ILI9340_SCAN_INTERLACED
/* Default value for frame_rate */
#define ILI9340_DEFAULT_FRAME_RATE ILI9340_FRAME_RATE_70 /* 70Hz */
/* Default value for gamma_curve */
#define ILI9340_DEFAULT_GAMMA_CURVE ILI9340_GAMMA_CURVE2_2 /*  $y=x^{2.2}$  */
```

The following colors are predefined in the **glcd_ili9340.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ILI9340 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ili9340.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ili9340.h**.
- The **..\EXAMPLES\Graphic Displays\ILI9340** directory contains fully functional code samples that may be used as references for ILI9340 initialization and usage.

5.12.6 Graphic LCD Functions Specific to the ILI9341 Controller

The ILI9341 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8/16 bit parallel interface and SPI serial modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ILI9341 controller's features, the following specific functions, declared in the **glcd_ili9341.h** header file, were implemented:

void ili9341_wrcmd(unsigned char cmd)

Writes a command to the ILI9341 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ili9341.h** header file:

```
#define ILI9341_CMD_NOP 0x00 /* No operation */
#define ILI9341_CMD_SOFT_RESET 0x01 /* Software reset */
#define ILI9341_CMD_GET_DISPLAY_ID 0x04 /* Get display identification
                                         information:
                                         LCD module manufacturer ID,
                                         module/driver version ID,
                                         module/driver ID */
#define ILI9341_CMD_GET_DISPLAY_STATUS 0x09 /* Get display status */
#define ILI9341_CMD_GET_PWR_MODE 0x0A /* Get the current power mode */
#define ILI9341_CMD_GET_MADCTL 0x0B /* Get the Memory Address Control
                                     status bits: MX, MY, MH, MV, ML */
#define ILI9341_CMD_GET_PIXEL_FORMAT 0x0C /* Get the display pixel
                                             format */
#define ILI9341_CMD_GET_DISPLAY_MODE 0x0D /* Returns the display image
                                             mode status */
#define ILI9341_CMD_GET_SIGNAL_MODE 0x0E /* Get the current display signal
                                             mode from the peripheral */
#define ILI9341_CMD_GET_SELF_DIAGNOSTIC 0x0F /* Returns the display
                                                self-diagnostic result */
#define ILI9341_CMD_ENT_SLEEP 0x10 /* Enter sleep mode */
#define ILI9341_CMD_EXIT_SLEEP 0x11 /* Exit from sleep mode */
#define ILI9341_CMD_ENT_PARTIAL_MODE 0x12 /* Enter partial display mode */
#define ILI9341_CMD_ENT_NORMAL_MODE 0x13 /* Enter normal display mode */
#define ILI9341_CMD_EXIT_INVERT_MODE 0x20 /* Exit from inverted display
                                             mode */
#define ILI9341_CMD_ENT_INVERT_MODE 0x21 /* Enter inverted display mode */
#define ILI9341_CMD_SET_GAMMA 0x26 /* Selects the gamma curve used by the
                                     display device */
#define ILI9341_CMD_BLANK_DISPLAY 0x28 /* Set display off, without clearing
                                         the frame buffer */
#define ILI9341_CMD_ON_DISPLAY 0x29 /* Set display on */
#define ILI9341_CMD_SET_COLUMN_ADDR 0x2A /* Set the column extent of the
                                             frame buffer accessed with the
                                             ILI9341_CMD_RD_MEM_CONT and
                                             ILI9341_CMD_WR_MEM_CONT
                                             commands */
```



```
#define ILI9341_CMD_SET_PAGE_ADDR 0x2B /* Set the page extent of the frame
                                         buffer accessed with the
                                         ILI9341_CMD_RD_MEM_CONT and
                                         ILI9341_CMD_WR_MEM_CONT
                                         Commands */
#define ILI9341_CMD_WR_MEM_START 0x2C /* Transfer image information from uC
                                         to ILI9341 starting with the
                                         location specified by
                                         ILI9341_CMD_SET_COLUMN_ADDR and
                                         ILI9341_CMD_SET_PAGE_ADDR */
#define ILI9341_CMD_COLOR_SET 0x2D /* Used to define the look-up table for
                                         16-bit to 18-bit color depth
                                         conversion */
#define ILI9341_CMD_RD_MEM_START 0x2E /* Transfer image information from
                                         ILI9341 to uC starting with the
                                         location specified by
                                         ILI9341_CMD_SET_COLUMN_ADDR and
                                         ILI9341_CMD_SET_PAGE_ADDR */
#define ILI9341_CMD_SET_PARTIAL_AREA 0x30 /* Defines the partial display
                                         mode area */
#define ILI9341_CMD_SET_SCROLL_AREA 0x33 /* Defines the vertical scrolling
                                         and fixed areas */
#define ILI9341_CMD_SET_TEAR_OFF 0x34 /* Disable sending synchronization
                                         information from the display */
#define ILI9341_CMD_SET_TEAR_ON 0x35 /* Enable sending synchronization
                                         information from the display */
#define ILI9341_CMD_SET_ADDR_MODE 0x36 /* Set read order from uC to frame
                                         buffer and from frame buffer to
                                         the display panel */
#define ILI9341_CMD_SET_SCROLL_START 0x37 /* Set the start of the vertical
                                         scrolling area in the frame
                                         buffer */
#define ILI9341_CMD_EXIT_IDLE_MODE 0x38 /* Exit idle mode */
#define ILI9341_CMD_ENT_IDLE_MODE 0x39 /* Enter idle mode */
#define ILI9341_CMD_SET_PIXEL_FORMAT 0x3A /* Set pixel format */
#define ILI9341_CMD_WR_MEM_CONT 0x3C /* Transfer image data from uC to
                                         ILI9341 continuing from the
                                         last ILI9341_CMD_WR_MEM_START or
                                         ILI9341_CMD_WR_MEM_CONT */
#define ILI9341_CMD_RD_MEM_CONT 0x3E /* Transfer image data from ILI9341 to
                                         uC continuing from the
                                         last ILI9341_CMD_RD_MEM_START or
                                         ILI9341_CMD_RD_MEM_CONT */
#define ILI9341_CMD_SET_TEAR_SCANLINE 0x44 /* Enable sending the TE signal
                                         to the uC when the display
                                         refresh reaches the provided
                                         scan line */
#define ILI9341_CMD_GET_TEAR_SCANLINE 0x45 /* Get the current scan line */
#define ILI9341_CMD_SET_BRIGHTNESS 0x51 /* Set display brightness */
#define ILI9341_CMD_GET_BRIGHTNESS 0x52 /* Get the display brightness */
#define ILI9341_CMD_SET_CTRL_DISPLAY 0x53 /* Set the brightness control
                                         block, display dimming and
                                         backlight */
#define ILI9341_CMD_GET_CTRL_DISPLAY 0x54 /* Get the brightness control
                                         block, display dimming and
                                         backlight status */
```

```
#define ILI9341_CMD_SET_CONTENT_ADAPTIVE_BRIGHTNESS 0x55 /* Set the
                                                         parameters for
                                                         the content
                                                         adaptive
                                                         brightness */
#define ILI9341_CMD_GET_CONTENT_ADAPTIVE_BRIGHTNESS 0x56 /* Get the
                                                         parameters for
                                                         the content
                                                         adaptive
                                                         brightness */
#define ILI9341_CMD_SET_CABC_MIN_BRIGHTNESS 0x5E /* Set the minimum display
                                                         brightness for
                                                         the content adaptive
                                                         brightness function */
#define ILI9341_CMD_GET_CABC_MIN_BRIGHTNESS 0x5F /* Get the minimum display
                                                         brightness for
                                                         the content adaptive
                                                         brightness function */
#define ILI9341_CMD_SET_RGB_INTF 0xB0 /* Set the operation status of the
                                         display interface */
#define ILI9341_CMD_SET_FRAME_RATE_NORMAL 0xB1 /* Set frame rate control
                                                  parameters in normal
                                                  mode/full colors */
#define ILI9341_CMD_SET_FRAME_RATE_IDLE 0xB2 /* Set frame rate control
                                                  parameters in
                                                  idle mode/8 colors */
#define ILI9341_CMD_SET_FRAME_RATE_PARTIAL 0xB3 /* Set frame rate control
                                                  parameters in
                                                  partial mode/full colors
                                                  */
#define ILI9341_CMD_SET_DISPLAY_INVERSION 0xB4 /* Set display inversion
                                                  mode parameters */
#define ILI9341_CMD_SET_BLANKING_PORCH 0xB5 /* Set blanking porch
                                                  parameters */
#define ILI9341_CMD_SET_DISPLAY_FUNTION_CTRL 0xB6 /* Set display scan
                                                  parameters, shift
                                                  direction, LCD type */
#define ILI9341_CMD_SET_ENTRY_MODE 0xB7 /* Set standby mode, low voltage
                                         detection control, output level
                                         of gate driver parameters. */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL1 0xB8 /* Set the grayscale data in
                                                  user interface image mode
                                                  */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL2 0xB9 /* Set the grayscale data in
                                                  still picture image mode
                                                  */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL3 0xBA /* Set the grayscale data in
                                                  user icon image mode */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL4 0xBB /* Set the minimum limit of
                                                  grayscale threshold value
                                                  */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL5 0xBC /* Set the transition time of
                                                  brightness level */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL7 0xBE /* Set the frequency of the
                                                  PWM_OUT output */
#define ILI9341_CMD_SET_BACKLIGHT_CTRL8 0xBF /* Set the polarity of the
                                                  LEDPWM signal and
                                                  controls the LEDON pin */
```

```
#define ILI9341_CMD_SET_POWER_CTRL1 0xC0 /* Set GVDD level */
#define ILI9341_CMD_SET_POWER_CTRL2 0xC1 /* Set the step-up circuits
factor */
#define ILI9341_CMD_SET_VCOM_CTRL1 0xC5 /* Set the VCOML and VCOMH
voltages */
#define ILI9341_CMD_SET_VCOM_CTRL2 0xC7 /* Set the VCOM offset voltage */
#define ILI9341_CMD_SET_POWER_CTRLA 0xCB
#define ILI9341_CMD_SET_POWER_CTRLB 0xCF
#define ILI9341_CMD_NVM_WRITE 0xD0 /* Write data to non-volatile
memory */
#define ILI9341_CMD_NVM_PROTECTION 0xD1 /* Enable writing to non-volatile
memory */
#define ILI9341_CMD_GET_NVM_STATUS 0xD2 /* Read the non-volatile memory
status */
#define ILI9341_CMD_GET_ID1 0xDA /* Get the LCD manufacturer ID */
#define ILI9341_CMD_GET_ID2 0xDB /* Get the LCD module/driver version ID */
#define ILI9341_CMD_GET_ID3 0xDC /* Get the LCD module/driver ID */
#define ILI9341_CMD_GET_ID4 0xD3 /* Get the IC device code */
#define ILI9341_CMD_SET_POSITIVE_GAMMA_CORRECTION 0xE0 /* Set positive
gamma correction
control
parameters */
#define ILI9341_CMD_SET_NEGATIVE_GAMMA_CORRECTION 0xE1 /* Set negative
gamma correction
control
parameters */
#define ILI9341_CMD_SET_DIGITAL_GAMMA_CTRL1 0xE2 /* Set macro adjustments
for red and blue gamma
curves */
#define ILI9341_CMD_SET_DIGITAL_GAMMA_CTRL2 0xE3 /* Set micro adjustments
for red and blue gamma
curves */
#define ILI9341_CMD_DRIVER_TIMING_CTRLA 0xE8
#define ILI9341_CMD_DRIVER_TIMING_CTRLB 0xEA
#define ILI9341_CMD_SET_POWER_ON_SEQ_CTRL 0xED /* Set power-on sequence:
soft start, enable VCL,
DDVDH, VG, VL, DDVDH
enhanced mode */
#define ILI9341_CMD_ENABLE_3G 0xF2 /* Enable 3 gamma control */
#define ILI9341_CMD_SET_INTERFACE_CTRL 0xF6 /* Set interface parameters:
data transfer method,
memory write control,
LSB/MSB first, display
operation mode, GDRAM
interface, RGB interface,
65k color mode format */
#define ILI9341_CMD_SET_PUMP_RATIO_CTRL 0xF7 /* Set pump ratio control:
DDVHD=2xVCI or
DDVHD=3xVCI */
```

void ili9341_wrdata(unsigned char data)

Writes data byte(s) to the ILI9341 controller after a command was issued using the **ili9341_wrcmd** function.

Parameter:

data to be sent to the controller.

unsigned char ili9341_rddata(void)

Reads result data byte(s) from the ILI9341 controller after a command was issued using the **ili9341_wrcmd** function.

Note: When used immediately after **ili9341_wrcmd**, this function must be called twice. The result of the first call is a dummy read and it is not valid.

void ili9341_wrdram(GLCDCOL_t color)

Writes color data for 1 pixel to the ILI9341 controller's display RAM.

Parameter:

color data to be sent to the controller.

Note: Before calling this function a **ILI9341_CMD_WR_MEM_START** or **ILI9341_CMD_WR_MEM_CONT** command must be issued to the controller using the **ili9341_wrcmd** function.

GLCDCOL_t ili9341_rddram(void)

Reads color data for 1 pixel from the ILI9341 controller's display RAM.

Note: Before calling this function a **ILI9341_CMD_RD_MEM_START** or **ILI9341_CMD_RD_MEM_CONT** command must be issued to the controller using the **ili9341_wrcmd** function.

void ili9341_sleep(bool on)

Puts the ILI9341 controller in sleep mode or exit from sleep mode.

Parameter:

on when **true** puts the controller in sleep mode, when **false** exits the sleep mode.

Notes:

- A delay of minimum 120ms must be present after exiting the sleep mode and entering sleep mode again.

The `glcd_ili9341.h` header file also contains the definition of the `GLCDINIT_t` type specific for the ILI9341 controller, used as parameter for the `glcd_init` function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */
    unsigned char pump_ratio:1; /* =0 -> DDVDH=2xVCI,
                                     =1 -> DDVDH=3xVCI */
    unsigned char ddvdh_enh_mode:1; /* DDVDH enhanced mode
                                     =0 -> disable,
                                     =1 -> enable */

    unsigned char cr_timing:1;
    unsigned char eq_timing:1;
    unsigned char precharge_timing:2;
    unsigned char vrh:6; /* set VRH=3.0+(vrh-3)*0.05 [V] */
    unsigned char vcoml:7; /* set VCOML=-2.5+vcoml*0.025 [V] */
    unsigned char vcomh:7; /* set VCOMH=2.7+vcomh*0.025 [V] */
    unsigned char vcom_offset:7; /* set VCOM offset=VM+vcom_offset-64
                                     */
    unsigned char lcd_type:1; /* LCD type =0 normally black,
                                     =1 normally white */
    unsigned char scan_mode:1; /* set vertical scan mode
                                     =0 interlaced,
                                     =1 non-interlaced */
    unsigned char frame_rate:5; /* set vertical frame rate 61..119Hz */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the `GLCDINIT_t` structure:

```
/* Initialization values for reverse_x */
#define ILI9341_REVX_NORM 0 /* No horizontal reverse */
#define ILI9341_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ILI9341_REVY_NORM 0 /* No vertical reverse */
#define ILI9341_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ILI9341_CL_BITS_RGB 0 /* RGB */
#define ILI9341_CL_BITS_BGR 1 /* BGR */

/* Initialization values for pump_ratio */
#define ILI9341_PUMP_RATIO_2X 0 // DDVDH=2xVCI
#define ILI9341_PUMP_RATIO_3X 1 // DDVDH=3xVCI

/* Initialization values for ddvdh_enh_mode */
#define ILI9341_DDVDH_ENH_MODE_OFF 0
#define ILI9341_DDVDH_ENH_MODE_ON 1
```

```
/* Initialization values for cr_timing */
#define ILI9341_CR_TIMING_DEF0U 1 /* CR timing = default */
#define ILI9341_CR_TIMING_DEF1U 0 /* CR timing = default-1 units */

/* Initialization values for eq_timing */
#define ILI9341_EQ_TIMING_DEF0U 1 /* EQ timing = default */
#define ILI9341_EQ_TIMING_DEF1U 0 /* EQ timing = default-1 units */

/* Initialization values for precharge_timing */
#define ILI9341_PRECHARGE_TIMING_DEF0U 2 /* Precharge timing = default */
#define ILI9341_PRECHARGE_TIMING_DEF1U 1 /* Precharge timing = default-1
units */
#define ILI9341_PRECHARGE_TIMING_DEF2U 0 /* Precharge timing = default-2
units */

/* Initialization values for scan_mode */
#define ILI9341_SCAN_INTERLACED 0
#define ILI9341_SCAN_NON_INTERLACED 1

/* Initialization values for lcd_type */
#define ILI9341_LCD_TYPE_BLACK 0
#define ILI9341_LCD_TYPE_WHITE 1

/* Initialization values for frame_rate */
#define ILI9341_FRAME_RATE_61 0x1F /* 61Hz */
#define ILI9341_FRAME_RATE_63 0x1E /* 63Hz */
#define ILI9341_FRAME_RATE_65 0x1D /* 65Hz */
#define ILI9341_FRAME_RATE_68 0x1C /* 68Hz */
#define ILI9341_FRAME_RATE_70 0x1B /* 70Hz */
#define ILI9341_FRAME_RATE_73 0x1A /* 73Hz */
#define ILI9341_FRAME_RATE_76 0x19 /* 76Hz */
#define ILI9341_FRAME_RATE_79 0x18 /* 79Hz */
#define ILI9341_FRAME_RATE_83 0x17 /* 83Hz */
#define ILI9341_FRAME_RATE_86 0x16 /* 86Hz */
#define ILI9341_FRAME_RATE_90 0x15 /* 90Hz */
#define ILI9341_FRAME_RATE_95 0x14 /* 95Hz */
#define ILI9341_FRAME_RATE_100 0x13 /* 100Hz */
#define ILI9341_FRAME_RATE_106 0x12 /* 106Hz */
#define ILI9341_FRAME_RATE_112 0x11 /* 112Hz */
#define ILI9341_FRAME_RATE_119 0x10 /* 119Hz */

/* Default initialization values for GLCDINIT_t */
/* Default value for reverse_x */
#define ILI9341_DEFAULT_REVX ILI9341_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ILI9341_DEFAULT_REVY ILI9341_REVY_NORM /* No vertical reverse */
/* Default value for cl_bits_order */
/* write in RGB order */
#define ILI9341_DEFAULT_CL_BITS ILI9341_CL_BITS_RGB
/* Default value for pump_ratio */
#define ILI9341_DEFAULT_PUMP_RATIO ILI9341_PUMP_RATIO_2X
/* Default value for ddvhd_enh_mode */
#define ILI9341_DEFAULT_DDVDH_ENH_MODE ILI9341_DDVDH_ENH_MODE_ON
/* Default value for cr_timing */
#define ILI9341_DEFAULT_CR_TIMING ILI9341_CR_TIMING_DEF0U
/* Default value for eq_timing */
#define ILI9341_DEFAULT_EQ_TIMING ILI9341_EQ_TIMING_DEF1U
/* Default value for precharge_timing */
#define ILI9341_DEFAULT_PRECHARGE_TIMING ILI9341_PRECHARGE_TIMING_DEF1U
```

```
/* Default value for vrh */
#define ILI9341_DEFAULT_VRH 0x26
/* Default value for vcoml */
#define ILI9341_DEFAULT_VCOML 0x3E
/* Default value for vcomh */
#define ILI9341_DEFAULT_VCOMH 0x35
/* Default value for vcom_offset */
#define ILI9341_DEFAULT_VCOM_OFFSET 0x3E
/* Default value for lcd_type */
#define ILI9341_DEFAULT_LCD_TYPE ILI9341_LCD_TYPE_WHITE
/* Default value for scan_mode */
#define ILI9341_DEFAULT_SCAN_MODE ILI9341_SCAN_INTERLACED
/* Default value for frame_rate */
#define ILI9341_DEFAULT_FRAME_RATE ILI9341_FRAME_RATE_70 /* 70Hz */
```

The following colors are predefined in the **glcd_ili9341.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ILI9341 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ili9341.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ili9341.h**.
- The **..\EXAMPLES\Graphic Displays\ILI9341** directory contains fully functional code samples that may be used as references for ILI9341 initialization and usage.

5.12.7 Graphic LCD Functions Specific to the PCD8544 Controller

In order to take full advantage of the PCD8544 controller's features, the following specific functions, declared in the **glcd_pcd8544.h** header file, were implemented:

void pcd8544_wrcmd(unsigned char cmd)

Writes a command to the PCD8544 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_pcd8544.h** header file:

```
#define PCD8544_FUNCTION_SET 0x20 /* Function set, horizontal addressing */
/* Puts controller in power-down mode,
   must be combined with PCD8544_FUNCTION_SET */
#define PCD8544_POWER_DOWN 0x04
/* Use extended instruction set,
   must be combined with PCD8544_FUNCTION_SET */
#define PCD8544_EXT_INST 0x01

#define PCD8544_DISPLAY_BLANK 0x08 /* Sets display blank */
#define PCD8544_DISPLAY_NORMAL 0x0C /* Sets display normal mode */
#define PCD8544_DISPLAY_ALL_ON 0x09 /* Sets all display segments on */
#define PCD8544_DISPLAY_INVERSE 0x0D /* Sets inverse video mode */
#define PCD8544_SETX 0x80 /* Sets X address of display RAM */
#define PCD8544_SETY 0x40 /* Sets Y address of display RAM */

/* Extended instruction set enabled by
   PCD8544_FUNCTION_SET+PCD8544_EXT_INST */
#define PCD8544_TEMP_CTRL 0x04 /* Sets temperature coefficient */
#define PCD8544_BIAS_SYSTEM 0x10 /* Sets bias system */
#define PCD8544_VLCD 0x80 /* Sets VLCD value */
```

A detailed description of the above mentioned commands can be found in the PCD8544 datasheet.

void pcd8544_setvlcd(unsigned char vlcd)

Controls the LCD contrast.

Parameter:

vlcd value for the VLCD voltage, allowed range is 0..127.

The **glcd_pcd8544.h** header file also contains the definition of the **GLCDINIT_t** type specific for the PCD8544 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */

    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);

    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char temp_coef:2; /* temperature coefficient
                               bits [0..3] */
    unsigned char bias:3; /* bias system bits [0..7] */
    unsigned char vlcd:7; /* VLCD set bits [0..127] */
} GLCDINIT_t;
```

The detailed description of the above mentioned initialization parameters can be found in the PCD8544 datasheet.

Notes:

- The **glcd_pcd8544.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_pcd8544.h**.
- The **..\EXAMPLES\Graphic Displays\PCD8544** directory contains fully functional code samples that may be used as references for PCD8544 initialization and usage.

5.12.8 Graphic LCD Functions Specific to the RA8875 Controller

The RA8875 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes.

To obtain higher display speed, the 16 bit interface mode is recommended.

The following graphic operations, implemented in the library, use the RA8875 hardware acceleration engine:

- solid line drawing
- triangle drawing and filling
- rectangle drawing and filling
- rectangle with rounded corners drawing and filling
- circle drawing and filling
- ellipse drawing and filling.

In order to take full advantage of the RA8875 controller's features, the following specific functions, declared in the **glcd_ra8875.h** header file, were implemented:

void ra8875_wrreg(unsigned char reg, unsigned char data)

Writes a data byte to a RA8875 controller's register.

Parameters:

reg register to be written

data byte to be written into the register.

The register may take one of the values defined in the following macros from the **glcd_ra8875.h** header file:

```
#define RA8875_STSR 0x00    /* Status Register */
#define RA8875_PWRR 0x01    /* Power and Display Control Register */
#define RA8875_MRWC 0x02    /* Memory Read/Write Command */
#define RA8875_PCSR 0x04    /* Pixel Clock Setting Register */
#define RA8875_SROC 0x05    /* Serial Flash/ROM Configuration Register */
#define RA8875_SFCLR 0x06   /* Serial Flash/ROM CLK Setting Register */
#define RA8875_SYSR 0x10    /* System Configuration Register */
#define RA8875_GPI 0x12     /* General Purpose Input */
#define RA8875_GPO 0x13     /* General Purpose Output */
#define RA8875_HDWR 0x14    /* LCD Horizontal Display Width Register */
#define RA8875_HNDFTR 0x15  /* Horizontal Non-Display Period Fine Tuning
Option Register */
#define RA8875_HNDR 0x16    /* LCD Horizontal Non-Display Period Register
*/
#define RA8875_HSTR 0x17    /* HSYNC Start Position Register */
#define RA8875_HPWR 0x18    /* HSYNC Pulse Width Register */
#define RA8875_VDHR0 0x19   /* LCD Vertical Display Height Register 0 */
#define RA8875_VDHR1 0x1A   /* LCD Vertical Display Height Register 1 */
#define RA8875_VNDR0 0x1B   /* LCD Vertical Non-Display Period
Register 0 */
#define RA8875_VNDR1 0x1C   /* LCD Vertical Non-Display Period
Register 1 */
#define RA8875_VSTR0 0x1D   /* VSYNC Start Position Register 0 */
#define RA8875_VSTR1 0x1E   /* VSYNC Start Position Register 1 */
#define RA8875_VPWR 0x1F    /* VSYNC Pulse Width Register */
#define RA8875_DPCR 0x20    /* Display Configuration Register */
#define RA8875_FNCR0 0x21   /* Font Control Register 0 */
#define RA8875_FNCR1 0x22   /* Font Control Register 1 */
```

```
#define RA8875_CGSR 0x23      /* CGRAM Select Register */
#define RA8875_HOFS0 0x24     /* Horizontal Scroll Offset Register 0 */
#define RA8875_HOFS1 0x25     /* Horizontal Scroll Offset Register 1 */
#define RA8875_VOFS0 0x26     /* Vertical Scroll Offset Register 0 */
#define RA8875_VOFS1 0x27     /* Vertical Scroll Offset Register 1 */
#define RA8875_FLDR 0x29      /* Font Line Distance Setting Register */
#define RA8875_F_CURXL 0x2A   /* Font Write Cursor Horizontal Position
                               Register 0 */
#define RA8875_F_CURXH 0x2B   /* Font Write Cursor Horizontal Position
                               Register 1 */
#define RA8875_F_CURL 0x2C    /* Font Write Cursor Vertical Position
                               Register 0 */
#define RA8875_F_CURXH 0x2D   /* Font Write Cursor Vertical Position
                               Register 1 */
#define RA8875_FWTSR 0x2E     /* Font Write Type Setting Register */
#define RA8875_SFRS 0x2F      /* Serial Font ROM Setting */
#define RA8875_HSAW0 0x30     /* Horizontal Start Point 0 of
                               Active Window */
#define RA8875_HSAW1 0x31     /* Horizontal Start Point 1 of
                               Active Window */
#define RA8875_VSAW0 0x32     /* Vertical Start Point 0 of Active Window */
#define RA8875_VSAW1 0x33     /* Vertical Start Point 1 of Active Window */
#define RA8875_HEAW0 0x34     /* Horizontal End Point 0 of Active Window */
#define RA8875_HEAW1 0x35     /* Horizontal End Point 1 of Active Window */
#define RA8875_VEAW0 0x36     /* Vertical End Point 0 of Active Window */
#define RA8875_VEAW1 0x37     /* Vertical End Point 1 of Active Window */
#define RA8875_HSSW0 0x38     /* Horizontal Start Point 0 of
                               Scroll Window */
#define RA8875_HSSW1 0x39     /* Horizontal Start Point 1 of
                               Scroll Window */
#define RA8875_VSSW0 0x3A     /* Vertical Start Point 0 of Scroll Window */
#define RA8875_VSSW1 0x3B     /* Vertical Start Point 1 of Scroll Window */
#define RA8875_HESW0 0x3C     /* Horizontal End Point 0 of Scroll Window */
#define RA8875_HESW1 0x3D     /* Horizontal End Point 1 of Scroll Window */
#define RA8875_VESW0 0x3E     /* Vertical End Point 0 of Scroll Window */
#define RA8875_VESW1 0x3F     /* Vertical End Point 1 of Scroll Window */
#define RA8875_MWCR0 0x40     /* Memory Write Control Register 0 */
#define RA8875_MWCR1 0x41     /* Memory Write Control Register 1 */
#define RA8875_BTCR 0x44      /* Blink Time Control Register */
#define RA8875_MRCD 0x45      /* Memory Read Cursor Direction */
#define RA8875_CURH0 0x46     /* Memory Write Cursor Horizontal Position
                               Register 0 */
#define RA8875_CURH1 0x47     /* Memory Write Cursor Horizontal Position
                               Register 1 */
#define RA8875_CURL0 0x48     /* Memory Write Cursor Vertical Position
                               Register 0 */
#define RA8875_CURL1 0x49     /* Memory Write Cursor Vertical Position
                               Register 1 */
#define RA8875_RCURH0 0x4A    /* Memory Read Cursor Horizontal Position
                               Register 0 */
#define RA8875_RCURH1 0x4B    /* Memory Read Cursor Horizontal Position
                               Register 1 */
#define RA8875_RCURV0 0x4C    /* Memory Read Cursor Vertical Position
                               Register 0 */
#define RA8875_RCURV1 0x4D    /* Memory Read Cursor Vertical Position
                               Register 1 */
#define RA8875_CURHS 0x4E     /* Font Write Cursor and Memory Write Cursor
                               Horizontal Size Register */
#define RA8875_CURVS 0x4F     /* Font Write Cursor Vertical Size
                               Register */
```

```
#define RA8875_BECR0 0x50 /* BTE Function Control Register 0 */
#define RA8875_BECR1 0x51 /* BTE Function Control Register 1 */
#define RA8875_LTPR0 0x52 /* Layer Transparency Register 0 */
#define RA8875_LTPR1 0x53 /* Layer Transparency Register 1 */
#define RA8875_HSBE0 0x54 /* Horizontal Source Point 0 of BTE */
#define RA8875_HSBE1 0x55 /* Horizontal Source Point 1 of BTE */
#define RA8875_VSBE0 0x56 /* Vertical Source Point 0 of BTE */
#define RA8875_VSBE1 0x57 /* Vertical Source Point 1 of BTE */
#define RA8875_HDBE0 0x58 /* Horizontal Destination Point 0 of BTE */
#define RA8875_HDBE1 0x59 /* Horizontal Destination Point 1 of BTE */
#define RA8875_VDBE0 0x5A /* Vertical Destination Point 0 of BTE */
#define RA8875_VDBE1 0x5B /* Vertical Destination Point 1 of BTE */
#define RA8875_BEWR0 0x5C /* BTE Width Register 0 */
#define RA8875_BEWR1 0x5D /* BTE Width Register 1 */
#define RA8875_BEHR0 0x5E /* BTE Height Register 0 */
#define RA8875_BEHR1 0x5F /* BTE Height Register 1 */
#define RA8875_BGCR0 0x60 /* Background Color Register 0 */
#define RA8875_BGCR1 0x61 /* Background Color Register 1 */
#define RA8875_BGCR2 0x62 /* Background Color Register 2 */
#define RA8875_FGCR0 0x63 /* Foreground Color Register 0 */
#define RA8875_FGCR1 0x64 /* Foreground Color Register 1 */
#define RA8875_FGCR2 0x65 /* Foreground Color Register 2 */
#define RA8875_PTNO 0x66 /* Pattern Set No for BTE */
#define RA8875_BGTR0 0x67 /* Background Color Register for
Transparent 0 */
#define RA8875_BGTR1 0x68 /* Background Color Register for
Transparent 1 */
#define RA8875_BGTR2 0x69 /* Background Color Register for
Transparent 2 */
#define RA8875_TPCR0 0x70 /* Touch Panel Control Register 0 */
#define RA8875_TPCR1 0x71 /* Touch Panel Control Register 1 */
#define RA8875_TPXH 0x72 /* Touch Panel X High Byte Data Register */
#define RA8875_TPYH 0x73 /* Touch Panel Y High Byte Data Register */
#define RA8875_TPYL 0x74 /* Touch Panel X/Y Low Byte Data Register */
#define RA8875_GCHP0 0x80 /* Graphic Cursor Horizontal Position
Register 0 */
#define RA8875_GCHP1 0x81 /* Graphic Cursor Horizontal Position
Register 1 */
#define RA8875_GCVPO 0x82 /* Graphic Cursor Vertical Position
Register 0 */
#define RA8875_GCVPI 0x83 /* Graphic Cursor Vertical Position
Register 1 */
#define RA8875_GCC0 0x84 /* Graphic Cursor Color 0 */
#define RA8875_GCC1 0x85 /* Graphic Cursor Color 1 */
#define RA8875_PLLC1 0x88 /* PLL Control Register 1 */
#define RA8875_PLLC2 0x89 /* PLL Control Register 2 */
#define RA8875_P1CR 0x8A /* PWM1 Control Register */
#define RA8875_P1DCR 0x8B /* PWM1 Duty Cycle Register */
#define RA8875_P2CR 0x8C /* PWM2 Control Register */
#define RA8875_P2DCR 0x8D /* PWM2 Duty Cycle Register */
#define RA8875_MCLR 0x8E /* Memory Clear Control Register */
#define RA8875_DCR 0x90 /* Draw Line/Circle/Square Control
Register */
#define RA8875_DLHSR0 0x91 /* Draw Line/Square Horizontal Start Address
Register 0 */
#define RA8875_DLHSR1 0x92 /* Draw Line/Square Horizontal Start Address
Register 1 */
#define RA8875_DLVSR0 0x93 /* Draw Line/Square Vertical Start Address
Register 0 */
```

```
#define RA8875_DLVSRL 0x94 /* Draw Line/Square Vertical Start Address  
                             Register 1 */  
#define RA8875_DLHER0 0x95 /* Draw Line/Square Horizontal End Address  
                             Register 0 */  
#define RA8875_DLHER1 0x96 /* Draw Line/Square Horizontal End Address  
                             Register 1 */  
#define RA8875_DLVER0 0x97 /* Draw Line/Square Vertical End Address  
                             Register 0 */  
#define RA8875_DLVER1 0x98 /* Draw Line/Square Vertical End Address  
                             Register 1 */  
#define RA8875_DCHR0 0x99 /* Draw Circle Center Horizontal Address  
                             Register 0 */  
#define RA8875_DCHR1 0x9A /* Draw Circle Center Horizontal Address  
                             Register 1 */  
#define RA8875_DCVR0 0x9B /* Draw Circle Center Vertical Address  
                             Register 0 */  
#define RA8875_DCVR1 0x9C /* Draw Circle Center Vertical Address  
                             Register 1 */  
#define RA8875_DCRR 0x9D /* Draw Circle Radius Register */  
#define RA8875_DECSCR 0xA0 /* Draw Ellipse/Ellipse Curve/Circle Square  
                             Control Register */  
#define RA8875_ELL_A0 0xA1 /* Draw Ellipse/Circle Square Long axis  
                             Setting Register 0 */  
#define RA8875_ELL_A1 0xA2 /* Draw Ellipse/Circle Square Long axis  
                             Setting Register 1 */  
#define RA8875_ELL_B0 0xA3 /* Draw Ellipse/Circle Square Short axis  
                             Setting Register 0 */  
#define RA8875_ELL_B1 0xA4 /* Draw Ellipse/Circle Square Short axis  
                             Setting Register 1 */  
#define RA8875_DEHR0 0xA5 /* Draw Ellipse/Circle Square Center  
                             Horizontal Address Register 0 */  
#define RA8875_DEHR1 0xA6 /* Draw Ellipse/Circle Square Center  
                             Horizontal Address Register 1 */  
#define RA8875_DEVR0 0xA7 /* Draw Ellipse/Circle Square Center Vertical  
                             Address Register 0 */  
#define RA8875_DEVR1 0xA8 /* Draw Ellipse/Circle Square Center Vertical  
                             Address Register 1 */  
#define RA8875_DTPH0 0xA9 /* Draw Triangle Point 2 Horizontal Address  
                             Register 0 */  
#define RA8875_DTPH1 0xAA /* Draw Triangle Point 2 Horizontal Address  
                             Register 1 */  
#define RA8875_DTPV0 0xAB /* Draw Triangle Point 2 Vertical Address  
                             Register 0 */  
#define RA8875_DTPV1 0xAC /* Draw Triangle Point 2 Vertical Address  
                             Register 1 */  
#define RA8875_SSAR0 0xB0 /* DMA Source Starting Address Register 0 */  
#define RA8875_SSAR1 0xB1 /* DMA Source Starting Address Register 1 */  
#define RA8875_SSAR2 0xB2 /* DMA Source Starting Address Register 2 */  
#define RA8875_DTNR0 0xB4 /* DMA Transfer Number Register 0 */  
#define RA8875_BWR0 0xB4 /* DMA Block Width Register 0 */  
#define RA8875_BWR1 0xB5 /* DMA Block Width Register 1 */  
#define RA8875_DTNR1 0xB6 /* DMA Transfer Number Register 1 */  
#define RA8875_BHR0 0xB6 /* DMA Block Height Register 0 */  
#define RA8875_BHR1 0xB7 /* DMA Block Height Register 1 */  
#define RA8875_DTNR2 0xB8 /* DMA Transfer Number Register 2 */  
#define RA8875_SPWR0 0xB8 /* DMA Source Picture Width Register 0 */  
#define RA8875_SPWR1 0xB9 /* DMA Source Picture Width Register 1 */  
#define RA8875_DMACR 0xBF /* DMA Configuration Register */  
#define RA8875_KSCR1 0xC0 /* Key-Scan Control Register 1 */  
#define RA8875_KSCR2 0xC1 /* Key-Scan Control Register 2 */
```

```
#define RA8875_KSDR0 0xC2 /* Key-Scan Data Register 0 */
#define RA8875_KSDR1 0xC3 /* Key-Scan Data Register 1 */
#define RA8875_KSDR2 0xC4 /* Key-Scan Data Register 2 */
#define RA8875_GPIOX 0xC7 /* Extra General Purpose IO Register */
#define RA8875_FWSAXA0 0xD0 /* Floating Windows Start Address XA 0 */
#define RA8875_FWSAXA1 0xD1 /* Floating Windows Start Address XA 1 */
#define RA8875_FWSAYA0 0xD2 /* Floating Windows Start Address YA 0 */
#define RA8875_FWSAYA1 0xD3 /* Floating Windows Start Address YA 1 */
#define RA8875_FWW0 0xD4 /* Floating Windows Width 0 */
#define RA8875_FWW1 0xD5 /* Floating Windows Width 1 */
#define RA8875_FWH0 0xD6 /* Floating Windows Height 0 */
#define RA8875_FWH1 0xD7 /* Floating Windows Height 1 */
#define RA8875_FWDXA0 0xD8 /* Floating Windows Display X Address 0 */
#define RA8875_FWDXA1 0xD9 /* Floating Windows Display X Address 1 */
#define RA8875_FWDYA0 0xDA /* Floating Windows Display Y Address 0 */
#define RA8875_FWDYA1 0xDB /* Floating Windows Display Y Address 1 */
#define RA8875_SACS_MODE 0xE0 /* Serial Flash/ROM Direct Access Mode */
#define RA8875_SACS_ADDR 0xE1 /* Serial Flash/ROM Direct Access Mode
                               Address */
#define RA8875_SACS_DATA 0xE2 /* Serial Flash/ROM Direct Access
                               Data Read */
#define RA8875_INTC1 0xF0 /* Interrupt Control Register 1 */
#define RA8875_INTC2 0xF1 /* Interrupt Control Register 2 */
```

unsigned char ra8875_rdreg(unsigned char reg)

Reads a data byte from a RA8875 controller's register.

Parameter:

reg register to be read.

unsigned char ra8875_rdstatus(void)

Reads the status of the RA8875 controller.

The returned status byte will contain the following status bits set/reset, as defined in the **glcd_ra8875.h** header file:

```
#define RA8875_STATUS_MEM_BUSY (1<<7) /* Memory Read/Write busy */
#define RA8875_STATUS_BTE_BUSY (1<<6) /* BTE busy */
#define RA8875_STATUS_TOUCH_EVENT (1<<5) /* Touch panel event detected */
#define RA8875_STATUS_SLEEP (1<<4) /* The controller is in SLEEP mode
*/
#define RA8875_STATUS_FLASH_BUSY (1<<0) /* FLASH/ROM busy in DMA mode */
```

void ra8875_membusy(void)

Waits until the RA8875 controller completes the current memory read/write operation.

void ra8875_btebusy(void)

Waits until the RA8875 controller completes the current BTE operation.

void ra8875_dmabusy(void)

Waits until the RA8875 controller completes the current DMA operation.

void ra8875_memwr(void)

Prepare to start writing to the graphic display memory.

void ra8875_wrddata(GLCDCOL_t color)

Writes color data to the graphic display memory after the **ra8875_memwr** function was executed.

Parameter:

color data to be sent to the controller.

Note: The **ra8875_wrddata** function can be executed multiple times, without the need for a new **ra8875_memwr** function call, until a new command will be issued to one of the RA8875 registers.

void ra8875_memrd(void)

Prepare to start reading from the graphic display memory.

Note: The function also performs the first dummy read.

GLCDCOL_t ra8875_rddata(void)

Reads color data from the graphic display memory after the **ra8875_memrd** function was executed.

Note: The **ra8875_rddata** function can be executed multiple times, without the need for a new **ra8875_memrd** function call, until a new command will be issued to one of the RA8875 registers.

void ra8875_setwindow(GLCDX_t x0, GLCDY_t y0, GLCDX_t x1, GLCDY_t y1)

Sets the current display window.

Parameters:

x0 horizontal coordinate of the left top window corner
y0 vertical coordinate of the left top window corner
x1 horizontal coordinate of the right bottom window corner
y1 vertical coordinate of the right bottom window corner.

void ra8875_setbkcolor(GLCDCOL_t color)

Sets the background color for graphic memory clear operation.

Parameter:

color to be used for background.

void ra8875_setfgcolor(GLCDCOL_t color)

Sets the foreground color for graphic memory fill and drawing operations.

Parameter:

color to be used for foreground.

ra8875_settpcolor(GLCDCOL_t color)

Sets the background transparent color for graphic memory fill and drawing operations.

Parameter:

color to be used as transparent background, for graphic memory fill and drawing operations.

void ra8875_sleep(bool on)

Puts the RA8875 controller in sleep mode or exit from sleep mode.

Parameter:

on when **true** puts the controller in sleep mode, when **false** exits the sleep mode.

Note: The function automatically inserts a 10ms delay after exiting the sleep mode in order to allow the controller's PLL to stabilize itself.

The **glcd_ra8875.h** header file also contains the definition of the **GLCDINIT_t** type specific for the RA8875 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned short osc_clk;    /* external crystal oscillator frequency
15000..30000 [kHz] */
    unsigned short pixel_clk; /* TFT LCD pixel clock frequency [kHz]
*/
} GLCDINIT_t;
```


The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Default value for reverse_x */
#define RA8875_DEFAULT_REVX 0 /* not horizontally reversed

/* Default value for reverse_y */
#define RA8875_DEFAULT_REVY 0 /* not vertically reversed

/* 7" 800x480 ER-TFTM070-5 display from EastRising Technology */
/* Default value for osc_clk external crystal clock frequency [kHz] */
#define RA8875_DEFAULT_OSC_CLK_FREQ 20000
/* TFT LCD pixel clock frequency [kHz] */
#define RA8875_DEFAULT_TFT_PIXEL_CLK_FREQ 30000
```

The following colors are predefined in the **glcd_ra8875.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The RA8875 library functions can operate the display in 256 or 64k color modes.
For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..1 - Blue color bits 0..1
- Bits 2..4 - Green color bits 0..2
- Bits 5..7 - Red color bits 0..2.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ra8875.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ra8875.h**.
- The **..\EXAMPLES\Graphic Displays\RA8875** directory contains fully functional code samples that may be used as references for RA8875 initialization and usage.

5.12.9 Graphic LCD Functions Specific to the S1D13700 Controller

In order to take full advantage of the S1D13700 controller's features, the following specific functions, declared in the **glcd_s1d13700.h** header file, were implemented:

void s1d_wrcmd(unsigned char cmd)

Writes a command to the S1D13700 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_s1d13700.h** header file:

```
#define S1D13700_SYSTEM_SET 0X40 /* Initialize device and display */
#define S1D13700_MWRITE 0X42 /* Write to display memory */
#define S1D13700_MREAD 0X43 /* Read from display memory */
#define S1D13700_SCROLL 0X44 /* Set display start address and display regions */
#define S1D13700_CSRW 0X46 /* Set cursor address */
#define S1D13700_CSRR 0X47 /* Read cursor address */
#define S1D13700_CSRRDIR_RIGHT 0X4C /* Set direction of cursor movement to right */
#define S1D13700_POWER_SAVE 0X53 /* Enter standby mode */
#define S1D13700_DISP_ON_OFF 0X58 /* Enable/disable display and display flashing */
#define S1D13700_HDOT_SCR 0X5A /* Set horizontal scroll position */
#define S1D13700_OVLAY 0X5B /* Set display overlay format */
#define S1D13700_CGRAM_ADDR 0X5C /* Set start address of character generator RAM */
#define S1D13700_CSRFORM 0X5D /* Set cursor type */
#define S1D13700_GRAYSCALE 0X60 /* Set grayscale depth */
```

A detailed description of the above mentioned commands can be found in the S1D13700 datasheet.

void s1d_wrdata(unsigned char data)

Writes a data byte to the S1D13700 controller.

Parameter:

data byte to be sent to the controller.

unsigned char s1d_rddata(void)

Reads a data byte from the S1D13700 controller.

Notes:

- The **glcd_s1d13700.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_s1d13700.h**.
- The **..\EXAMPLES\Graphic Displays\S1D13700** directory contains fully functional code samples that may be used as references for S1D13700 initialization and usage.

5.12.10 Graphic LCD Functions Specific to the S6D0164 Controller

The S6D0164 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit parallel interface mode with 256 or 64k colors.

Both 176x220 (portrait) and 220x176 (landscape) display modes are supported.

In order to take full advantage of the S6D0164 controller's features, the following specific functions, declared in the **glcd_s6d0164.h** header file, were implemented:

void s6d0164_wrcmd(unsigned char cmd)

Writes a command to the S6D0164 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_s6d0164.h** header file:

```
/* S6D0164 command register definitions */
#define S6D0164_CMD_RD_PROD_CODE 0x00 /* Read product code */
#define S6D0164_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define S6D0164_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform
                                           control */
#define S6D0164_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define S6D0164_CMD_DISPLAY_CONTROL 0x07 /* Display control register */
#define S6D0164_CMD_BLANK_PERIOD_CONTROL1 0x08 /* Blank period control
                                                register 1 */
#define S6D0164_CMD_FRAME_CYCLE_CONTROL 0x0b /* Frame cycle control
                                                register */
#define S6D0164_CMD_EXT_IF_CONTROL 0x0c /* External display interface
                                           control register */
#define S6D0164_CMD_START_OSC 0x0f /* Start oscillator register */
#define S6D0164_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define S6D0164_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define S6D0164_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define S6D0164_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define S6D0164_CMD_POWER_CONTROL5 0x14 /* Power control 5 register */
#define S6D0164_CMD_VCI_RECYCLING 0x15 /* VCI recycling period setting
                                           register */
#define S6D0164_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define S6D0164_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define S6D0164_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define S6D0164_CMD_SOFTWARE_RESET 0x28 /* Software reset register */
#define S6D0164_CMD_GATE_SCAN 0x30 /* Gate scan position register */
#define S6D0164_CMD_VERT_SCROLL_CONTROL1_END 0x31 /* Vertical scroll
                                                    control 1 end addr. */
#define S6D0164_CMD_VERT_SCROLL_CONTROL1_START 0x32 /* Vertical scroll
                                                       control 1 start
                                                       addr. */
#define S6D0164_CMD_VERT_SCROLL_CONTROL2 0x33 /* Vertical scroll
                                                    control 2 */
#define S6D0164_CMD_SCREEN_DRIVING_POS_END 0x34 /* Partial Screen end
                                                    driving position */
#define S6D0164_CMD_SCREEN_DRIVING_POS_START 0x35 /* Partial Screen start
                                                       driving position */
```

```
#define S6D0164_CMD_HORIZ_RAM_ADDR_END 0x36 /* Address of horizontal
                                              end window position */
#define S6D0164_CMD_HORIZ_RAM_ADDR_START 0x37 /* Address of horizontal
                                              start window position */
#define S6D0164_CMD_VERT_RAM_ADDR_END 0x38 /* Address of vertical end
                                              window position */
#define S6D0164_CMD_VERT_RAM_ADDR_START 0x39 /* Address of vertical start
                                              window position */

#define S6D0164_CMD_GAMMA_CONTROL1 0x50 /* Gamma control 1 */
#define S6D0164_CMD_GAMMA_CONTROL2 0x51 /* Gamma control 2 */
#define S6D0164_CMD_GAMMA_CONTROL3 0x52 /* Gamma control 3 */
#define S6D0164_CMD_GAMMA_CONTROL4 0x53 /* Gamma control 4 */
#define S6D0164_CMD_GAMMA_CONTROL5 0x54 /* Gamma control 5 */
#define S6D0164_CMD_GAMMA_CONTROL6 0x55 /* Gamma control 6 */
#define S6D0164_CMD_GAMMA_CONTROL7 0x56 /* Gamma control 7 */
#define S6D0164_CMD_GAMMA_CONTROL8 0x57 /* Gamma control 8 */
#define S6D0164_CMD_GAMMA_CONTROL9 0x58 /* Gamma control 9 */
#define S6D0164_CMD_GAMMA_CONTROL10 0x59 /* Gamma control 10 */
```

A detailed description of the above mentioned command registers can be found in the S6D0164 datasheet.

void s6d0164_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the S6D0164 controller.

Parameters:

index command register index
data to be written.

unsigned short s6d0164_rdreg(unsigned char index)

Reads the contents of a command register of the S6D0164 controller.

Parameters:

index command register index.

void s6d0164_wrdata(unsigned short data)

Writes data to the S6D0164 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short s6d0164_rddata(void)

Reads data from the S6D0164 controller's Graphic Display RAM.

The **glcd_s6d0164.h** header file also contains the definition of the **GLCDINIT_t** type specific for the S6D0164 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from
       external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to
       external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */
    unsigned char lcd_type:1; /* LCD type =0 normally black,
                               =1 normally white */
    unsigned char vci1:4; /* VCI1 voltage */
    unsigned char vcoml:7; /* VCOML=GVDD*(0.534+0.006*(vcoml-15))
                           [V] */
    unsigned char vcomh:7; /* VCOMH=GVDD*(0.4015+0.0055*vcomh) [V] */
    unsigned char gamma_voltage:7; /* GVDD=2.50+gamma_voltage*0.02
                                     [V] */

    /* pointer to an array located in FLASH memory
       which contains gamma control adjustment
       values for registers 1..10 */
    flash unsigned short *gamma_control;
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define S6D0164_REVX_NORM 0 /* No horizontal reverse */
#define S6D0164_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define S6D0164_REVY_NORM 0 /* No vertical reverse */
#define S6D0164_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define S6D0164_CL_BITS_RGB 0 /* Write color bits to display RAM in RGB
order */
#define S6D0164_CL_BITS_BGR 1 /* Write color bits to display RAM in BGR
order */

/* Initialization values for lcd_type */
#define S6D0164_LCD_TYPE_BLACK 0
#define S6D0164_LCD_TYPE_WHITE 1

/* Initialization values for vci1 */
#define S6D0164_VCI1_1_35V 0 /* VCI1=1.35V */
#define S6D0164_VCI1_1_75V 1 /* VCI1=1.75V */
#define S6D0164_VCI1_2_07V 2 /* VCI1=2.07V */
#define S6D0164_VCI1_2_16V 3 /* VCI1=2.16V */
#define S6D0164_VCI1_2_25V 4 /* VCI1=2.25V */
#define S6D0164_VCI1_2_34V 5 /* VCI1=2.34V */
```

```
#define S6D0164_VCI1_2_43V 6 /* VCI1=2.43V */
#define S6D0164_VCI1_2_52V 7 /* VCI1=2.52V */
#define S6D0164_VCI1_2_58V 8 /* VCI1=2.58V */
#define S6D0164_VCI1_2_64V 9 /* VCI1=2.64V */
#define S6D0164_VCI1_2_70V 10 /* VCI1=2.70V */
#define S6D0164_VCI1_2_76V 11 /* VCI1=2.76V */
#define S6D0164_VCI1_2_82V 12 /* VCI1=2.82V */
#define S6D0164_VCI1_2_88V 13 /* VCI1=2.88V */
#define S6D0164_VCI1_2_94V 14 /* VCI1=2.94V */
#define S6D0164_VCI1_3_00V 15 /* VCI1=3.00V */

/* Default value for reverse_x */
#define S6D0164_DEFAULT_REVX S6D0164_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define S6D0164_DEFAULT_REVY S6D0164_REVY_NORM /* No vertical reverse */
/* Default value for cl_bits_order
   (color bits writing order to display RAM) */
#define S6D0164_DEFAULT_CL_BITS S6D0164_CL_BITS_RGB /* write in
                                                         RGB order */

/* Default value for lcd_type */
#define S6D0164_DEFAULT_LCD_TYPE S6D0164_LCD_TYPE_WHITE
/* Default value for vci1 */
#define S6D0164_DEFAULT_VCI1 S6D0164_VCI1_2_70V
/* Default value for vcoml */
#define S6D0164_DEFAULT_VCOML 0x49
/* Default value for vcomh */
#define S6D0164_DEFAULT_VCOMH 0x42
/* Default value for gamma_voltage */
#define S6D0164_DEFAULT_GAMMA_VOLTAGE 0x6c
/* Use the default initialization values, stored in the library,
   for the gamma control registers */
#define S6D0164_DEFAULT_GAMMA 0
```

The following colors are redefined in the **glcd_s6d0164.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The S6D0164 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_s6d0164.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_s6d0164.h**.
- The **..\EXAMPLES\Graphic Displays\S6D0164** directory contains fully functional code samples that may be used as references for S6D0164 initialization and usage.

5.12.11 Graphic LCD Functions Specific to the S6D1121 Controller

The S6D1121 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 bit interface mode with 256 or 64k colors.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the S6D1121 controller's features, the following specific functions, declared in the **glcd_s6d1121.h** header file, were implemented:

void s6d1121_wrcmd(unsigned char cmd)

Writes a command to the S6D1121 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_s6d1121.h** header file:

```
/* S6D1121 command register definitions */
#define S6D1121_CMD_RD_PROD_CODE 0x00 /* Read product code */
#define S6D1121_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define S6D1121_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform
                                           control */
#define S6D1121_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define S6D1121_CMD_OSC_CONTROL 0x04 /* Oscillator control register */
#define S6D1121_CMD_DISPLAY_CONTROL1 0x07 /* Display control register 1 */
#define S6D1121_CMD_DISPLAY_CONTROL2 0x08 /* Display control register 2 */
#define S6D1121_CMD_FRAME_CYCLE_CONTROL1 0x0a /* Frame cycle control 1 */
#define S6D1121_CMD_FRAME_CYCLE_CONTROL2 0x0b /* Frame cycle control 2 */
#define S6D1121_CMD_EXT_IF_CONTROL 0x0c /* External display interface
                                           control register */
#define S6D1121_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define S6D1121_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define S6D1121_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define S6D1121_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define S6D1121_CMD_POWER_CONTROL5 0x14 /* Power control 5 register */
#define S6D1121_CMD_POWER_CONTROL6 0x15 /* Power control 6 register */
#define S6D1121_CMD_POWER_CONTROL7 0x16 /* Power control 7 register */
#define S6D1121_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define S6D1121_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define S6D1121_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define S6D1121_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define S6D1121_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define S6D1121_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define S6D1121_CMD_GAMMA_CONTROL4 0x33 /* Gamma control 4 */
#define S6D1121_CMD_GAMMA_CONTROL5 0x34 /* Gamma control 5 */
#define S6D1121_CMD_GAMMA_CONTROL6 0x35 /* Gamma control 6 */
#define S6D1121_CMD_GAMMA_CONTROL7 0x36 /* Gamma control 7 */
#define S6D1121_CMD_GAMMA_CONTROL8 0x37 /* Gamma control 8 */
#define S6D1121_CMD_GAMMA_CONTROL9 0x38 /* Gamma control 9 */
#define S6D1121_CMD_GAMMA_CONTROL10 0x39 /* Gamma control 10 */
#define S6D1121_CMD_GAMMA_CONTROL11 0x3a /* Gamma control 11 */
#define S6D1121_CMD_GAMMA_CONTROL12 0x3b /* Gamma control 12 */
#define S6D1121_CMD_GAMMA_CONTROL13 0x3c /* Gamma control 13 */
#define S6D1121_CMD_GAMMA_CONTROL14 0x3d /* Gamma control 14 */
#define S6D1121_CMD_VERT_SCROLL_CONTROL 0x41 /* Vertical scroll control */
```



```
#define S6D1121_CMD_SCREEN1_DRIVING_POS_START 0x42 /* Screen 1 driving
                                                    position start */
#define S6D1121_CMD_SCREEN1_DRIVING_POS_END 0x43 /* Screen 1 driving
                                                    position end */
#define S6D1121_CMD_SCREEN2_DRIVING_POS_START 0x44 /* Screen 2 driving
                                                    position start */
#define S6D1121_CMD_SCREEN2_DRIVING_POS_END 0x45 /* Screen 2 driving
                                                    position end */
#define S6D1121_CMD_HORIZ_RAM_ADDR_START_END 0x46 /* Address of horizontal
                                                    start/end window
                                                    positions */
#define S6D1121_CMD_VERT_RAM_ADDR_END 0x47 /* Address of vertical end
                                                    window positions */
#define S6D1121_CMD_VERT_RAM_ADDR_START 0x48 /* Address of vertical start
                                                    window positions */
#define S6D1121_CMD_MDDI_WAKEUP_CONTROL 0x50 /* MDDI wake up control */
#define S6D1121_CMD_MDDI_WAKEUP_START 0x51 /* MDDI wake up start
                                                    position */
#define S6D1121_CMD_SUBPANEL_CONTROL1 0x52 /* Sub panel control 1 */
#define S6D1121_CMD_SUBPANEL_CONTROL2 0x53 /* Sub panel control 2 */
#define S6D1121_CMD_SUBPANEL_CONTROL3 0x54 /* Sub panel control 3 */
#define S6D1121_CMD_GPIO_CONTROL1 0x55 /* GPIO control 1 */
#define S6D1121_CMD_GPIO_CONTROL2 0x56 /* GPIO control 2 */
#define S6D1121_CMD_GPIO_CONTROL3 0x57 /* GPIO control 3 */
#define S6D1121_CMD_GPIO_CONTROL4 0x58 /* GPIO control 4 */
#define S6D1121_CMD_GPIO_CONTROL5 0x59 /* GPIO control 5 */
#define S6D1121_CMD_MTP_CONTROL 0x60 /* Multi Time Programmable
                                        control */
#define S6D1121_CMD_MTP_RD_VCOMH 0x61 /* Multi Time Programmable read
                                        VCOMH */
#define S6D1121_CMD_MTP_TEST_KEY 0x62 /* Multi Time Programmable test
                                        key */
#define S6D1121_CMD_GOE_TIMING_CONTROL 0x70 /* GOE start/end timing
                                        control */
#define S6D1121_CMD_GSP_CLK_DELAY_CONTROL 0x71 /* GSP clock delay
                                        control */
#define S6D1121_CMD_VCOM_OUTPUT_CONTROL 0x78 /* VCOM output control */
#define S6D1121_CMD_PANEL_SIG_CONTROL1 0x79 /* Panel signal control 1 */
#define S6D1121_CMD_PANEL_SIG_CONTROL2 0x7A /* Panel signal control 2 */
```

A detailed description of the above mentioned command registers can be found in the S6D1121 datasheet.

void s6d1121_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the S6D1121 controller.

Parameters:

index command register index
data to be written.

unsigned short s6d1121_rdreg(unsigned char index)

Reads the contents of a command register of the S6D1121 controller.

Parameters:

index command register index.

void s6d1121_wrdata(unsigned short data)

Writes data to the S6D1121 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short s6d1121_rddata(void)

Reads data from the S6D1121 controller's Graphic Display RAM.

The **glcd_s6d1121.h** header file also contains the definition of the **GLCDINIT_t** type specific for the S6D1121 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */
    unsigned char lcd_type:1; /* LCD type =0 normally black,
                               =1 normally white */
    unsigned char vcil:3; /* VCI1 voltage */
    unsigned char vcoml:6; /* VCOML=2.52+vcoml*0.04 [V] */
    unsigned char vcomh:6; /* VCOMH=3.52+(vcomh-10)*0.033 [V] */
    unsigned char vcomdc:6; /* VCOMDC=2.40+vcomdc*0.03125 [V] */
    unsigned char gamma_voltage:6; /* GVDD=3+gamma_voltage*0.03 [V] */
    /* pointer to an array located in FLASH memory
       which contains gamma control adjustment
       values for registers 1..14 */
    flash unsigned short *gamma_control;
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define S6D1121_REVX_NORM 0 /* No horizontal reverse */
#define S6D1121_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define S6D1121_REVY_NORM 0 /* No vertical reverse */
#define S6D1121_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define S6D1121_CL_BITS_RGB 0 /* Write color bits to display RAM
                               in RGB order */
#define S6D1121_CL_BITS_BGR 1 /* Write color bits to display RAM
                               in BGR order */

/* Initialization values for lcd_type */
#define S6D1121_LCD_TYPE_BLACK 0
#define S6D1121_LCD_TYPE_WHITE 1

/* Initialization values for vci1 */
#define S6D1121_VCI1_0_68VCIREF 0 /* VCI1=0.68xVCI_REF */
#define S6D1121_VCI1_0_83VCIREF 1 /* VCI1=0.83xVCI_REF */
#define S6D1121_VCI1_0_92VCIREF 2 /* VCI1=0.92xVCI_REF */
#define S6D1121_VCI1_1_00VCIREF 3 /* VCI1=1.00xVCI_REF */
#define S6D1121_VCI1_0_575VCIREF 4 /* VCI1=0.575xVCI_REF */

/* Default value for reverse_x */
#define S6D1121_DEFAULT_REVX S6D1121_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define S6D1121_DEFAULT_REVY S6D1121_REVY_NORM /* No vertical reverse */
/* Default value for cl_bits_order (color bits writing order to
   display RAM): write in RGB order */
#define S6D1121_DEFAULT_CL_BITS S6D1121_CL_BITS_RGB
/* Default value for lcd_type */
#define S6D1121_DEFAULT_LCD_TYPE S6D1121_LCD_TYPE_WHITE
/* Default value for vci1 */
#define S6D1121_DEFAULT_VCI1 S6D1121_VCI1_1_00VCIREF
/* Default value for vcoml */
#define S6D1121_DEFAULT_VCOML 0x2A
/* Default value for vcomh */
#define S6D1121_DEFAULT_VCOMH 0x26
/* Default value for vcomdc */
#define S6D1121_DEFAULT_VCOMDC 0x25
/* Default value for gamma_voltage */
#define S6D1121_DEFAULT_GAMMA_VOLTAGE 0x20
/* Use the default initialization values, stored in the library,
   for the gamma control registers */
#define S6D1121_DEFAULT_GAMMA 0
```

The following colors are redefined in the **glcd_s6d1121.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The S6D1121 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_s6d1121.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_s6d1121.h**.
- The **..\EXAMPLES\Graphic Displays\S6D1121** directory contains fully functional code samples that may be used as references for S6D1121 initialization and usage.

5.12.12 Graphic LCD Functions Specific to the SED1335 Controller

In order to take full advantage of the SED1335 controller's features, the following specific functions, declared in the **glcd_sed1335.h** header file, were implemented:

void sed1335_wrcmd(unsigned char cmd)

Writes a command to the SED1335 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_sed1335.h** header file:

```
#define SED1335_SYSTEM_SET 0X40 /* Initialize device and display */
#define SED1335_MWRITE 0X42 /* Write to display memory */
#define SED1335_MREAD 0X43 /* Read from display memory */
#define SED1335_SCROLL 0X44 /* Set display start address and display
                             regions */
#define SED1335_CSRW 0X46 /* Set cursor address */
#define SED1335_CSRR 0X47 /* Read cursor address */
#define SED1335_CSRDIR_RIGHT 0X4C /* Set direction of cursor movement
                                   to right */
#define SED1335_SLEEP_IN 0X53 /* Enter standby mode */
#define SED1335_DISP_ON_OFF 0X58 /* Enable/disable display and
                                   display flashing */
#define SED1335_HDOT_SCR 0X5A /* Set horizontal scroll position */
#define SED1335_OVLAY 0X5B /* Set display overlay format */
#define SED1335_CGRAM_ADDR 0X5C /* Set start address of character
                                   generator RAM */
#define SED1335_CSRFORM 0X5D /* Set cursor type */
```

A detailed description of the above mentioned commands can be found in the SED1335 datasheet.

void sed1335_wrdata(unsigned char data)

Writes a data byte to the SED1335 controller.

Parameter:

data byte to be sent to the controller.

unsigned char sed1335_rddata(void)

Reads a data byte from the SED1335 controller.

void sed1335_fastmode(unsigned char on)

Specifies if the BUSY flag should be tested on data read/write in order to reduce display flicker.

Parameter:

on if set to a non-zero value specifies that the BUSY flag will not be tested in order to increase display speed, however flicker will appear.

Notes:

- When the **glcd_init** function is called, it enables BUSY flag testing, so that the display will not flicker.
- The **glcd_sed1335.h** header file is automatically #included when the main **glcd.h** header file is #included. Therefore there is no need to explicitly #include **glcd_sed1335.h**.
- The **..\EXAMPLES\Graphic Displays\SED1335** directory contains fully functional code samples that may be used as references for SED1335 initialization and usage.

5.12.13 Graphic LCD Functions Specific to the SED1530 Controller

In order to take full advantage of the SED1530 controller's features, the following specific functions, declared in the `glcd_sed1530.h` header file, were implemented:

void sed1530_wrcmd(unsigned char cmd)

Writes a command to the SED1530 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the `glcd_sed1530.h` header file:

```
#define SED1530_CMD_START_LINE 0x40 /* set display start line */
#define SED1530_CMD_SET_PAGE 0xB0 /* set display page address */
#define SED1530_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define SED1530_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define SED1530_CMD_ADC_SELECT_NORM 0xA0 /* set relationship between RAM
column address and display
driver: normal */
#define SED1530_CMD_ADC_SELECT_REV 0xA1 /* set relationship between RAM
column address and display
driver: reversed */
#define SED1530_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define SED1530_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define SED1530_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
contents */
#define SED1530_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define SED1530_CMD_DISP_OFF 0xAE /* display off */
#define SED1530_CMD_DISP_ON 0xAF /* display on */
#define SED1530_CMD_LCD_BIAS_16 0xA2 /* sets voltage ratio for LCD bias
to 1/6 */
#define SED1530_CMD_LCD_BIAS_15 0xA3 /* sets voltage ratio for LCD bias
to 1/5 */
#define SED1530_CMD_COM0_63 0xC0 /* sets the COM output scan
direction 0->63 */
#define SED1530_CMD_COM63_0 0xC8 /* sets the COM output scan
direction 63->0 */
#define SED1530_CMD_POWER_CTRL 0x28 /* turns on/off the
voltage follower (| bit 0),
voltage regulator (| bit 1),
voltage booster (| bit 2) */
#define SED1530_VOLT_FOLLOWER_ON (1<<0) /* enable voltage follower */
#define SED1530_VOLT_REGULATOR_ON (1<<1) /* enable voltage regulator */
#define SED1530_VOLT_BOOSTER_ON (1<<2) /* enable voltage booster */

#define SED1530_CMD_ELECTRONIC_VOLUME 0x80 /* sets the electronic volume
register in order to control
the V5 LCD drive voltage */
#define SED1530_CMD_RESET 0xE2 /* resets the controller */
```

A detailed description of the above mentioned commands can be found in the SED1530 datasheet.

void sed1530_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the V5 LCD drive voltage, allowed range is 0..31.

The **glcd_sed1530.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SED1530 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char lcd_bias:1; /* =0 1/6 LCD bias, =1 1/5 LCD bias */
    unsigned char reverse_x:1; /* reverse display horizontally (ADC) */
    unsigned char rev132_x0:1; /* set to 1 for displays that use
                               reversed RAM column address
                               (reverse_x=1) driver and the pixel
                               with x=0 is connected to column
                               driver #132 */
    unsigned char reverse_y:1; /* reverse display vertically (COM) */
    unsigned char lcd_contrast:4; /* V5 LCD drive voltage: [0..31] */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for lcd_bias initialization */
#define SED1530_LCD_BIAS_16 0 /* sets LCD bias drive ratio 1/6 */
#define SED1530_LCD_BIAS_15 1 /* sets LCD bias drive ratio 1/5 */

/* values used for reverse_x initialization */
#define SED1530_REVX_NORM 0 /* set relationship between RAM column address
                             and display driver: normal (ADC=0) */
#define SED1530_REVX_REV 1 /* set relationship between RAM column address
                             and display driver: reversed (ADC=1) */

/* values used for rev132_x0 initialization,
   effective only when reverse_x=1 (SED1530_REVX_REV) */
#define SED1530_REV132_X0NC 0 /* pixel with x=0 is not connected to
                               column driver #132 when ADC=1 */
#define SED1530_REV132_X0CON 1 /* pixel with x=0 is connected to
                               column driver #132 when ADC=1 */

/* values used for reverse_y initialization */
#define SED1530_REVY_NORM 0 /* sets the vertical COM output scan
                             direction 0->63 */
#define SED1530_REVY_REV 1 /* sets the vertical COM output scan
                             direction 63->0 */
```



```
/* default initialization values */
/* default value for LCD bias */
#define SED1530_DEFAULT_LCD_BIAS SED1530_LCD_BIAS_16
/* default value for reverse_x */
#define SED1530_DEFAULT_REVX SED1530_REVX_NORM
/* default value for rev132_x0,
   effective only when reverse_x=1 (SED1530_REVX_REV) */
#define SED1530_DEFAULT_REV132_X0 SED1530_REV132_X0NC
/* default value for reverse_y */
#define SED1530_DEFAULT_REVY SED1530_REVY_NORM
/* default contrast */
#define SED1530_DEFAULT_CONTRAST 7
```

The detailed description of the above mentioned initialization parameters can be found in the SED1530 datasheet.

Notes:

- The **glcd_sed1530.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_sed1530.h**.
- The **..\EXAMPLES\Graphic Displays\SED1530** directory contains fully functional code samples that may be used as references for SED1530 initialization and usage.

5.12.14 Graphic LCD Functions Specific to the SPLC501C Controller

In order to take full advantage of the SPLC501C controller's features, the following specific functions, declared in the **glcd_splc501.h** header file, were implemented:

void splc501_wrcmd(unsigned char cmd)

Writes a command to the SPLC501C controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_splc501.h** header file:

```
#define SPLC501_CMD_START_LINE 0x40 /* set display start line */
#define SPLC501_CMD_SET_PAGE 0xB0 /* set display page address */
#define SPLC501_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define SPLC501_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define SPLC501_CMD_ADC_SELECT_NORM 0xA0 /* set relationship between
RAM column address and display
driver: normal */
#define SPLC501_CMD_ADC_SELECT_REV 0xA1 /* set relationship between
RAM column address and display
driver: reversed */
#define SPLC501_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define SPLC501_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define SPLC501_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
contents */
#define SPLC501_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define SPLC501_CMD_DISP_OFF 0xAE /* display off */
#define SPLC501_CMD_DISP_ON 0xAF /* display on */
#define SPLC501_CMD_LCD_BIAS_19 0xA2 /* sets voltage ratio for LCD bias
to 1/9 */
#define SPLC501_CMD_LCD_BIAS_17 0xA3 /* sets voltage ratio for LCD bias
to 1/7 */
#define SPLC501_CMD_COM0_63 0xC0 /* sets the COM output scan
direction 0->63 */
#define SPLC501_CMD_COM63_0 0xC8 /* sets the COM output scan
direction 63->0 */
#define SPLC501_CMD_POWER_CTRL 0x28 /* turns on/off the
voltage follower (| bit 0),
voltage regulator (| bit 1),
voltage booster (| bit 2) */
#define SPLC501_VOLT_FOLLOWER_ON (1<<0) /* enable voltage follower */
#define SPLC501_VOLT_REGULATOR_ON (1<<1) /* enable voltage regulator */
#define SPLC501_VOLT_BOOSTER_ON (1<<2) /* enable voltage booster */
#define SPLC501_CMD_VOLT_REG_V5 0x20 /* sets the V5 voltage regulator
internal resistor ratio */
#define SPLC501_CMD_ELECTRONIC_VOLUME 0x81 /* sets the electronic volume
register in order to control
the V5 LCD drive voltage */
#define SPLC501_CMD_SET_DRIVING_MODE 0xD2 /* used to set the LCD driving
mode */
#define SPLC501_CMD_RESET 0xE2 /* resets the controller */
```

A detailed description of the above mentioned commands can be found in the SPLC501C datasheet.

void splc501_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the V5 LCD drive voltage, allowed range is 0..63.

The **glcd_splc501.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SPLC501C controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char lcd_bias:1; /* =0 1/9 LCD bias, =1 1/7 LCD bias */
    unsigned char lcd_bias:1; /* =0 1/6 LCD bias, =1 1/5 LCD bias */
    unsigned char reverse_x:1; /* reverse display horizontally (ADC) */
    unsigned char rev132_x0:1; /* set to 1 for displays that use
                               reversed RAM column address
                               (reverse_x=1) driver and the pixel
                               with x=0 is connected to column
                               driver #132 */
    unsigned char reverse_y:1; /* reverse display vertically (COM) */
    unsigned char volt_reg_v5:3; /* set V5 voltage regulator internal
                               resistor ratio [0..7] */
    unsigned char driving_mode:2; /* set LCD driving mode:
                                0 - mode 1, 1 - mode 2,
                                2 - mode 3, 3 - mode 4 */
    unsigned char lcd_contrast:5; /* LCD contrast voltage: [0..63] */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for lcd_bias initialization */
#define SPLC501_LCD_BIAS_19 0 /* sets LCD bias drive ratio 1/9 */
#define SPLC501_LCD_BIAS_17 1 /* sets LCD bias drive ratio 1/7 */

/* values used for reverse_x initialization */
#define SPLC501_REVX_NORM 0 /* set relationship between RAM column address
and display driver: normal (ADC=0) */
#define SPLC501_REVX_REV 1 /* set relationship between RAM column address
and display driver: reversed (ADC=1) */

/* values used for rev132_x0 initialization,
   effective only when reverse_x=1 (SPLC501_REVX_REV) */
#define SPLC501_REV132_X0NC 0 /* pixel with x=0 is not connected to column
driver #132 when ADC=1 */
#define SPLC501_REV132_X0CON 1 /* pixel with x=0 is connected to column
driver #132 when ADC=1 */
```

```
/* values used for reverse_y initialization */
#define SPLC501_REVY_NORM 0 /* sets the vertical COM output scan direction
0->63 */
#define SPLC501_REVY_REV 1 /* sets the vertical COM output scan direction
63->0 */

/* values used for driving_mode initialization */
#define SPLC501_DRIVING_MODE1 0 /* driving mode 1 */
#define SPLC501_DRIVING_MODE2 1 /* driving mode 2 */
#define SPLC501_DRIVING_MODE3 2 /* driving mode 3 */
#define SPLC501_DRIVING_MODE4 3 /* driving mode 4 */

/* default initialization values */
/* default value for LCD bias */
#define SPLC501_DEFAULT_LCD_BIAS SPLC501_LCD_BIAS_19
/* default value for reverse_x */
#define SPLC501_DEFAULT_REVX SPLC501_REVX_NORM
/* default value for rev132_x0,
    effective only when reverse_x=1 (SPLC501_REVX_REV) */
#define SPLC501_DEFAULT_REV132_X0 SPLC501_REV132_X0NC
/* default value for reverse_y */
#define SPLC501_DEFAULT_REVY SPLC501_REVY_NORM
/* default V5 voltage regulator internal resistor ratio */
#define SPLC501_DEFAULT_VOLT_REG_V5 6
/* default LCD driving mode */
#define SPLC501_DEFAULT_DRIVING_MODE SPLC501_DRIVING_MODE1
/* default contrast */
#define SPLC501_DEFAULT_CONTRAST 7
```

The detailed description of the above mentioned initialization parameters can be found in the SPLC501C datasheet.

Notes:

- The **glcd_spic501.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_spic501.h**.
- The **..\EXAMPLES\Graphic Displays\SPLC501C** directory contains fully functional code samples that may be used as references for SPLC501C initialization and usage.

5.12.15 Graphic LCD Functions Specific to the SSD1289 Controller

The SSD1289 library functions supplied with the CodeVisionAVR Advanced license, operate the controller in 8 and 16 bit interface modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the SSD1289 controller's features, the following specific functions, declared in the **glcd_ssd1289.h** header file, were implemented:

void ssd1289_wrcmd(unsigned char cmd)

Writes a command to the SSD1289 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_ssd1289.h** header file:

```
/* SSD1289 command register definitions */
#define SSD1289_CMD_OSC 0x00 /* Oscillator register */
#define SSD1289_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define SSD1289_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform
                                           control */
#define SSD1289_CMD_POWER_CONTROL1 0x03 /* Power control 1 */
#define SSD1289_CMD_CMP_REG1 0x05 /* Compare register 1 */
#define SSD1289_CMD_CMP_REG2 0x06 /* Compare register 2 */
#define SSD1289_CMD_DISPLAY_CONTROL 0x07 /* Display control register */
#define SSD1289_CMD_FRAME_CYCLE 0x0b /* Frame cycle control register */
#define SSD1289_CMD_POWER_CONTROL2 0x0c /* Power control 2 register */
#define SSD1289_CMD_POWER_CONTROL3 0x0d /* Power control 3 register */
#define SSD1289_CMD_POWER_CONTROL4 0x0e /* Power control 4 register */
#define SSD1289_CMD_GATE_SCAN_POS 0x0f /* Gate scan position register */
#define SSD1289_CMD_SLEEP_MODE 0x10 /* Sleep mode register */
#define SSD1289_CMD_ENTRY_MODE 0x11 /* Entry mode register */
#define SSD1289_CMD_GENERIC_IF_CTRL 0x15 /* Generic interface control
                                           register */
#define SSD1289_CMD_HORIZ_PORCH 0x16 /* Horizontal porch register */
#define SSD1289_CMD_VERT_PORCH 0x17 /* Vertical porch register */
#define SSD1289_CMD_POWER_CONTROL5 0x1e /* Power control 5 register */
#define SSD1289_CMD_GDDRAM_DATA 0x22 /* GDDRAM read/write data register */
#define SSD1289_CMD_GDDRAM_WR_MASK1 0x23 /* GDDRAM write data mask 1
                                           register */
#define SSD1289_CMD_GDDRAM_WR_MASK2 0x24 /* GDDRAM write data mask 2
                                           register */
#define SSD1289_CMD_FRAME_FREQ 0x25 /* Frame frequency control register */
#define SSD1289_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define SSD1289_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define SSD1289_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define SSD1289_CMD_GAMMA_CONTROL4 0x33 /* Gamma control 4 */
#define SSD1289_CMD_GAMMA_CONTROL5 0x34 /* Gamma control 5 */
#define SSD1289_CMD_GAMMA_CONTROL6 0x35 /* Gamma control 6 */
#define SSD1289_CMD_GAMMA_CONTROL7 0x36 /* Gamma control 7 */
#define SSD1289_CMD_GAMMA_CONTROL8 0x37 /* Gamma control 8 */
#define SSD1289_CMD_GAMMA_CONTROL9 0x3a /* Gamma control 9 */
#define SSD1289_CMD_GAMMA_CONTROL10 0x3b /* Gamma control 10 */
```

```
#define SSD1289_CMD_VERT_SCROLL1 0x41 /* Vertical scroll control for
                                         screen 1 */
#define SSD1289_CMD_VERT_SCROLL2 0x42 /* Vertical scroll control for
                                         screen 2 */
#define SSD1289_CMD_HORIZ_RAM_ADDR 0x44 /* Addresses of horizontal
                                         start/end window positions */
#define SSD1289_CMD_VERT_RAM_ADDR_START 0x45 /* Address of vertical start
                                         window positions */
#define SSD1289_CMD_VERT_RAM_ADDR_END 0x46 /* Address of vertical end
                                         window positions */
#define SSD1289_CMD_DRV_POS_START1 0x48 /* Driving start line position for
                                         screen 1 */
#define SSD1289_CMD_DRV_POS_END1 0x49 /* Driving end line position for
                                         screen 1 */
#define SSD1289_CMD_DRV_POS_START2 0x4a /* Driving start line position for
                                         screen 2 */
#define SSD1289_CMD_DRV_POS_END2 0x4b /* Driving end line position for
                                         screen 2 */
#define SSD1289_CMD_GDDRAMX 0x4e /* Set GDDRAM X address counter
                                         register */
#define SSD1289_CMD_GDDRAMY 0x4f /* Set GDDRAM Y address counter
                                         register
```

A detailed description of the above mentioned command registers can be found in the SSD1289 datasheet.

void ssd1289_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the SSD1289 controller.

Parameters:

index command register index
data to be written.

unsigned short ssd1289_rdreg(unsigned char index)

Reads the contents of a command register of the SSD1289 controller.

Parameters:

index command register index.

void ssd1289_wrdata(unsigned short data)

Writes data to the SSD1289 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short ssd1289_rddata(void)

Reads data from the SSD1289 controller's Graphic Display RAM.

The `glcd_ssd1289.h` header file also contains the definition of the `GLCDINIT_t` type specific for the SSD1289 controller, used as parameter for the `glcd_init` function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */

    /* power control registers bits */
    unsigned char stepup_factor:3; /* step-up factor of the step-up
                                     circuit, see BT0..BT2 bits in
                                     the datasheet */
    unsigned char stepup_cycle:4; /* controls the cycle for the
                                     step-up circuit */
    unsigned char crt_source:3; /* adjusts the amount of current
                                   from the constant current source
                                   in the internal op. amplifier
                                   circuit (AP0..AP2 bits) */
    unsigned char vcix2:3; /* adjusts the VCIX2 voltage */
    unsigned char vlcd63:4; /* adjusts the VLCD63 voltage */
    unsigned char vcoml:5; /* adjusts the amplitude of the
                             VcomL alternating drive voltage */
    unsigned char vcomh:5; /* adjusts the amplitude of the VcomH
                             voltage
                              $VcomH = VLCD63 * (0.35 + vcomh * 0.01)$  [V] */
    unsigned char frame_freq:4; /* LCD frame frequency */
    /* positive gamma control registers bits */
    unsigned char pkp00:3; /* PKP00..PKP02 positive gamma micro adj. */
    unsigned char pkp10:3; /* PKP10..PKP12 positive gamma micro adj. */
    unsigned char pkp20:3; /* PKP20..PKP22 positive gamma micro adj. */
    unsigned char pkp30:3; /* PKP30..PKP32 positive gamma micro adj. */
    unsigned char pkp40:3; /* PKP40..PKP42 positive gamma micro adj. */
    unsigned char pkp50:3; /* PKP50..PKP52 positive gamma micro adj. */
    unsigned char prp00:3; /* PRP00..PRP02 positive gamma gradient
                             adj. */
    unsigned char prp10:3; /* PRP10..PRP12 positive gamma gradient
                             adj. */
    unsigned char vrp00:4; /* VRP00..VRP03 positive gamma amplification
                             adj. */
    unsigned char vrp10:5; /* VRP10..VRP14 positive gamma amplification
                             adj. */

    /* negative gamma control registers bits */
    unsigned char pkn00:3; /* PKN00..PKN02 negative gamma micro adj. */
    unsigned char pkn10:3; /* PKN10..PKN12 negative gamma micro adj. */
    unsigned char pkn20:3; /* PKN20..PKN22 positive gamma micro adj. */
    unsigned char pkn30:3; /* PKN30..PKN32 positive gamma micro adj. */
    unsigned char pkn40:3; /* PKN40..PKN42 negative gamma micro adj. */
    unsigned char pkn50:3; /* PKN50..PKN52 negative gamma micro adj. */
    unsigned char prn00:3; /* PRN00..PRN02 negative gamma gradient
                             adj. */
}
```

```
    unsigned char prn10:3; /* PRN10..PRN12 negative gamma gradient
                           adj. */
    unsigned char vrn00:4; /* VRN00..VRN03 negative gamma amplification
                           adj. */
    unsigned char vrn10:5; /* VRN10..VRN14 negative gamma
                           amplification adj. */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define SSD1289_REVX_NORM 0 /* No horizontal reverse */
#define SSD1289_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define SSD1289_REVY_NORM 0 /* No vertical reverse */
#define SSD1289_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define SSD1289_CL_BITS_RGB 0 /* Write color bits to display RAM
                              in RGB order */
#define SSD1289_CL_BITS_BGR 1 /* Write color bits to display RAM
                              in BGR order */

/* Initilization values for dc30 step-up circuit cycle */
#define SSD1289_STEPUP_FLINE24 0 /* Fline *24 */
#define SSD1289_STEPUP_FLINE16 1 /* Fline *16 */
#define SSD1289_STEPUP_FLINE12 2 /* Fline *12 */
#define SSD1289_STEPUP_FLINE8 3 /* Fline *8 */
#define SSD1289_STEPUP_FLINE6 4 /* Fline *6 */
#define SSD1289_STEPUP_FLINE5 5 /* Fline *5 */
#define SSD1289_STEPUP_FLINE4 6 /* Fline *4 */
#define SSD1289_STEPUP_FLINE3 7 /* Fline *3 */
#define SSD1289_STEPUP_FLINE2 8 /* Fline *2 */
#define SSD1289_STEPUP_FLINE1 9 /* Fline *1 */
#define SSD1289_STEPUP_FOSC4 10 /* Fosc /4 (Fosc=510kHz) */
#define SSD1289_STEPUP_FOSC6 11 /* Fosc /6 */
#define SSD1289_STEPUP_FOSC8 12 /* Fosc /8 */
#define SSD1289_STEPUP_FOSC10 13 /* Fosc /10 */
#define SSD1289_STEPUP_FOSC12 14 /* Fosc /12 */
#define SSD1289_STEPUP_FOSC16 15 /* Fosc /16 */

/* Initialization values for the VCIX2 voltage */
#define SSD1289_VCIX2_5V1 0 /* 5.1V */
#define SSD1289_VCIX2_5V2 1 /* 5.2V */
#define SSD1289_VCIX2_5V3 2 /* 5.3V */
#define SSD1289_VCIX2_5V4 3 /* 5.4V */
#define SSD1289_VCIX2_5V5 4 /* 5.5V */
#define SSD1289_VCIX2_5V6 5 /* 5.6V */
#define SSD1289_VCIX2_5V7 6 /* 5.7V */
#define SSD1289_VCIX2_5V8 7 /* 5.8V */
```



```
/* Initialization values for the VLCD63 voltage */
#define SSD1289_VLCD63_3V08 0 /* VLCD63=3.08V */
#define SSD1289_VLCD63_3V24 1 /* VLCD63=3.24V */
#define SSD1289_VLCD63_3V40 2 /* VLCD63=3.40V */
#define SSD1289_VLCD63_3V56 3 /* VLCD63=3.56V */
#define SSD1289_VLCD63_3V70 4 /* VLCD63=3.70V */
#define SSD1289_VLCD63_3V86 5 /* VLCD63=3.86V */
#define SSD1289_VLCD63_4V04 6 /* VLCD63=4.04V */
#define SSD1289_VLCD63_4V18 7 /* VLCD63=4.18V */
#define SSD1289_VLCD63_4V33 8 /* VLCD63=4.33V */
#define SSD1289_VLCD63_4V49 9 /* VLCD63=4.49V */
#define SSD1289_VLCD63_4V67 10 /* VLCD63=4.67V */
#define SSD1289_VLCD63_4V80 11 /* VLCD63=4.80V */
#define SSD1289_VLCD63_5V00 12 /* VLCD63=5.00V */
#define SSD1289_VLCD63_5V14 13 /* VLCD63=5.14V */
#define SSD1289_VLCD63_5V29 14 /* VLCD63=5.29V */
#define SSD1289_VLCD63_5V45 15 /* VLCD63=5.45V */

/* Initialization values for the VcomL voltage */
#define SSD1289_VCOML_0_60 0 /* VcomL=VLCD63*0.60 */
#define SSD1289_VCOML_0_63 1 /* VcomL=VLCD63*0.63 */
#define SSD1289_VCOML_0_66 2 /* VcomL=VLCD63*0.66 */
#define SSD1289_VCOML_0_69 3 /* VcomL=VLCD63*0.69 */
#define SSD1289_VCOML_0_72 4 /* VcomL=VLCD63*0.72 */
#define SSD1289_VCOML_0_75 5 /* VcomL=VLCD63*0.75 */
#define SSD1289_VCOML_0_78 6 /* VcomL=VLCD63*0.78 */
#define SSD1289_VCOML_0_81 7 /* VcomL=VLCD63*0.81 */
#define SSD1289_VCOML_0_84 8 /* VcomL=VLCD63*0.84 */
#define SSD1289_VCOML_0_87 9 /* VcomL=VLCD63*0.87 */
#define SSD1289_VCOML_0_90 10 /* VcomL=VLCD63*0.90 */
#define SSD1289_VCOML_0_93 11 /* VcomL=VLCD63*0.93 */
#define SSD1289_VCOML_0_96 12 /* VcomL=VLCD63*0.96 */
#define SSD1289_VCOML_0_99 13 /* VcomL=VLCD63*0.99 */
#define SSD1289_VCOML_1_02 14 /* VcomL=VLCD63*1.02 */
#define SSD1289_VCOML_EXT_RES 15 /* VcomL is set by an external
                                variable resistor */
#define SSD1289_VCOML_1_05 16 /* VcomL=VLCD63*1.05 */
#define SSD1289_VCOML_1_08 17 /* VcomL=VLCD63*1.08 */
#define SSD1289_VCOML_1_11 18 /* VcomL=VLCD63*1.11 */
#define SSD1289_VCOML_1_14 19 /* VcomL=VLCD63*1.14 */
#define SSD1289_VCOML_1_17 20 /* VcomL=VLCD63*1.17 */
#define SSD1289_VCOML_1_20 21 /* VcomL=VLCD63*1.20 */
#define SSD1289_VCOML_1_23 22 /* VcomL=VLCD63*1.23 */

/* Initialization values for frame_freq */
#define SSD1289_FRAME50 0 /* 50Hz */
#define SSD1289_FRAME55 2 /* 55Hz */
#define SSD1289_FRAME60 5 /* 60Hz */
#define SSD1289_FRAME65 8 /* 65Hz */
#define SSD1289_FRAME70 0x0A /* 70Hz */
#define SSD1289_FRAME75 0x0C /* 75Hz */
#define SSD1289_FRAME80 0x0E /* 80Hz */
```

```
/* Default value for reverse_x */
#define SSD1289_DEFAULT_REVX SSD1289_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define SSD1289_DEFAULT_REVY SSD1289_REVY_NORM /* No vertical reverse */

/* Default value for cl_bits_order
   (color bits writing order to display RAM),
   write in RGB order */
#define SSD1289_DEFAULT_CL_BITS SSD1289_CL_BITS_RGB

/* Power control 1 BT0..BT2 step-up factor of the step-up circuit */
#define SSD1289_DEFAULT_STEPUP_FACTOR 4
/* Power control 1 DC0..DC3 step-up circuit cycle */
#define SSD1289_DEFAULT_STEPUP_CYCLE SSD1289_STEPUP_FOSC4
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the internal operational
   amplifier circuit */
#define SSD1289_DEFAULT_CRT_SOURCE 2
/* Default value for VCIX2 voltage */
#define SSD1289_DEFAULT_VCIX2 SSD1289_VCIX2_5V1
/* Default value for VLCD63 voltage */
#define SSD1289_DEFAULT_VLCD63 SSD1289_VLCD63_4V80
/* Default value for VcomL alternating drive voltage */
#define SSD1289_DEFAULT_VCOML SSD1289_VCOML_0_72
/* Default value for VcomH=VLCD63*(0.35+0x1A*0.01) */
#define SSD1289_DEFAULT_VCOMH 0x1A
/* Default value for driving waveform control FLD bit,
   splits one frame into 3 fields to reduce flicker */
#define SSD1289_DEFAULT_FLD 1
/* Default value for LCD frame frequency */
#define SSD1289_DEFAULT_FRAME_FREQ SSD1289_FRAME80

/* Default initialization values for the gamma control register bits */
/* PKP00..PKP02 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKP00 7
/* PKP10..PKP12 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKP10 7
/* PKP20..PKP22 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKP20 4
/* PKP30..PKP32 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKP30 2
/* PKP40..PKP42 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKP40 4
/* PKP50..PKP52 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKP50 2
/* PRP00..PRP02 positive gamma gradient adj. */
#define SSD1289_DEFAULT_PRP00 2
/* PRP10..PRP12 positive gamma gradient adj. */
#define SSD1289_DEFAULT_PRP10 5
/* VRP00..VRP03 positive gamma amplification adj. */
#define SSD1289_DEFAULT_VRP00 2
/* VRP10..VRP14 positive gamma amplification adj. */
#define SSD1289_DEFAULT_VRP10 3
/* PKN00..PKN02 negative gamma micro adj. */
#define SSD1289_DEFAULT_PKN00 7
/* PKN10..PKN12 negative gamma micro adj. */
#define SSD1289_DEFAULT_PKN10 5
/* PKN20..PKN22 positive gamma micro adj. */
#define SSD1289_DEFAULT_PKN20 4
/* PKN30..PKN32 positive gamma micro adj. */
```

```
#define SSD1289_DEFAULT_PKN30 2
/* PKN40..PKN42 negative gamma micro adj. */
#define SSD1289_DEFAULT_PKN40 4
/* PKN50..PKN52 negative gamma micro adj. */
#define SSD1289_DEFAULT_PKN50 2
/* PRN00..PRN02 negative gamma gradient adj. */
#define SSD1289_DEFAULT_PRN00 2
/* PRN10..PRN12 negative gamma gradient adj. */
#define SSD1289_DEFAULT_PRN10 5
/* VRN00..VRN03 negative gamma amplification adj. */
#define SSD1289_DEFAULT_VRN00 2
/* VRN10..VRN14 negative gamma amplification adj. */
#define SSD1289_DEFAULT_VRN10 3
```

The following colors are predefined in the **glcd_ssd1289.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The SSD1289 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ssd1289.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1289.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1289** directory contains fully functional code samples that may be used as references for SSD1289 initialization and usage.

5.12.16 Graphic OLED Display Functions Specific to the SSD1303 and SH1101A Controllers

In order to take full advantage of the Solomon Systech SSD1303 and Sino Wealth SH1101A OLED controllers' features, the following specific functions, declared in the **glcd_ssd1303.h** header file, were implemented:

void ssd1303_wrcmd(unsigned char cmd)

Writes a command to the SSD1303 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1303.h** header file:

```
#define SSD1303_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define SSD1303_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define SSD1303_CMD_SET_HORIZ_SCROLL 0x26 /* horizontal scroll setup */
#define SSD1303_CMD_HORIZ_SCROLL_OFF 0x2E /* deactivate horizontal scroll */
#define SSD1303_CMD_HORIZ_SCROLL_ON 0x2F /* activate horizontal scroll */
#define SSD1303_CMD_START_LINE 0x40 /* set display start line */
#define SSD1303_CMD_SET_PAGE 0xB0 /* set display page address */

#define SSD1303_CMD_SET_CONTRAST 0x81 /* sets the contrast control register */
#define SSD1303_CMD_SET_BRIGHTNESS 0x82 /* sets the brightness control register */
#define SSD1303_CMD_SET_LUT 0x91 /* sets the Look Up Table */
#define SSD1303_CMD_SET_COLOR_BANK1_16 0x92 /* sets the colors for banks 1-16 */
#define SSD1303_CMD_SET_COLOR_BANK17_32 0x93 /* sets the colors for banks 17-32 */

#define SSD1303_CMD_ADC_SELECT_NORM 0xA0 /* set the relationship between RAM column
                                         address and display driver: normal */
#define SSD1303_CMD_ADC_SELECT_REV 0xA1 /* set the relationship between RAM column
                                         address and display driver: reversed */

#define SSD1303_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define SSD1303_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define SSD1303_CMD_MUX_RATIO 0xA8 /* set multiplex ratio */
#define SSD1303_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM contents */
#define SSD1303_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define SSD1303_CMD_DC_DC 0xAD /* turn the DC/DC converter on/off */
#define SSD1303_DC_DC_OFF 0x8A /* second byte of the command: DC/DC off */
#define SSD1303_DC_DC_ON 0x8B /* second byte of the command: DC/DC on */

#define SSD1303_CMD_DISP_OFF 0xAE /* display off */
#define SSD1303_CMD_DISP_ON 0xAF /* display on */

#define SSD1303_CMD_COM0_63 0xC0 /* sets the COM output scan direction 0->63 */
#define SSD1303_CMD_COM63_0 0xC8 /* sets the COM output scan direction 63->0 */

#define SSD1303_CMD_DISPL_OFFSET 0xD3 /* set display offset */
#define SSD1303_CMD_DISPL_CLK 0xD5 /* set display clock division ratio and
                                     oscillator frequency */
#define SSD1303_CMD_AREA_COLOR_POWER_SAVE 0xD8 /* set area color and
                                                  power-save modes */
#define SSD1303_CMD_POWER_SAVE_OFF 0 /* second command byte for power-save off */
#define SSD1303_CMD_POWER_SAVE_ON 0x05 /* second command byte for power-save on */
```

```
#define SSD1303_CMD_PRECHARGE_PERIOD 0xD9 /* set pre-charge period for Phase 1
                                           and Phase 2 */
#define SSD1303_CMD_COM_CONFIG 0xDA /* set COM pins hardware configuration: interlaced
                                     or non-interlaced */
#define SSD1303_CMD_INTERLACED 0x12 /* second command byte for interlaced operation */
#define SSD1303_CMD_NON_INTERLACED 0x02 /* second command byte for
                                         non-interlaced operation */

#define SSD1303_CMD_VCOM_DESELECT 0xDB /* set VCOM deselect level */
```

A detailed description of the above mentioned commands can be found in the SSD1303 datasheet.

void ssd1303_setcontrast(unsigned char contrast)

Controls the OLED display contrast.

Parameter:

contrast sets the contrast value, the allowed range being 0..255.

The **glcd_ssd1303.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SSD1303 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char reverse_x:1; /* reverse display horizontally (ADC) */
    unsigned char reverse_xoffs:3; /* specify the X offset when
                                   plotting pixels if reverse_x=1,
                                   the usual value is
                                   132-GLCD_MAXX */
    unsigned char reverse_y:1; /* reverse display vertically (COM) */
    unsigned char interlaced:1; /* use vertically interlaced display */
    unsigned char contrast; /* OLED display contrast */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for reverse_x initialization */
#define SSD1303_REVX_NORM 0 /* set the relationship between RAM column
                             address and display driver: normal */
#define SSD1303_REVX_REV 1 /* set the relationship between RAM column
                             address and display driver: reversed */

/* values used for reverse_y initialization */
#define SSD1303_REVY_NORM 0 /* sets the vertical COM output scan direction
0->63 */
#define SSD1303_REVY_REV 1 /* sets the vertical COM output scan direction
63->0 */
```

```
/* values used for interlaced initialization */
#define SSD1303_NON_INTERLACED 0
#define SSD1303_INTERLACED 1

/* default initialization values */
/* default value for reverse_x */
#define SSD1303_DEFAULT_REVX SSD1303_REVX_NORM
/* default value for reverse_xoffs
    effective only when reverse_x=1 (SSD1303_REVX_REV) */
#define SSD1303_DEFAULT_REV_XOFFS (132-_GLCD_MAX_X_)
/* default value for reverse_y */
#define SSD1303_DEFAULT_REVY SSD1303_REVY_NORM
/* default value for interlaced */
#define SSD1303_DEFAULT_INTERLACED SSD1303_INTERLACED
/* default contrast */
#define SSD1303_DEFAULT_CONTRAST 128
```

The detailed description of the above mentioned initialization parameters can be found in the SSD1303 datasheet.

Notes:

- The **glcd_ssd1303.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1303.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1303** directory contains fully functional code samples that may be used as references for SSD1303, SH1101A initialization and usage.

5.12.17 Graphic OLED Display Functions Specific to the SSD1306 Controller

In order to take full advantage of the Solomon Systech SSD1306 controllers' features, the following specific functions, declared in the **glcd_ssd1306.h** header file, were implemented:

void ssd1306_wrcmd(unsigned char cmd)

Writes a command to the SSD1306 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1306.h** header file:

```
#define SSD1306_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define SSD1306_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define SSD1306_CMD_SET_HORIZ_SCROLL 0x26 /* horizontal scroll setup */
#define SSD1306_CMD_HORIZ_SCROLL_OFF 0x2E /* deactivate horizontal scroll */
#define SSD1306_CMD_HORIZ_SCROLL_ON 0x2F /* activate horizontal scroll */
#define SSD1306_CMD_START_LINE 0x40 /* set display start line */
#define SSD1306_CMD_SET_PAGE 0xB0 /* set display page address */

#define SSD1306_CMD_SET_CONTRAST 0x81 /* sets the contrast control register */
#define SSD1306_CMD_SET_BRIGHTNESS 0x82 /* sets the brightness control register */
#define SSD1306_CMD_SET_LUT 0x91 /* sets the Look Up Table */
#define SSD1306_CMD_SET_COLOR_BANK1_16 0x92 /* sets the colors for banks 1-16 */
#define SSD1306_CMD_SET_COLOR_BANK17_32 0x93 /* sets the colors for banks 17-32 */

#define SSD1306_CMD_ADC_SELECT_NORM 0xA0 /* set the relationship between RAM column
                                         address and display driver: normal */
#define SSD1306_CMD_ADC_SELECT_REV 0xA1 /* set the relationship between RAM column
                                         address and display driver: reversed */

#define SSD1306_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define SSD1306_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define SSD1306_CMD_MUX_RATIO 0xA8 /* set multiplex ratio */
#define SSD1306_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM contents */
#define SSD1306_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define SSD1306_CMD_DC_DC 0x8D /* turn the DC/DC converter on/off */
#define SSD1306_DC_DC_OFF 0x10 /* second byte of the command: DC/DC off */
#define SSD1306_DC_DC_ON 0x14 /* second byte of the command: DC/DC on */

#define SSD1306_CMD_DISP_OFF 0xAE /* display off */
#define SSD1306_CMD_DISP_ON 0xAF /* display on */

#define SSD1306_CMD_COM0_63 0xC0 /* sets the COM output scan direction 0->63 */
#define SSD1306_CMD_COM63_0 0xC8 /* sets the COM output scan direction 63->0 */

#define SSD1306_CMD_DISPL_OFFSET 0xD3 /* set display offset */
#define SSD1306_CMD_DISPL_CLK 0xD5 /* set display clock division ratio and
                                     oscillator frequency */
#define SSD1306_CMD_AREA_COLOR_POWER_SAVE 0xD8 /* set area color and
                                                  power-save modes */
#define SSD1306_CMD_POWER_SAVE_OFF 0 /* second command byte for power-save off */
#define SSD1306_CMD_POWER_SAVE_ON 0x05 /* second command byte for power-save on */
```

```
#define SSD1306_CMD_PRECHARGE_PERIOD 0xD9 /* set pre-charge period for Phase 1
                                           and Phase 2 */
#define SSD1306_CMD_COM_CONFIG 0xDA /* set COM pins hardware configuration: interlaced
                                     or non-interlaced */
#define SSD1306_CMD_INTERLACED 0x12 /* second command byte for interlaced operation */
#define SSD1306_CMD_NON_INTERLACED 0x02 /* second command byte for
                                         non-interlaced operation */

#define SSD1306_CMD_VCOM_DESELECT 0xDB /* set VCOM deselect level */
```

A detailed description of the above mentioned commands can be found in the SSD1306 datasheet.

void ssd1306_setcontrast(unsigned char contrast)

Controls the OLED display contrast.

Parameter:

contrast sets the contrast value, the allowed range being 0..255.

The **glcd_ssd1306.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SSD1306 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char reverse_x:1; /* reverse display horizontally (ADC) */
    unsigned char reverse_y:1; /* reverse display vertically (COM) */
    unsigned char interlaced:1; /* use vertically interlaced display */
    unsigned char external_vcc:1; /* =0 Vcc is generated by the
                                internal DC/DC converter
                                =1 Vcc is applied from an external
                                source */
    unsigned char contrast; /* OLED display contrast */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for reverse_x initialization */
#define SSD1306_REVX_NORM 0 /* set the relationship between RAM column
                           address and display driver: normal */
#define SSD1306_REVX_REV 1 /* set the relationship between RAM column
                           address and display driver: reversed */

/* values used for reverse_y initialization */
#define SSD1306_REVY_NORM 0 /* sets the vertical COM output scan direction
0->63 */
#define SSD1306_REVY_REV 1 /* sets the vertical COM output scan direction
63->0 */
```



```
/* values used for interlaced initialization */
#define SSD1306_NON_INTERLACED 0
#define SSD1306_INTERLACED 1

/* values used for external_vcc initialization */
/* Vcc is generated by the internal DC/DC converter */
#define SSD1306_USE_INTERNAL_DCDC 0
/* Vcc is applied externally */
#define SSD1306_USE_EXTERNAL_VCC 1

/* default initialization values */
/* default value for reverse_x */
#define SSD1306_DEFAULT_REVX SSD1306_REVX_NORM
/* default value for reverse_y */
#define SSD1306_DEFAULT_REVY SSD1306_REVY_NORM
/* default value for interlaced */
#if _GLCD_MAXY==32
/* 128x32 displays use non-interlaced mode */
#define SSD1306_DEFAULT_INTERLACED SSD1306_NON_INTERLACED
#else
/* 128x64 displays use interlaced mode */
#define SSD1306_DEFAULT_INTERLACED SSD1306_INTERLACED
#endif
/* default value for external_vcc */
/* Vcc is generated by the internal DC/DC converter */
#define SSD1306_DEFAULT_VCC SSD1306_USE_INTERNAL_DCDC
/* default contrast */
#define SSD1306_DEFAULT_CONTRAST 128
```

The detailed description of the above mentioned initialization parameters can be found in the SSD1306 datasheet.

Notes:

- The **glcd_ssd1306.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1306.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1306** directory contains fully functional code samples that may be used as references for SSD1306 initialization and usage.

5.12.18 Graphic OLED Display Functions Specific to the SSD1322 Controller

In order to take full advantage of the Solomon Systech SSD1322 OLED display controller's features, the following specific functions, declared in the **glcd_ssd1322.h** header file, were implemented:

void ssd1322_wrcmd(unsigned char cmd)

Writes a command to the SSD1322 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1322.h** header file:

```
#define SSD1322_CMD_SET_COLUMN_ADDR 0x15 /* Set column start and end
addresses */
#define SSD1322_CMD_SET_ROW_ADDR 0x75 /* Set row start and end
addresses */
#define SSD1322_CMD_WRITE_RAM 0x5C /* Enable MCU to write data into
GDRAM */
#define SSD1322_CMD_READ_RAM 0x5D /* Enable MCU to read data from
GDRAM */
#define SSD1322_CMD_REMAP_MODE 0xA0 /* Set Re-map and dual COM line
modes */
#define SSD1322_CMD_SET_START_LINE 0xA1 /* Set display start line */
#define SSD1322_CMD_SET_DISPLAY_OFFSET 0xA2 /* Set display offset */
#define SSD1322_CMD_DISPLAY_OFF 0xA4 /* Entire display off */
#define SSD1322_CMD_DISPLAY_ON 0xA5 /* Entire display on */
#define SSD1322_CMD_DISPLAY_NORMAL 0xA6 /* Normal display */
#define SSD1322_CMD_DISPLAY_INVERSE 0xA7 /* Inverse display */
#define SSD1322_CMD_DISPLAY_PARTIAL_ON 0xA8 /* Enable partial display
mode */
#define SSD1322_CMD_DISPLAY_PARTIAL_OFF 0xA9 /* Exit from partial display
mode */
#define SSD1322_CMD_FUNC_SEL 0xAB /* Function selection */
#define SSD1322_CMD_SLEEP_ON 0xAE /* Enter sleep mode */
#define SSD1322_CMD_SLEEP_OFF 0xAF /* Exit sleep mode */
#define SSD1322_CMD_SET_PHASE_LENGTH 0xB1 /* Set phase 1 and 2 periods */
#define SSD1322_CMD_SET_FRONT_CLK 0xB3 /* Set front clock divider/
oscillator frequency */
#define SSD1322_CMD_SET_DISPLAY_ENHA 0xB4 /* Display enhancement A */
#define SSD1322_CMD_SET_GPIO 0xB5 /* Set GPIO pins state */
#define SSD1322_CMD_SET_PRECHARGE2 0xB6 /* Set second pre-charge
period */
/* This command is sent to enable the SSD1322_CMD_SET_GRAYSCALE_TBL
command */
#define SSD1322_CMD_EN_GRAYSCALE_TABLE 0x00
#define SSD1322_CMD_SET_GRAYSCALE_TBL 0xB8 /* Set gray scale table */
#define SSD1322_CMD_SET_GRAYSCALE_LIN 0xB9 /* Set default linear gray
scale table */
#define SSD1322_CMD_SET_PRECHARGE_VOLT 0xBB /* Set the pre-charge voltage
level */
#define SSD1322_CMD_SET_VCOMH 0xBE /* Set the COM deselect voltage
level */
#define SSD1322_CMD_SET_CONTRAST 0xC1 /* Set the contrast value */
```

```
#define SSD1322_CMD_SET_MASTER_CONTRAST 0xC7 /* Set master contrast
                                              current */
#define SSD1322_CMD_SET_MUX_RATIO 0xCA /* Set MUX ratio: 15..127 */
#define SSD1322_CMD_SET_DISPLAY_ENHB 0xD1 /* Display enhancement B */
#define SSD1322_CMD_SET_COMMAND_LOCK 0xFD /* Set MCU protection status */
```

A detailed description of the above mentioned commands can be found in the SSD1322 datasheet.

void ssd1322_wldata(unsigned char data)

Writes a byte of data to the SSD1322 controller.

Parameter:

data byte to be sent to the controller.

unsigned char ssd1322_rddata(void)

Reads a byte of data from the SSD1322 controller.

void ssd1322_setcontrast(unsigned char contrast)

Controls the OLED display contrast.

Parameter:

contrast sets the contrast value, the allowed range being 0..127.

The **glcd_ssd1322.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SSD1322 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* Default font after initialization */
    /* Pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* Pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char divset:4; /* Front clock divider */
    unsigned char osc_freq:4; /* Oscillator frequency */
    unsigned char phase1:4; /* Phase 1 period */
    unsigned char phase2:4; /* Phase 2 period */
    /* Pre-charge voltage= Vcc*(0.2+precharge_v*0.01275) */
    unsigned char precharge_v:5;
    unsigned char vcomh:3; /* VCOMH voltage= Vcc*(0.72+vcomh*0.02) */
    /* horizontal segment offset of pixel with x=0 */
    unsigned char offset_x0;
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char com_split:1; /* enable odd/even split of COM pins */
    unsigned char dual_com:1; /* =0 - disable dual COM mode
                               =1 - enable dual COM mode */
}
```

```
/* Second pre-charge period [DCLK cycles] */
unsigned char precharge_t2:4;
unsigned char contrast; /* Contrast current= ISEG*contrast */
/* Reduce the output current for all levels of gray
   to (master_contrast+1)/16 */
unsigned char master_contrast:4;
unsigned char gpio0:2; /* GPIO0 configuration */
unsigned char gpio1:2; /* GPIO1 configuration */
/* pointer to gray scale table with gamma settings,
   located in FLASH memory */
flash unsigned char *gray_scale_table;
} GLCDINIT_t;
```

Note: The **offset_x0** configuration parameter, representing the OLED display's segment number which corresponds to the pixel with the horizontal coordinate x=0 is usually 0. However the **DD-12864** and **DD-25664** displays, manufactured by Densitron, have the segment 112 connected to the pixel with x=0. So for these displays **offset_x0=112**.

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for divset */
#define SSD1322_DIV1 0 /* Divide osc. by 1 */
#define SSD1322_DIV2 1 /* Divide osc. by 2 */
#define SSD1322_DIV4 2 /* Divide osc. by 4 */
#define SSD1322_DIV8 3 /* Divide osc. by 8 */
#define SSD1322_DIV16 4 /* Divide osc. by 16 */
#define SSD1322_DIV32 5 /* Divide osc. by 32 */
#define SSD1322_DIV64 6 /* Divide osc. by 64 */
#define SSD1322_DIV128 7 /* Divide osc. by 128 */
#define SSD1322_DIV256 8 /* Divide osc. by 256 */
#define SSD1322_DIV512 9 /* Divide osc. by 512 */
#define SSD1322_DIV1024 10 /* Divide osc. by 1024 */

/* Initialization values for phase1 */
#define SSD1322_PHASE1_5DCLK 2 /* Phase 1 period=5 DCLK cycles */
#define SSD1322_PHASE1_7DCLK 3 /* Phase 1 period=7 DCLK cycles */
#define SSD1322_PHASE1_9DCLK 4 /* Phase 1 period=9 DCLK cycles */
#define SSD1322_PHASE1_11DCLK 5 /* Phase 1 period=11 DCLK cycles */
#define SSD1322_PHASE1_13DCLK 6 /* Phase 1 period=13 DCLK cycles */
#define SSD1322_PHASE1_15DCLK 7 /* Phase 1 period=15 DCLK cycles */
#define SSD1322_PHASE1_17DCLK 8 /* Phase 1 period=17 DCLK cycles */
#define SSD1322_PHASE1_19DCLK 9 /* Phase 1 period=19 DCLK cycles */
#define SSD1322_PHASE1_21DCLK 10 /* Phase 1 period=21 DCLK cycles */
#define SSD1322_PHASE1_23DCLK 11 /* Phase 1 period=23 DCLK cycles */
#define SSD1322_PHASE1_25DCLK 12 /* Phase 1 period=25 DCLK cycles */
#define SSD1322_PHASE1_27DCLK 13 /* Phase 1 period=27 DCLK cycles */
#define SSD1322_PHASE1_29DCLK 14 /* Phase 1 period=29 DCLK cycles */
#define SSD1322_PHASE1_31DCLK 15 /* Phase 1 period=31 DCLK cycles */

/* Initialization values for phase2 */
#define SSD1322_PHASE2_3DCLK 3 /* Phase 2 period=3 DCLK cycles */
#define SSD1322_PHASE2_4DCLK 4 /* Phase 2 period=4 DCLK cycles */
#define SSD1322_PHASE2_5DCLK 5 /* Phase 2 period=5 DCLK cycles */
#define SSD1322_PHASE2_6DCLK 6 /* Phase 2 period=6 DCLK cycles */
#define SSD1322_PHASE2_7DCLK 7 /* Phase 2 period=7 DCLK cycles */
#define SSD1322_PHASE2_8DCLK 8 /* Phase 2 period=8 DCLK cycles */
#define SSD1322_PHASE2_9DCLK 9 /* Phase 2 period=9 DCLK cycles */
#define SSD1322_PHASE2_10DCLK 10 /* Phase 2 period=10 DCLK cycles */
```

```
#define SSD1322_PHASE2_11DCLK 11 /* Phase 2 period=11 DCLK cycles */
#define SSD1322_PHASE2_12DCLK 12 /* Phase 2 period=12 DCLK cycles */
#define SSD1322_PHASE2_13DCLK 13 /* Phase 2 period=13 DCLK cycles */
#define SSD1322_PHASE2_14DCLK 14 /* Phase 2 period=14 DCLK cycles */
#define SSD1322_PHASE2_15DCLK 15 /* Phase 2 period=15 DCLK cycles */

/* Initialization values for reverse_x */
#define SSD1322_REVX_NORM 0 /* Scan from Column 0 to Column n-1 */
#define SSD1322_REVX_REV 1 /* Scan from Column n-1 to Column 0 */

/* Initialization values for reverse_y */
#define SSD1322_REVY_NORM 0 /* Scan from COM0 to COMn-1 */
#define SSD1322_REVY_REV 1 /* Scan from COMn-1 to COM0 */

/* Initialization values for com_split */
#define SSD1322_COM_SPLIT_OFF 0
#define SSD1322_COM_SPLIT_ON 1

/* Initialization values for dual_com */
#define SSD1322_DUAL_COM_OFF 0 /* Disable dual COM mode */
#define SSD1322_DUAL_COM_ON 1 /* Enable dual COM mode */

/* Initialization values for gpio0 and gpio1 */
#define SSD1322_GPIO_HIZ 0 /* I/O pin HiZ, no input */
#define SSD1322_GPIO_INPUT 1 /* Set I/O pin as input */
#define SSD1322_GPIO_OUTPUT_LOW 2 /* Set I/O pin as output with logic
                                   level 0 */
#define SSD1322_GPIO_OUTPUT_HIGH 3 /* Set I/O pin as output with logic
                                   level 1 */

/* Initialization value for gray_scale_table */
#define SSD1322_GRAY_SCALE_LINEAR NULL /* Use a linear gray scale */

/* Default value for divset */
#define SSD1322_DEFAULT_DIVSET SSD1322_DIV2
/* Default value for osc_freq */
#define SSD1322_DEFAULT_OSC_FREQ 0x09
/* Default value for phase1 */
#define SSD1322_DEFAULT_PHASE1 SSD1322_PHASE1_31DCLK
/* Default value for phase2 */
#define SSD1322_DEFAULT_PHASE2 SSD1322_PHASE2_15DCLK
/* Default value for precharge_v */
#define SSD1322_DEFAULT_PRECHARGE_V 0x1F
/* Default value for offset_x0,
   For Densitron DD-12864 and DD-25664 displays use 112 */
#define SSD1322_DEFAULT_OFFSETX0 0
/* Default value for reverse_x */
#define SSD1322_DEFAULT_REVX SSD1322_REVX_NORM
/* Default value for reverse_y */
#define SSD1322_DEFAULT_REVY SSD1322_REVY_NORM
/* Default value for com_split */
#define SSD1322_DEFAULT_COM_SPLIT SSD1322_COM_SPLIT_OFF
/* Default value for dual_com */
#define SSD1322_DEFAULT_DUAL_COM SSD1322_DUAL_COM_OFF
/* Default value for precharge_t2 */
#define SSD1322_DEFAULT_PRECHARGE_T2 8
/* Default value for vcomh */
#define SSD1322_DEFAULT_VCOMH 7
```

```
/* Default value for contrast */
#define SSD1322_DEFAULT_CONTRAST 0xDF
/* Default value for master_contrast */
#define SSD1322_DEFAULT_MASTER_CONTRAST 15
/* Default value for gpio0 */
#define SSD1322_DEFAULT_GPIO0 SSD1322_GPIO_HIZ
/* Default value for gpio1 */
#define SSD1322_DEFAULT_GPIO1 SSD1322_GPIO_HIZ
/* Default value for gray_scale_table */
#define SSD1322_DEFAULT_GRAY_SCALE SSD1322_GRAY_SCALE_LINEAR
```

The detailed description of the above mentioned initialization parameters can be found in the SSD1322 datasheet.

The following example shows how to initialize the SSD1322 controller with an user defined gray scale table:

```
#include <io.h>
#include <stdio.h>
#include <glcd.h>

/* Include the font needed by the demo */
#include <font5x7.h>

/* Gray scale table used for gray level display linearization
   Modify accordingly for your display, based on the datasheet */
flash unsigned char gray_scale_tbl[15]=
    {0x01,0x0D,0x19,0x25,0x31,0x3D,0x49,0x55,
     0x61,0x6D,0x79,0x85,0x9D,0xA9,0xB4};

void main()
{
    GLCDINIT_t glcd_init_data;

    /* 5x7 font is used */
    glcd_init_data.font=font5x7;

    /* No need for reading data from external memory */
    glcd_init_data.readxmem=NULL;

    /* No need for reading data from external memory */
    glcd_init_data.writexmem=NULL;

    /* Set the Front Clock Divider */
    glcd_init_data.divset=SSD1322_DEFAULT_DIVSET;

    /* Set the Oscillator Frequency */
    glcd_init_data.osc_freq=SSD1322_DEFAULT_OSC_FREQ;

    /* Set the Phase 1 Period */
    glcd_init_data.phase1=SSD1322_DEFAULT_PHASE1;

    /* Set the Phase 2 Period */
    glcd_init_data.phase2=SSD1322_DEFAULT_PHASE2;

    /* Set the Pre-charge Voltage */
    glcd_init_data.precharge_v=SSD1322_DEFAULT_PRECHARGE_V;
```

```
/* Set the VCOMH voltage */
glcd_init_data.vcomh=SSD1322_DEFAULT_VCOMH;

/* Set the horizontal segment offset of pixel with x=0
   Modify accordingly for your display, based on the datasheet
   For most displays it should be 0 */
glcd_init_data.offset_x0=0;

/* The horizontal coordinates are not reversed for the
   Modify accordingly for your display, based on the datasheet */
glcd_init_data.reverse_x=SSD1322_REVX_NORM;

/* The vertical coordinates are not reversed for the
   Modify accordingly for your display, based on the datasheet */
glcd_init_data.reverse_y=SSD1322_REVY_NORM;

/* Horizontal COM connections are not splitted odd/even
   Modify accordingly for your display, based on the datasheet */
glcd_init_data.com_split=SSD1322_COM_SPLIT_OFF;

/* The display uses Dual COM mode
   Modify accordingly for your display, based on the datasheet */
glcd_init_data.dual_com=SSD1322_DUAL_COM_ON;

/* Set the Second Pre-charge Period */
glcd_init_data.precharge_t2=SSD1322_DEFAULT_PRECHARGE_T2;

/* Set the Contrast Current */
glcd_init_data.contrast=SSD1322_DEFAULT_CONTRAST;

/* Set the Master Contrast Current */
glcd_init_data.master_contrast=SSD1322_DEFAULT_MASTER_CONTRAST;

/* The General Purpose Input/Outputs are not used */
glcd_init_data.gpio0=SSD1322_GPIO_HIZ;
glcd_init_data.gpio1=SSD1322_GPIO_HIZ;

/* Specify an user defined gray scale table for your display */
glcd_init_data.gray_scale_table=gray_scale_tbl;

/* Initialize the SSD1322 graphic controller */
glcd_init(&glcd_init_data);

/* Display literal char string located in FLASH */
glcd_outtextf("SSD1322 Graphics Demo");

while (1)
}
```

The SSD1322 controller supports 16 levels of gray.

When using the **Graphic Display Functions**, the **GLCDCOL_t** data types, which specify the display color, can take values from 0 to 15.

The **glcd_ssd1322.h** header file contains definitions for some usual levels of gray:

```
#define GLCD_CL_BLACK 0x00
#define GLCD_CL_DARK_GRAY 0x04
#define GLCD_CL_GRAY 0x08
#define GLCD_CL_LIGHT_GRAY 0x0C
#define GLCD_CL_WHITE 0x0F
```

Notes:

- The **glcd_ssd1322.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1322.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1322** directory contains fully functional code samples that may be used as references for SSD1322 initialization and usage.

5.12.19 Graphic OLED Display Functions Specific to the SSD1331 Controller

The library for the Solomon Systech SSD1331 controller supports color OLED 96x64 displays with 256 or 64k color resolution and hardware graphic acceleration for drawing:

- lines
- rectangles
- filled rectangles
- filled circles
- filled ellipses.

The following functions, declared in the **glcd_ssd1331.h** header file, were implemented:

void ssd1331_wrcmd(unsigned char cmd)

Writes a command to the SSD1331 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1331.h** header file:

```
#define SSD1331_CMD_SET_COLUMN_ADDR 0x15    /* Set column start and end
                                              addresses */
#define SSD1331_CMD_DRAW_LINE 0x21         /* Draw line */
#define SSD1331_CMD_DRAW_RECTANGLE 0x22    /* Draw rectangle */
#define SSD1331_CMD_COPY 0x23              /* Copy block */
#define SSD1331_CMD_DIM_WINDOW 0x24        /* Window will become darker */
#define SSD1331_CMD_CLEAR_WINDOW 0x25      /* Clear window */
#define SSD1331_CMD_FILL_CTRL 0x26         /* Enable/disable fill when
                                              drawing rectangle */
#define SSD1331_CMD_SET_SCROLL 0x27         /* Continuous horizontal &
                                              vertical scrolling setup */
#define SSD1331_CMD_STOP_SCROLL 0x2E       /* Stop scrolling */
#define SSD1331_CMD_START_SCROLL 0x2F      /* Start scrolling */
#define SSD1331_CMD_SET_ROW_ADDR 0x75      /* Set row start and end
                                              addresses */
#define SSD1331_CMD_SET_CONTRAST_A 0x81     /* Set the contrast current for
                                              color A */
#define SSD1331_CMD_SET_CONTRAST_B 0x82     /* Set the contrast current for
                                              color B */
#define SSD1331_CMD_SET_CONTRAST_C 0x83     /* Set the contrast current for
                                              color C */
#define SSD1331_CMD_SET_MASTER_CURRENT 0x87 /* Set master current */
```



```
#define SSD1331_CMD_SET_PRECHARGE2_A 0x8A /* Set second pre-charge speed  
for color A */  
#define SSD1331_CMD_SET_PRECHARGE2_B 0x8B /* Set second pre-charge speed  
for color B */  
#define SSD1331_CMD_SET_PRECHARGE2_C 0x8C /* Set second pre-charge speed  
for color C */  
#define SSD1331_CMD_REMAP_MODE 0xA0 /* Set Re-map/Color Depth */  
#define SSD1331_CMD_SET_START_LINE 0xA1 /* Set display start line */  
#define SSD1331_CMD_SET_DISPLAY_OFFSET 0xA2 /* Set display offset */  
#define SSD1331_CMD_DISPLAY_NORMAL 0xA4 /* Normal display */  
#define SSD1331_CMD_DISPLAY_ALL_ON 0xA5 /* Set all display pixels on */  
#define SSD1331_CMD_DISPLAY_ALL_OFF 0xA6 /* Set all display pixels  
off */  
#define SSD1331_CMD_DISPLAY_INVERSE 0xA7 /* Inverse display */  
#define SSD1331_CMD_SET_MUX_RATIO 0xA8 /* Set multiplex ratio */  
#define SSD1331_CMD_SET_MASTER_CONFIG 0xAD /* Set master configuration */  
#define SSD1331_CMD_DISPLAY_OFF 0xAE /* Display off */  
#define SSD1331_CMD_DISPLAY_ON 0xAF /* Display on */  
#define SSD1331_CMD_POWERSAVE_MODE 0xB0 /* Power save mode */  
#define SSD1331_CMD_SET_PHASE_LENGTH 0xB1 /* Set phase 1 and 2 periods */  
#define SSD1331_CMD_SET_FRONT_CLK 0xB3 /* Set front clock  
divider/oscillator  
frequency */  
#define SSD1331_CMD_SET_GRAYSCALE_TBL 0xB8 /* Set gray scale pulse  
width table */  
#define SSD1331_CMD_SET_GRAYSCALE_LIN 0xB9 /* Set default linear gray  
scale pulse width table */  
#define SSD1331_CMD_SET_PRECHARGE_VOLT 0xBB /* Set the pre-charge voltage  
level */  
#define SSD1331_CMD_SET_VCOMH 0xBE /* Set the COM deselect voltage  
level */  
#define SSD1331_CMD_SET_COMMAND_LOCK 0xFD /* Set MCU protection status */
```

A detailed description of the above mentioned commands can be found in the SSD1331 datasheet.

unsigned char ssd1331_rdstatus(void)

Reads the status byte from the SSD1331 controller.

void ssd1331_busy(void)

Waits until the controller has finished executing a hardware accelerated drawing command.

void ssd1331_wrdata(unsigned char data)

Writes a byte of data to the SSD1331 controller.

Parameter:

data byte to be sent to the controller.

unsigned char ssd1331_rddata(void)

Reads a byte of data from the SSD1331 controller.

void ssd1331_setcontrast(unsigned char contrast)

Controls the OLED display master contrast.

Parameter:

contrast sets the contrast value, the allowed range being 0..15.

The **glcd_ssd1331.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SSD1331 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* Default font after initialization */
    /* Pointer to the function used for reading a byte from
       external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* Pointer to the function used for writing a byte to
       external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char divset:4; /* Front clock divider */
    unsigned char osc_freq:4; /* Oscillator frequency */
    unsigned char phase1:4; /* Phase 1 period: 1..15 [DCLK cycles] */
    unsigned char phase2:4; /* Phase 2 period: 1..15 [DCLK cycles] */
    unsigned char precharge_v:5; /* Pre-charge voltage=
                                   Vcc*(0.1+precharge_v*0.0125) */
    unsigned char vcomh:5; /* VCOMH voltage= Vcc*(0.44+vcomh*0.0122) */
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char color_bgr:1; /* =0 - color order: R, G, B
                                   =1 - color order: B, G, R */
    unsigned char com_split:1; /* enable odd/even split of COM pins
                                   (interlaced display) */
    unsigned char precharge_t2_red; /* Second pre-charge period
                                       [DCLK cycles] for red color */
    unsigned char precharge_t2_green; /* Second pre-charge period
                                       [DCLK cycles] for green
                                       color */
    unsigned char precharge_t2_blue; /* Second pre-charge period
                                       [DCLK cycles] for blue
                                       color */
    unsigned char contrast_red; /* Contrast current= ISEG*contrast
                                   for red color */
    unsigned char contrast_green; /* Contrast current= ISEG*contrast
                                   for green color */
    unsigned char contrast_blue; /* Contrast current= ISEG*contrast
                                   for blue color */
    unsigned char master_current:4; /* Reduce the output current for
                                       all colors to
                                       (master_current+1)/16 */
    flash unsigned char *gray_scale_table; /* pointer to gray scale
                                             table for gamma correction
                                             (array located in FLASH
                                             with 32 byte values
                                             A NULL pointer specifies
                                             to use the default
                                             table */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for divset
#define SSD1331_DIV1 0 /* Divide osc. by 1 */
#define SSD1331_DIV2 1 /* Divide osc. by 2 */
#define SSD1331_DIV4 2 /* Divide osc. by 4 */
#define SSD1331_DIV8 3 /* Divide osc. by 8 */
#define SSD1331_DIV16 4 /* Divide osc. by 16 */
#define SSD1331_DIV32 5 /* Divide osc. by 32 */
#define SSD1331_DIV64 6 /* Divide osc. by 64 */
#define SSD1331_DIV128 7 /* Divide osc. by 128 */
#define SSD1331_DIV256 8 /* Divide osc. by 256 */
#define SSD1331_DIV512 9 /* Divide osc. by 512 */
#define SSD1331_DIV1024 10 /* Divide osc. by 1024 */

/* Initialization values for reverse_x */
#define SSD1331_REVX_NORM 0 /* Scan from COM0 to COMn-1 */
#define SSD1331_REVX_REV 1 /* Scan from COMn-1 to COM0 */

/* Initialization values for reverse_y */
#define SSD1331_REVY_NORM 0 /* Scan from COM0 to COMn-1 */
#define SSD1331_REVY_REV 1 /* Scan from COMn-1 to COM0 */

/* Initialization values for color_bgr */
#define SSD1331_COLOR_RGB 0 /* Use R, G, B color order */
#define SSD1331_COLOR_BGR 1 /* Use B, G, R color order */

/* Initialization values for com_split */
#define SSD1331_COM_SPLIT_OFF 0
#define SSD1331_COM_SPLIT_ON 1

/* Initialization value for gray_scale_table */
#define SSD1331_GRAY_SCALE_LINEAR NULL /* Use a linear gray scale */

/* Default value for divset */
#define SSD1331_DEFAULT_DIVSET SSD1331_DIV2
/* Default value for osc_freq */
#define SSD1331_DEFAULT_OSC_FREQ 0x0F
/* Default value for phase1 */
#define SSD1331_DEFAULT_PHASE1 1
/* Default value for phase2 */
#define SSD1331_DEFAULT_PHASE2 3
/* Default value for precharge_v */
#define SSD1331_DEFAULT_PRECHARGE_V 0x1D
/* Default value for reverse_x */
#define SSD1331_DEFAULT_REVX SSD1331_REVX_NORM
/* Default value for reverse_y */
#define SSD1331_DEFAULT_REVY SSD1331_REVY_NORM
/* Default value for color_bgr */
#define SSD1331_DEFAULT_COLOR_BGR SSD1331_COLOR_RGB
/* Default value for com_split */
#define SSD1331_DEFAULT_COM_SPLIT SSD1331_COM_SPLIT_OFF
/* Default values for precharge_t2_red, precharge_t2_green,
precharge_t2_blue */
#define SSD1331_DEFAULT_PRECHARGE_T2_RED 0x64
#define SSD1331_DEFAULT_PRECHARGE_T2_GREEN 0x78
#define SSD1331_DEFAULT_PRECHARGE_T2_BLUE 0x64
/* Default value for vcomh */
#define SSD1331_DEFAULT_VCOMH 0x3F
```

```
/* Default values for contrast_red, contrast_green, contrast_blue */
#define SSD1331_DEFAULT_CONTRAST_RED 0x91
#define SSD1331_DEFAULT_CONTRAST_GREEN 0x50
#define SSD1331_DEFAULT_CONTRAST_BLUE 0x7D
/* Default value for master_current */
#define SSD1331_DEFAULT_MASTER_CURRENT 6
/* Default value for gray_scale_table */
#define SSD1331_DEFAULT_GRAY_SCALE SSD1331_GRAY_SCALE_LINEAR
```

The detailed description of the above mentioned initialization parameters can be found in the SSD1331 datasheet.

The following colors are predefined in the **glcd_ssd1331.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The SSD1331 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..1 - Blue color bits 0..1
- Bits 2..4 - Green color bits 0..2
- Bits 5..7 - Red color bits 0..2.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ssd1331.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1331.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1331** directory contains a fully functional code example that may be used as references for SSD1331 initialization and usage.

5.12.20 Graphic OLED Display Functions Specific to the SSD1332 Controller

The library for the Solomon Systech SSD1332 controller supports color OLED 96x64 displays with 256 or 64k color resolution and hardware graphic acceleration for drawing:

- lines
- rectangles
- filled rectangles
- filled circles
- filled ellipses.

The following functions, declared in the **glcd_ssd1332.h** header file, were implemented:

void ssd1332_wrcmd(unsigned char cmd)

Writes a command to the SSD1332 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1332.h** header file:

```
#define SSD1332_CMD_SET_COLUMN_ADDR 0x15    /* Set column start and end
                                              addresses */
#define SSD1332_CMD_DRAW_LINE 0x21         /* Draw line */
#define SSD1332_CMD_DRAW_RECTANGLE 0x22    /* Draw rectangle */
#define SSD1332_CMD_COPY 0x23              /* Copy block */
#define SSD1332_CMD_DIM_WINDOW 0x24        /* Window will become darker */
#define SSD1332_CMD_CLEAR_WINDOW 0x25      /* Clear window */
#define SSD1332_CMD_FILL_CTRL 0x26         /* Enable/disable fill when
                                              drawing rectangle */
#define SSD1332_CMD_SET_SCROLL 0x27        /* Continuous horizontal &
                                              vertical scrolling setup */
#define SSD1332_CMD_SET_ROW_ADDR 0x75      /* Set row start and end
                                              addresses */
#define SSD1332_CMD_SET_CONTRAST_A 0x81     /* Set the contrast current for
                                              color A */
#define SSD1332_CMD_SET_CONTRAST_B 0x82     /* Set the contrast current for
                                              color B */
#define SSD1332_CMD_SET_CONTRAST_C 0x83     /* Set the contrast current for
                                              color C */
#define SSD1332_CMD_SET_MASTER_CURRENT 0x87 /* Set master current */
#define SSD1332_CMD_REMAP_MODE 0xA0        /* Set Re-map/Color Depth */
#define SSD1332_CMD_SET_START_LINE 0xA1    /* Set display start line */
#define SSD1332_CMD_SET_DISPLAY_OFFSET 0xA2 /* Set display offset */
#define SSD1332_CMD_DISPLAY_NORMAL 0xA4    /* Normal display */
#define SSD1332_CMD_DISPLAY_ALL_ON 0xA5    /* Set all display pixels on */
#define SSD1332_CMD_DISPLAY_ALL_OFF 0xA6   /* Set all display pixels
                                              off */
#define SSD1332_CMD_DISPLAY_INVERSE 0xA7   /* Inverse display */
#define SSD1332_CMD_SET_MUX_RATIO 0xA8     /* Set multiplex ratio */
#define SSD1332_CMD_SET_MASTER_CONFIG 0xAD /* Set master configuration */
#define SSD1332_CMD_DISPLAY_OFF 0xAE       /* Display off */
#define SSD1332_CMD_DISPLAY_ON 0xAF        /* Display on */
#define SSD1332_CMD_POWERSAVE_MODE 0xB0    /* Power save mode */
```

```
#define SSD1332_CMD_SET_PHASE_LENGTH 0xB1 /* Set phase 1 and 2 periods */
#define SSD1332_CMD_SET_FRONT_CLK 0xB3 /* Set front clock
dividing/oscillator
frequency */
#define SSD1332_CMD_SET_GRAYSCALE_TBL 0xB8 /* Set gray scale pulse width
table */
#define SSD1332_CMD_SET_GRAYSCALE_LIN 0xB9 /* Set default linear gray
scale pulse width table */
#define SSD1332_CMD_SET_VPA 0xBB /* Set Precharge Voltage for
color A */
#define SSD1332_CMD_SET_VPB 0xBC /* Set Precharge Voltage for
color B */
#define SSD1332_CMD_SET_VPC 0xBD /* Set Precharge Voltage for
color C */
#define SSD1332_CMD_SET_VCOMH 0xBE /* Set the COM deselect voltage
level */
```

A detailed description of the above mentioned commands can be found in the SSD1332 datasheet.

unsigned char ssd1332_rdstatus(void)

Reads the status byte from the SSD1332 controller.

void ssd1332_busy(void)

Waits until the controller has finished executing a hardware accelerated drawing command.

void ssd1332_wrdata(unsigned char data)

Writes a byte of data to the SSD1332 controller.

Parameter:

data byte to be sent to the controller.

unsigned char ssd1332_rddata(void)

Reads a byte of data from the SSD1332 controller.

void ssd1332_setcontrast(unsigned char contrast)

Controls the OLED display master contrast.

Parameter:

contrast sets the contrast value, the allowed range being 0..15.

The `glcd_ssd1332.h` header file also contains the definition of the `GLCDINIT_t` type specific for the SSD1332 controller, used as parameter for the `glcd_init` function:

```
typedef struct
{
    flash unsigned char *font; /* Default font after initialization */
    /* Pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* Pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char divset:4; /* Front clock divider */
    unsigned char osc_freq:4; /* Oscillator frequency */
    unsigned char phase1:4; /* Phase 1 period: 1..15 [DCLK cycles] */
    unsigned char phase2:4; /* Phase 2 period: 1..15 [DCLK cycles] */
    unsigned char vcomh:5; /* VCOMH voltage= Vcc*(0.44+vcomh*0.0122) */
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char com_split:1; /* enable odd/even split of COM pins
                               (interlaced display) */
    unsigned char vp_red; /* Precharge Voltage for red color
                          (0.43+vp_red*0.00445)*Vref [V] */
    unsigned char vp_green; /* Precharge Voltage for green color
                            (0.43+vp_green*0.00445)*Vref [V] */
    unsigned char vp_blue; /* Precharge Voltage for blue color
                           (0.43+vp_blue*0.00445)*Vref [V] */
    unsigned char contrast_red; /* Contrast current= ISEG*contrast
                               for red color */
    unsigned char contrast_green; /* Contrast current= ISEG*contrast
                                for green color */
    unsigned char contrast_blue; /* Contrast current= ISEG*contrast
                                for blue color */
    unsigned char master_current:4; /* Reduce the output current for
                                   all colors to
                                   (master_current+1)/16 */
    flash unsigned char *gray_scale_table; /* pointer to gray scale
                                           table for gamma correction
                                           (array located in FLASH
                                           with 32 byte values)
                                           A NULL pointer specifies
                                           to use the default
                                           table */
} GLCDINIT_t;
```

Note: The SSD1332 controller doesn't allow changing the color scan order: RGB or BGR by hardware.

This function is accomplished by software in the library.

In order to specify the desired color order, select one of the following options in the **Project|Configure|Libraries|Graphic Displays** menu:

- SSD1332 96x64 OLED 256 (or 64k) Colors *RGB* 8Bit Bus
- SSD1332 96x64 OLED 256 (or 64k) Colors *BGR* 8Bit Bus.

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for divset
#define SSD1332_DIV1 0 /* Divide osc. by 1 */
#define SSD1332_DIV2 1 /* Divide osc. by 2 */
#define SSD1332_DIV4 2 /* Divide osc. by 4 */
#define SSD1332_DIV8 3 /* Divide osc. by 8 */
#define SSD1332_DIV16 4 /* Divide osc. by 16 */
#define SSD1332_DIV32 5 /* Divide osc. by 32 */
#define SSD1332_DIV64 6 /* Divide osc. by 64 */
#define SSD1332_DIV128 7 /* Divide osc. by 128 */
#define SSD1332_DIV256 8 /* Divide osc. by 256 */
#define SSD1332_DIV512 9 /* Divide osc. by 512 */
#define SSD1332_DIV1024 10 /* Divide osc. by 1024 */

/* Initialization values for reverse_x */
#define SSD1332_REVX_NORM 0 /* Scan from COM0 to COMn-1 */
#define SSD1332_REVX_REV 1 /* Scan from COMn-1 to COM0 */

/* Initialization values for reverse_y */
#define SSD1332_REVY_NORM 0 /* Scan from COM0 to COMn-1 */
#define SSD1332_REVY_REV 1 /* Scan from COMn-1 to COM0 */

/* Initialization values for color_bgr */
#define SSD1332_COLOR_RGB 0 /* Use R, G, B color order */
#define SSD1332_COLOR_BGR 1 /* Use B, G, R color order */

/* Initialization values for com_split */
#define SSD1332_COM_SPLIT_OFF 0
#define SSD1332_COM_SPLIT_ON 1

/* Initialization value for gray_scale_table */
#define SSD1332_GRAY_SCALE_LINEAR NULL /* Use a linear gray scale */

/* Default value for divset */
#define SSD1332_DEFAULT_DIVSET SSD1332_DIV1
/* Default value for osc_freq */
#define SSD1332_DEFAULT_OSC_FREQ 0x0F
/* Default value for phase1 */
#define SSD1332_DEFAULT_PHASE1 0x0F
/* Default value for phase2 */
#define SSD1332_DEFAULT_PHASE2 1
/* Default value for reverse_x */
#define SSD1332_DEFAULT_REVX SSD1332_REVX_NORM
/* Default value for reverse_y */
#define SSD1332_DEFAULT_REVY SSD1332_REVY_NORM
/* Default value for com_split */
#define SSD1332_DEFAULT_COM_SPLIT SSD1332_COM_SPLIT_OFF
/* Default values for vp_red, vp_green, vp_blue */
#define SSD1332_DEFAULT_VP_RED 0x00
#define SSD1332_DEFAULT_VP_GREEN 0x40
#define SSD1332_DEFAULT_VP_BLUE 0x7F
/* Default value for vcomh */
#define SSD1332_DEFAULT_VCOMH 0x3F
/* Default values for contrast_red, contrast_green, contrast_blue */
#define SSD1332_DEFAULT_CONTRAST_RED 0x30
#define SSD1332_DEFAULT_CONTRAST_GREEN 0x11
#define SSD1332_DEFAULT_CONTRAST_BLUE 0xEF
/* Default value for master_current */
#define SSD1332_DEFAULT_MASTER_CURRENT 15
```



```
/* Default value for gray_scale_table */  
#define SSD1332_DEFAULT_GRAY_SCALE SSD1332_GRAY_SCALE_LINEAR
```

The detailed description of the above mentioned initialization parameters can be found in the SSD1332 datasheet.

The following colors are predefined in the **glcd_ssd1332.h** header file:

```
GLCD_CL_BLACK  
GLCD_CL_WHITE  
GLCD_CL_GRAY  
GLCD_CL_LIGHT_GRAY  
GLCD_CL_GREEN  
GLCD_CL_LIME  
GLCD_CL_BLUE  
GLCD_CL_RED  
GLCD_CL_AQUA  
GLCD_CL_YELLOW  
GLCD_CL_MAGENTA  
GLCD_CL_CYAN  
GLCD_CL_DARK_CYAN  
GLCD_CL_ORANGE  
GLCD_CL_PINK  
GLCD_CL_BROWN  
GLCD_CL_VIOLET  
GLCD_CL_SILVER  
GLCD_CL_GOLD  
GLCD_CL_NAVY  
GLCD_CL_MAROON  
GLCD_CL_PURPLE  
GLCD_CL_OLIVE
```

The SSD1332 library functions can operate the display in 256 or 64k color modes.
For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..1 - Blue color bits 0..1
- Bits 2..4 - Green color bits 0..2
- Bits 5..7 - Red color bits 0..2.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ssd1332.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1332.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1332** directory contains a fully functional code example that may be used as references for SSD1332 initialization and usage.

5.12.21 Graphic OLED Display Functions Specific to the SSD1351 Controller

In order to take full advantage of the Solomon Systech SSD1351 color OLED 128x96 and 128x128 display controller's features, the following specific functions, declared in the **glcd_ssd1351.h** header file, were implemented:

void ssd1351_wrcmd(unsigned char cmd)

Writes a command to the SSD1351 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1351.h** header file:

```
#define SSD1351_CMD_SET_COLUMN_ADDR 0x15 /* Set column start and end
addresses */
#define SSD1351_CMD_SET_ROW_ADDR 0x75 /* Set row start and end
addresses */
#define SSD1351_CMD_WRITE_RAM 0x5C /* Enable MCU to write data into
GDRAM */
#define SSD1351_CMD_READ_RAM 0x5D /* Enable MCU to read data from
GDRAM */
#define SSD1351_CMD_REMAP_MODE 0xA0 /* Set Re-map/Color Depth */
#define SSD1351_CMD_SET_START_LINE 0xA1 /* Set display start line */
#define SSD1351_CMD_SET_DISPLAY_OFFSET 0xA2 /* Set display offset */
#define SSD1351_CMD_DISPLAY_ALL_OFF 0xA4 /* All display pixels off */
#define SSD1351_CMD_DISPLAY_ALL_ON 0xA5 /* All display pixels on */
#define SSD1351_CMD_DISPLAY_NORMAL 0xA6 /* Normal display */
#define SSD1351_CMD_DISPLAY_INVERSE 0xA7 /* Inverse display */
#define SSD1351_CMD_DISPLAY_PARTIAL_ON 0xA8 /* Enable partial display
mode */
#define SSD1351_CMD_DISPLAY_PARTIAL_OFF 0xA9 /* Exit partial display
mode */
#define SSD1351_CMD_FUNC_SEL 0xAB /* Function selection */
#define SSD1351_CMD_SLEEP_ON 0xAE /* Enter sleep mode */
#define SSD1351_CMD_SLEEP_OFF 0xAF /* Exit sleep mode */
#define SSD1351_CMD_SET_PHASE_LENGTH 0xB1 /* Set phase 1 and 2 periods */
#define SSD1351_CMD_SET_FRONT_CLK 0xB3 /* Set front clock divider/
oscillator frequency */
#define SSD1351_CMD_SET_VSL 0xB4 /* Set Segment Low Voltage
(VSL) */
#define SSD1351_CMD_SET_GPIO 0xB5 /* Set GPIO pins state */
#define SSD1351_CMD_SET_PRECHARGE2 0xB6 /* Set second pre-charge
period */
#define SSD1351_CMD_SET_GRAYSCALE_TBL 0xB8 /* Set gray scale pulse
width table */
```

```
#define SSD1351_CMD_SET_GRAYSCALE_LIN 0xB9 /* Set default linear gray
                                             scale pulse width table */
#define SSD1351_CMD_SET_PRECHARGE_VOLT 0xBB /* Set the pre-charge
                                             voltage level */
#define SSD1351_CMD_SET_VCOMH 0xBE /* Set the COM deselect
                                     voltage level */
#define SSD1351_CMD_SET_CONTRAST 0xC1 /* Set the contrast current
                                       for colors */
#define SSD1351_CMD_SET_MASTER_CONTRAST 0xC7 /* Set master contrast
                                              current */
#define SSD1351_CMD_SET_MUX_RATIO 0xCA /* Set MUX ratio: 15..127 */
#define SSD1351_CMD_SET_COMMAND_LOCK 0xFD /* Set MCU protection status */
```

A detailed description of the above mentioned commands can be found in the SSD1351 datasheet.

void ssd1351_wrddata(unsigned char data)

Writes a byte of data to the SSD1351 controller.

Parameter:

data byte to be sent to the controller.

unsigned char ssd1351_rddata(void)

Reads a byte of data from the SSD1351 controller.

void ssd1351_setcontrast(unsigned char contrast)

Controls the OLED display master contrast.

Parameter:

contrast sets the contrast value, the allowed range being 0..15.

The **glcd_ssd1351.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SSD1351 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* Default font after initialization */
    /* Pointer to the function used for reading a byte from external
memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* Pointer to the function used for writing a byte to external
memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char divset:4; /* Front clock divider */
    unsigned char osc_freq:4; /* Oscillator frequency */
    unsigned char phasel:4; /* Phase 1 period */
    unsigned char phase2:4; /* Phase 2 period */
    unsigned char precharge_v:5; /* Pre-charge voltage=
                                Vcc*(0.2+precharge_v*0.01275) */
    unsigned char vcomh:3; /* VCOMH voltage= Vcc*(0.72+vcomh*0.02) */
}
```

```
unsigned char reverse_x:1; /* reverse display horizontally */
unsigned char reverse_y:1; /* reverse display vertically */
unsigned char color_bgr:1; /* =0 - color order: R, G, B
                             =1 - color order: B, G, R */
unsigned char com_split:1; /* enable odd/even split of COM pins
                             (interlaced display) */
unsigned char precharge_t2:4; /* Second pre-charge period
                               [DCLK cycles] */
unsigned char contrast_red; /* Contrast current= ISEG*contrast
                             for red color */
unsigned char contrast_green; /* Contrast current= ISEG*contrast
                              for green color */
unsigned char contrast_blue; /* Contrast current= ISEG*contrast
                              for blue color */
unsigned char master_contrast:4; /* Reduce the output current for
                                 all colors to
                                 (master_contrast+1)/16 */
unsigned char gpio0:2; /* GPIO0 configuration */
unsigned char gpio1:2; /* GPIO1 configuration */
/* pointer to gray scale table with gamma correction settings
   (63 values), located in FLASH memory */
flash unsigned char *gray_scale_table;
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for divset */
#define SSD1351_DIV1 0 /* Divide osc. by 1 */
#define SSD1351_DIV2 1 /* Divide osc. by 2 */
#define SSD1351_DIV4 2 /* Divide osc. by 4 */
#define SSD1351_DIV8 3 /* Divide osc. by 8 */
#define SSD1351_DIV16 4 /* Divide osc. by 16 */
#define SSD1351_DIV32 5 /* Divide osc. by 32 */
#define SSD1351_DIV64 6 /* Divide osc. by 64 */
#define SSD1351_DIV128 7 /* Divide osc. by 128 */
#define SSD1351_DIV256 8 /* Divide osc. by 256 */
#define SSD1351_DIV512 9 /* Divide osc. by 512 */
#define SSD1351_DIV1024 10 /* Divide osc. by 1024 */

/* Initialization values for phasel */
#define SSD1351_PHASE1_5DCLK 2 /* Phase 1 period=5 DCLK cycles */
#define SSD1351_PHASE1_7DCLK 3 /* Phase 1 period=7 DCLK cycles */
#define SSD1351_PHASE1_9DCLK 4 /* Phase 1 period=9 DCLK cycles */
#define SSD1351_PHASE1_11DCLK 5 /* Phase 1 period=11 DCLK cycles */
#define SSD1351_PHASE1_13DCLK 6 /* Phase 1 period=13 DCLK cycles */
#define SSD1351_PHASE1_15DCLK 7 /* Phase 1 period=15 DCLK cycles */
#define SSD1351_PHASE1_17DCLK 8 /* Phase 1 period=17 DCLK cycles */
#define SSD1351_PHASE1_19DCLK 9 /* Phase 1 period=19 DCLK cycles */
#define SSD1351_PHASE1_21DCLK 10 /* Phase 1 period=21 DCLK cycles */
#define SSD1351_PHASE1_23DCLK 11 /* Phase 1 period=23 DCLK cycles */
#define SSD1351_PHASE1_25DCLK 12 /* Phase 1 period=25 DCLK cycles */
#define SSD1351_PHASE1_27DCLK 13 /* Phase 1 period=27 DCLK cycles */
#define SSD1351_PHASE1_29DCLK 14 /* Phase 1 period=29 DCLK cycles */
#define SSD1351_PHASE1_31DCLK 15 /* Phase 1 period=31 DCLK cycles */
```

```
/* Initialization values for phase2 */
#define SSD1351_PHASE2_3DCLK 3 /* Phase 2 period=3 DCLK cycles */
#define SSD1351_PHASE2_4DCLK 4 /* Phase 2 period=4 DCLK cycles */
#define SSD1351_PHASE2_5DCLK 5 /* Phase 2 period=5 DCLK cycles */
#define SSD1351_PHASE2_6DCLK 6 /* Phase 2 period=6 DCLK cycles */
#define SSD1351_PHASE2_7DCLK 7 /* Phase 2 period=7 DCLK cycles */
#define SSD1351_PHASE2_8DCLK 8 /* Phase 2 period=8 DCLK cycles */
#define SSD1351_PHASE2_9DCLK 9 /* Phase 2 period=9 DCLK cycles */
#define SSD1351_PHASE2_10DCLK 10 /* Phase 2 period=10 DCLK cycles */
#define SSD1351_PHASE2_11DCLK 11 /* Phase 2 period=11 DCLK cycles */
#define SSD1351_PHASE2_12DCLK 12 /* Phase 2 period=12 DCLK cycles */
#define SSD1351_PHASE2_13DCLK 13 /* Phase 2 period=13 DCLK cycles */
#define SSD1351_PHASE2_14DCLK 14 /* Phase 2 period=14 DCLK cycles */
#define SSD1351_PHASE2_15DCLK 15 /* Phase 2 period=15 DCLK cycles */

/* Initialization values for reverse_x */
#define SSD1351_REVX_NORM 0 /* Scan from Column 0 to Column n-1 */
#define SSD1351_REVX_REV 1 /* Scan from Column n-1 to Column 0 */

/* Initialization values for reverse_y */
#define SSD1351_REVY_NORM 0 /* Scan from COM0 to COMn-1 */
#define SSD1351_REVY_REV 1 /* Scan from COMn-1 to COM0 */

/* Initialization values for com_split */
#define SSD1351_COM_SPLIT_OFF 0
#define SSD1351_COM_SPLIT_ON 1

/* Initialization values for gpio0 and gpio1 */
#define SSD1351_GPIO_HIZ 0 /* I/O pin HiZ, no input */
#define SSD1351_GPIO_INPUT 1 /* Set I/O pin as input */
#define SSD1351_GPIO_OUTPUT_LOW 2 /* Set I/O pin as output with
                                   logic level 0 */
#define SSD1351_GPIO_OUTPUT_HIGH 3 /* Set I/O pin as output with
                                   logic level 1 */

/* Initialization value for gray_scale_table */
#define SSD1351_GRAY_SCALE_LINEAR NULL /* Use a linear gray scale */

/* Default value for divset */
#define SSD1351_DEFAULT_DIVSET SSD1351_DIV2
/* Default value for osc_freq */
#define SSD1351_DEFAULT_OSC_FREQ 0x0F
/* Default value for phase1 */
#define SSD1351_DEFAULT_PHASE1 SSD1351_PHASE1_5DCLK
/* Default value for phase2 */
#define SSD1351_DEFAULT_PHASE2 SSD1351_PHASE2_3DCLK
/* Default value for precharge_v */
#define SSD1351_DEFAULT_PRECHARGE_V 0x17
/* Default value for reverse_x */
#define SSD1351_DEFAULT_REVX SSD1351_REVX_NORM
/* Default value for reverse_y */
#define SSD1351_DEFAULT_REVY SSD1351_REVY_NORM
/* Default value for color_bgr */
#define SSD1351_DEFAULT_COLOR_BGR SSD1351_COLOR_RGB
/* Default value for com_split */
#define SSD1351_DEFAULT_COM_SPLIT SSD1351_COM_SPLIT_OFF
/* Default value for precharge_t2 */
#define SSD1351_DEFAULT_PRECHARGE_T2 1
```

```
/* Default value for vcomh */
#define SSD1351_DEFAULT_VCOMH 5
/* Default values for contrast_red, contrast_green, contrast_blue */
#define SSD1351_DEFAULT_CONTRAST_RED 0x88
#define SSD1351_DEFAULT_CONTRAST_GREEN 0x70
#define SSD1351_DEFAULT_CONTRAST_BLUE 0x88
/* Default value for master_contrast */
#define SSD1351_DEFAULT_MASTER_CONTRAST 15
/* Default value for gpio0 */
#define SSD1351_DEFAULT_GPIO0 SSD1351_GPIO_HIZ
/* Default value for gpio1 */
#define SSD1351_DEFAULT_GPIO1 SSD1351_GPIO_HIZ
/* Default value for gray_scale_table */
#define SSD1351_DEFAULT_GRAY_SCALE SSD1351_GRAY_SCALE_LINEAR
```

The detailed description of the above mentioned initialization parameters can be found in the SSD1351 datasheet.

The following colors are predefined in the **glcd_ssd1351.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The SSD1351 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..1 - Blue color bits 0..1
- Bits 2..4 - Green color bits 0..2
- Bits 5..7 - Red color bits 0..2.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ssd1351.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1351.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1351** directory contains a fully functional code example that may be used as references for SSD1351 initialization and usage.

5.12.22 Graphic LCD Functions Specific to the SSD1963 Controller

The SSD1963 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes. To obtain higher display speed, the 16 bit interface mode is recommended.

In order to take full advantage of the SSD1963 controller's features, the following specific functions, declared in the **glcd_ssd1963.h** header file, were implemented:

void ssd1963_wrcmd(unsigned char cmd)

Writes a command to the SSD1963 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_ssd1963.h** header file:

```
#define SSD1963_CMD_NOP 0x00 /* No operation */
#define SSD1963_CMD_SOFT_RESET 0x01 /* Software reset */
#define SSD1963_CMD_GET_PWR_MODE 0x0A /* Get the current power mode */
#define SSD1963_CMD_GET_ADDR_MODE 0x0B /* Get the frame buffer to the
display panel read order */
#define SSD1963_CMD_GET_DISPLAY_MODE 0x0D /* Returns the display
image mode status */
#define SSD1963_CMD_GET_SIGNAL_MODE 0x0E /* Get the current display signal
mode from the peripheral */
#define SSD1963_CMD_ENT_SLEEP 0x10 /* Enter sleep mode */
#define SSD1963_CMD_EXIT_SLEEP 0x11 /* Exit from sleep mode */
#define SSD1963_CMD_ENT_PARTIAL_MODE 0x12 /* Enter partial display mode */
#define SSD1963_CMD_ENT_NORMAL_MODE 0x13 /* Enter normal display mode */
#define SSD1963_CMD_EXIT_INVERT_MODE 0x20 /* Exit from inverted display
mode */
#define SSD1963_CMD_ENT_INVERT_MODE 0x21 /* Enter inverted display mode */
#define SSD1963_CMD_SET_GAMMA 0x26 /* Selects the gamma curve used by the
display device */
#define SSD1963_CMD_BLANK_DISPLAY 0x28 /* Set display off, without clearing
the frame buffer */
#define SSD1963_CMD_ON_DISPLAY 0x29 /* Set display on */
#define SSD1963_CMD_SET_COLUMN_ADDR 0x2A /* Set the column extent of the
frame buffer accessed with the
SSD1963_CMD_RD_MEM_CONT and
SSD1963_CMD_WR_MEM_CONT
commands */
#define SSD1963_CMD_SET_PAGE_ADDR 0x2B /* Set the page extent of the frame
buffer accessed with the
SSD1963_CMD_RD_MEM_CONT and
SSD1963_CMD_WR_MEM_CONT
commands */
```


CodeVisionAVR

```
#define SSD1963_CMD_WR_MEM_START 0x2C /* Transfer image information from uC
                                         to SSD1963 starting with the
                                         location specified by
                                         SSD1963_CMD_SET_COLUMN_ADDR and
                                         SSD1963_CMD_SET_PAGE_ADDR */
#define SSD1963_CMD_RD_MEM_START 0x2E /* Transfer image information from
                                         SSD1963 to uC starting with the
                                         location specified by
                                         SSD1963_CMD_SET_COLUMN_ADDR and
                                         /* SSD1963_CMD_SET_PAGE_ADDR */
#define SSD1963_CMD_SET_PARTIAL_AREA 0x30 /* Defines the partial display
                                         mode area */
#define SSD1963_CMD_SET_SCROLL_AREA 0x33 /* Defines the vertical scrolling
                                         and fixed areas */
#define SSD1963_CMD_SET_TEAR_OFF 0x34 /* Disable sending synchronization
                                         information from the display */
#define SSD1963_CMD_SET_TEAR_ON 0x35 /* Enable sending synchronization
                                         information from the display */
#define SSD1963_CMD_SET_ADDR_MODE 0x36 /* Set read order from uC to frame
                                         buffer and from frame buffer to
                                         the display panel */
#define SSD1963_CMD_SET_SCROLL_START 0x37 /* Set the start of the vertical
                                         scrolling area in the frame
                                         buffer */
#define SSD1963_CMD_EXIT_IDLE_MODE 0x38 /* Exit idle mode */
#define SSD1963_CMD_ENT_IDLE_MODE 0x39 /* Enter idle mode */
#define SSD1963_CMD_SET_PIXEL_FORMAT 0x3A /* Set pixel format: */
#define SSD1963_PIXEL_3BIT 0x10 /* 3-bit/pixel */
#define SSD1963_PIXEL_8BIT 0x20 /* 8-bit/pixel */
#define SSD1963_PIXEL_12BIT 0x30 /* 12-bit/pixel */
#define SSD1963_PIXEL_16BIT 0x50 /* 16-bit/pixel */
#define SSD1963_PIXEL_18BIT 0x60 /* 18-bit/pixel */
#define SSD1963_PIXEL_24BIT 0x70 /* 24-bit/pixel */

#define SSD1963_CMD_WR_MEM_CONT 0x3C /* Transfer image data from uC to
                                         SSD1963 continuing from the
                                         last SSD1963_CMD_WR_MEM_START or
                                         SSD1963_CMD_WR_MEM_CONT */
#define SSD1963_CMD_RD_MEM_CONT 0x3E /* Transfer image data from SSD1963 to
                                         uC continuing from the
                                         last SSD1963_CMD_RD_MEM_START or
                                         SSD1963_CMD_RD_MEM_CONT */
#define SSD1963_CMD_SET_TEAR_SCANLINE 0x44 /* Enable sending the TE signal
                                         to the uC when the
                                         display refresh reaches the
                                         provided scanline */
#define SSD1963_CMD_GET_TEAR_SCANLINE 0x45 /* Get the current scanline */
#define SSD1963_CMD_RD_DDB 0xA1 /* Read the Device Descriptor Block
                                         of SSD1963: */
#define SSD1963_SUPPLIER_ID 0x5701 /* Solomon Systech supplier ID */
#define SSD1963_PRODUCT_ID 0x61 /* SSD1963 product ID */
#define SSD1963_REVISION 0x01 /* SSD1963 minimal revision */

#define SSD1963_CMD_SET_LCD_MODE 0xB0 /* Set LCD panel mode and
                                         resolution */
#define SSD1963_CMD_GET_LCD_MODE 0xB1 /* Get LCD panel mode and
                                         resolution */
#define SSD1963_CMD_SET_HOR_PERIOD 0xB4 /* Set front porch settings */
#define SSD1963_CMD_GET_HOR_PERIOD 0xB5 /* Get front porch settings */
```

```
#define SSD1963_CMD_SET_VER_PERIOD 0xB6 /* Set the vert. blanking interval
                                         between last scan line
                                         and next LFRAME pulse */
#define SSD1963_CMD_GET_VER_PERIOD 0xB7 /* Get the vert. blanking interval
                                         between last scan line
                                         and next LFRAME pulse */
#define SSD1963_CMD_SET_GPIO_CONF 0xB8 /* Set GPIO configuration */
#define SSD1963_CMD_GET_GPIO_CONF 0xB9 /* Get GPIO configuration */
#define SSD1963_CMD_SET_GPIO_VAL 0xBA /* Write data to the GPIOs configured
                                         as outputs */
#define SSD1963_CMD_GET_GPIO_STATUS 0xBB /* Read data from the GPIOs
                                         configured as inputs */
#define SSD1963_CMD_SET_POST_PROC 0xBC /* Set the image post processor */
#define SSD1963_CMD_GET_POST_PROC 0xBD /* Get the image post processor */
#define SSD1963_CMD_SET_PWM_CONF 0xBE /* Set PWM configuration */
#define SSD1963_CMD_GET_PWM_CONF 0xBF /* Get PWM configuration */
#define SSD1963_CMD_SET_LCD_GEN0 0xC0 /* Set the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 0 */
#define SSD1963_CMD_GET_LCD_GEN0 0xC1 /* Get the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 0 */
#define SSD1963_CMD_SET_LCD_GEN1 0xC2 /* Set the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 1 */
#define SSD1963_CMD_GET_LCD_GEN1 0xC3 /* Get the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 1 */
#define SSD1963_CMD_SET_LCD_GEN2 0xC4 /* Set the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 2 */
#define SSD1963_CMD_GET_LCD_GEN2 0xC5 /* Get the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 2 */
#define SSD1963_CMD_SET_LCD_GEN3 0xC6 /* Set the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 3 */
#define SSD1963_CMD_GET_LCD_GEN3 0xC7 /* Get the rise, fall, period and
                                         toggling properties
                                         of LCD signal generator 3 */
#define SSD1963_CMD_SET_GPIO0_ROP 0xC8 /* Set GPIO0 with respect to LCD
                                         signal generators using
                                         ROP3 operation */
#define SSD1963_CMD_GET_GPIO0_ROP 0xC9 /* Get GPIO0 properties with respect
                                         to LCD signal generators */
#define SSD1963_CMD_SET_GPIO1_ROP 0xCA /* Set GPIO1 with respect to LCD
                                         signal generators using
                                         ROP3 operation */
#define SSD1963_CMD_GET_GPIO1_ROP 0xCB /* Get GPIO1 properties with respect
                                         to LCD signal generators */
#define SSD1963_CMD_SET_GPIO2_ROP 0xCC /* Set GPIO2 with respect to LCD
                                         signal generators using
                                         ROP3 operation */
#define SSD1963_CMD_GET_GPIO2_ROP 0xCD /* Get GPIO2 properties with respect
                                         to LCD signal generators */
#define SSD1963_CMD_SET_GPIO3_ROP 0xCE /* Set GPIO3 with respect to LCD
                                         signal generators using
                                         ROP3 operation */
#define SSD1963_CMD_GET_GPIO3_ROP 0xCF /* Get GPIO3 properties with respect
                                         to LCD signal generators */
```

```
#define SSD1963_CMD_SET_DBC_CONF 0xD0 /* Set Dynamic Backlight Control
configuration */
#define SSD1963_CMD_GET_DBC_CONF 0xD1 /* Get Dynamic Backlight Control
configuration */
#define SSD1963_CMD_SET_DBC_THRES 0xD4 /* Set the threshold for each level
of power saving */
#define SSD1963_CMD_GET_DBC_THRES 0xD5 /* Get the threshold for each level
of power saving */
#define SSD1963_CMD_SET_PLL 0xE0 /* Start the PLL */
#define SSD1963_CMD_SET_PLL_MN 0xE2 /* Set the PLL divider (M) and
multiplier (N) */
#define SSD1963_CMD_GET_PLL_MN 0xE3 /* Get the PLL divider (M) and
multiplier (N) */
#define SSD1963_CMD_GET_PLL_STATUS 0xE4 /* Get the current PLL status */
#define SSD1963_CMD_DEEP_SLEEP 0xE5 /* Set deep sleep mode, PLL will be
stopped */
#define SSD1963_CMD_SET_PCLK 0xE6 /* Set pixel clock (LSHIFT signal)
frequency */
#define SSD1963_CMD_GET_PCLK 0xE7 /* Get pixel clock (LSHIFT signal)
frequency settings */
#define SSD1963_CMD_SET_PDATA_INTERFACE 0xF0 /* Set the pixel data format
used for parallel mode
communication with
the uC: */

#define SSD1963_PIXEL_DATA_8BIT 0 /* 8-bit */
#define SSD1963_PIXEL_DATA_9BIT 6 /* 9-bit */
#define SSD1963_PIXEL_DATA_12BIT 1 /* 12-bit */
#define SSD1963_PIXEL_DATA_16BIT 2 /* 16-bit packed */
#define SSD1963_PIXEL_DATA_16BIT565 3 /* 16-bit 565 format */
#define SSD1963_PIXEL_DATA_18BIT 4 /* 18-bit */
#define SSD1963_PIXEL_DATA_24BIT 5 /* 24-bit */

#define SSD1963_CMD_GET_PDATA_INTERFACE 0xF1 /* Get the pixel data format
used for parallel mode
communication with
the uC */
```

void ssd1963_wrddata(unsigned char data)

Writes data byte(s) to the SSD1963 controller after a command was issued using the **ssd1963_wrcmd** function.

Parameter:

data to be sent to the controller.

unsigned char ssd1963_rddata(void)

Reads result data byte(s) from the SSD1963 controller after a command was issued using the **ssd1963_wrcmd** function.

void ssd1963_wrdrdram(GLCDCOL_t color)

Writes color data for 1 pixel to the SSD1963 controller's display RAM.

Parameter:

color data to be sent to the controller.

Note: Before calling this function a **SSD1963_CMD_WR_MEM_START** or **SSD1963_CMD_WR_MEM_CONT** command must be issued to the controller using the **ssd1963_wrcmd** function.

GLCDCOL_t ssd1963_rddram(void)

Reads color data for 1 pixel from the SSD1963 controller's display RAM.

Note: Before calling this function a **SSD1963_CMD_RD_MEM_START** or **SSD1963_CMD_RD_MEM_CONT** command must be issued to the controller using the **ssd1963_wrcmd** function.

void ssd1963_sleep(bool on)

Puts the SSD1963 controller in sleep mode or exit from sleep mode.

Parameter:

on when **true** puts the controller in sleep mode, when **false** exits the sleep mode.

Notes:

- The function automatically inserts a 5ms delay after entering or exiting the sleep mode.
- A delay of minimum 120ms must be present after exiting the sleep mode and entering sleep mode again.

The **glcd_ssd1963.h** header file also contains the definition of the **GLCDINIT_t** type specific for the SSD1963 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned short ctrl_clk; /* SSD1963 controller external clock
                              (crystal) frequency [kHz] */
    unsigned short tft_pixel_clk; /* TFT pixel clock frequency [kHz] */
    unsigned char hpulse_width; /* TFT panel horizontal pulse width
                                  [pixel clock cycles] */
    unsigned char hfront_porch; /* TFT panel horizontal front porch
                                  width [pixel clock cycles] */
    unsigned char hback_porch; /* TFT panel horizontal back porch width
                                  [pixel clock cycles] */
    unsigned char vpulse_width; /* TFT panel vertical pulse width
                                  [line cycles] */
}
```

```
    unsigned char vfront_porch; /* TFT panel vertical front porch width
                                [line cycles] */
    unsigned char vback_porch; /* TFT panel vertical back porch width
                                [line cycles] */
    unsigned char tft24bit:1; /* specify TFT panel data width
                                =0 - 18bit, =1 - 24bit */
    unsigned char lshift:1; /* specify the dot clock pulse polarity
                                =0 - data latch on falling edge
                                =1 - data latch on rising edge */
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                order to the display RAM
                                =0 -> RGB, =1 ->BGR */

} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for tft24bit */
#define SSD1963_TFT_DATA_WIDTH18 0 /* TFT panel data width 18 bit */
#define SSD1963_TFT_DATA_WIDTH24 1 /* TFT panel data width 24 bit */

/* Initialization values for lshift */
/* data latch on falling edge */
#define SSD1963_LSHIFT_LATCH_FALLING_EDGE 0
/* data latch on rising edge */
#define SSD1963_LSHIFT_LATCH_RISING_EDGE 1

/* Initialization values for reverse_x */
#define SSD1963_REVX_NORM 0 /* No horizontal reverse */
#define SSD1963_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define SSD1963_REVY_NORM 0 /* No vertical reverse */
#define SSD1963_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
/* Write color bits to display RAM in RGB order */
#define SSD1963_CL_BITS_RGB 0
/* Write color bits to display RAM in BGR order */
#define SSD1963_CL_BITS_BGR 1

/* Default initialization values for GLCDINIT_t */
#define SSD1963_DEFAULT_CTRL_CLK 10000 /* external clock frequency [kHz] */

#if (( _GLCD_MAXX_==320) && ( _GLCD_MAXY_==240))
/* 3.5" 320x240 display */
/* TFT LCD pixel clock frequency [kHz] */
#define SSD1963_DEFAULT_TFT_PIXEL_CLK_FREQ 6500

#define SSD1963_DEFAULT_TFT_HOR_PULSE_WIDTH 20
#define SSD1963_DEFAULT_TFT_HOR_FRONT_PORCH 20
#define SSD1963_DEFAULT_TFT_HOR_BACK_PORCH 48

#define SSD1963_DEFAULT_TFT_VER_PULSE_WIDTH 2
#define SSD1963_DEFAULT_TFT_VER_FRONT_PORCH 4
#define SSD1963_DEFAULT_TFT_VER_BACK_PORCH 16
```

CodeVisionAVR

```
/* default tft24bit to 18 bit TFT */
#define SSD1963_DEFAULT_TFT_DATA_WIDTH SSD1963_TFT_DATA_WIDTH18

#elif ((_GLCD_MAXX_==480) && (_GLCD_MAXY_==272))
/* 4.3" 480x272 display */
/* TFT LCD pixel clock frequency [kHz] */
#define SSD1963_DEFAULT_TFT_PIXEL_CLK_FREQ 9000

#define SSD1963_DEFAULT_TFT_HOR_PULSE_WIDTH 41
#define SSD1963_DEFAULT_TFT_HOR_FRONT_PORCH 2
#define SSD1963_DEFAULT_TFT_HOR_BACK_PORCH 2

#define SSD1963_DEFAULT_TFT_VER_PULSE_WIDTH 10
#define SSD1963_DEFAULT_TFT_VER_FRONT_PORCH 2
#define SSD1963_DEFAULT_TFT_VER_BACK_PORCH 2

/* default tft24bit to 18 bit TFT */
#define SSD1963_DEFAULT_TFT_DATA_WIDTH SSD1963_TFT_DATA_WIDTH18

#elif ((_GLCD_MAXX_==800) && (_GLCD_MAXY_==480))
/* 7" 800x480 display */
/* TFT LCD pixel clock frequency [kHz] */
#define SSD1963_DEFAULT_TFT_PIXEL_CLK_FREQ 33300

#define SSD1963_DEFAULT_TFT_HOR_PULSE_WIDTH 40
#define SSD1963_DEFAULT_TFT_HOR_FRONT_PORCH 82
#define SSD1963_DEFAULT_TFT_HOR_BACK_PORCH 7

#define SSD1963_DEFAULT_TFT_VER_PULSE_WIDTH 17
#define SSD1963_DEFAULT_TFT_VER_FRONT_PORCH 29
#define SSD1963_DEFAULT_TFT_VER_BACK_PORCH 22

/* default tft24bit to 18 bit TFT */
#define SSD1963_DEFAULT_TFT_DATA_WIDTH SSD1963_TFT_DATA_WIDTH18
#endif

/* Default value for lshift */
#define SSD1963_DEFAULT_LSHIFT SSD1963_LSHIFT_LATCH_FALLING_EDGE

/* Default value for reverse_x */
/* No horizontal reverse */
#define SSD1963_DEFAULT_REVX SSD1963_REVX_NORM

/* Default value for reverse_y */
/* No vertical reverse */
#define SSD1963_DEFAULT_REVY SSD1963_REVY_NORM

/* Default value for cl_bits_order */
/* Write in RGB order */
#define SSD1963_DEFAULT_CL_BITS SSD1963_CL_BITS_RGB
```

The following colors are predefined in the **glcd_ssd1963.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The SSD1963 library functions can operate the display in 256 or 64k color modes.

For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ssd1963.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd1963.h**.
- The **..\EXAMPLES\Graphic Displays\SSD1963** directory contains fully functional code samples that may be used as references for SSD1963 initialization and usage.

5.12.23 Graphic LCD Functions Specific to the SSD2119 Controller

The SSD2119 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes.

To obtain higher display speed, the 16 bit interface mode is recommended.

In order to take full advantage of the SSD2119 controller's features, the following specific functions, declared in the **glcd_ssd2119.h** header file, were implemented:

void ssd2119_wrcmd(unsigned char cmd)

Writes a command to the SSD2119 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_ssd2119.h** header file:

```
/* SSD2119 command register definitions */
#define SSD2119_CMD_OSC 0x00 /* Oscillator register */
#define SSD2119_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define SSD2119_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform
control */
#define SSD2119_CMD_POWER_CONTROL1 0x03 /* Power control 1 */
#define SSD2119_CMD_DISPLAY_CONTROL 0x07 /* Display control register */
#define SSD2119_CMD_FRAME_CYCLE 0x0b /* Frame cycle control register */
#define SSD2119_CMD_POWER_CONTROL2 0x0c /* Power control 2 register */
#define SSD2119_CMD_POWER_CONTROL3 0x0d /* Power control 3 register */
#define SSD2119_CMD_POWER_CONTROL4 0x0e /* Power control 4 register */
#define SSD2119_CMD_GATE_SCAN_POS 0x0f /* Gate scan position register */
#define SSD2119_CMD_SLEEP_MODE 0x10 /* Sleep mode register */
#define SSD2119_CMD_ENTRY_MODE 0x11 /* Entry mode register */
#define SSD2119_CMD_DEEP_SLEEP_MODE 0x12 /* Deep sleep mode register */
#define SSD2119_CMD_GENERIC_IF_CTRL 0x15 /* Generic interface control
register */
#define SSD2119_CMD_HORIZ_PORCH 0x16 /* Horizontal porch register */
#define SSD2119_CMD_VERT_PORCH 0x17 /* Vertical porch register */
#define SSD2119_CMD_POWER_CONTROL5 0x1e /* Power control 5 register */
#define SSD2119_CMD_GDDRAM_DATA 0x22 /* GDDRAM read/write data register */
#define SSD2119_CMD_FRAME_FREQ 0x25 /* Frame frequency control register */
#define SSD2119_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define SSD2119_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define SSD2119_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define SSD2119_CMD_GAMMA_CONTROL4 0x33 /* Gamma control 4 */
#define SSD2119_CMD_GAMMA_CONTROL5 0x34 /* Gamma control 5 */
#define SSD2119_CMD_GAMMA_CONTROL6 0x35 /* Gamma control 6 */
#define SSD2119_CMD_GAMMA_CONTROL7 0x36 /* Gamma control 7 */
#define SSD2119_CMD_GAMMA_CONTROL8 0x37 /* Gamma control 8 */
#define SSD2119_CMD_GAMMA_CONTROL9 0x3a /* Gamma control 9 */
#define SSD2119_CMD_GAMMA_CONTROL10 0x3b /* Gamma control 10 */
#define SSD2119_CMD_VERT_SCROLL1 0x41 /* Vertical scroll control for
screen 1 */
#define SSD2119_CMD_VERT_SCROLL2 0x42 /* Vertical scroll control for
screen 2 */
```



```
#define SSD2119_CMD_HORIZ_RAM_ADDR 0x44 /* Addresses of horizontal
                                         start/end window positions */
#define SSD2119_CMD_VERT_RAM_ADDR_START 0x45 /* Address of vertical start
                                              window positions */
#define SSD2119_CMD_VERT_RAM_ADDR_END 0x46 /* Address of vertical end
                                              window positions */
#define SSD2119_CMD_DRV_POS_START1 0x48 /* Driving start line position for
                                         screen 1 */
#define SSD2119_CMD_DRV_POS_END1 0x49 /* Driving end line position for
                                         screen 1 */
#define SSD2119_CMD_DRV_POS_START2 0x4a /* Driving start line position for
                                         screen 2 */
#define SSD2119_CMD_DRV_POS_END2 0x4b /* Driving end line position for
                                         screen 2 */
#define SSD2119_CMD_GDDRAMX 0x4e /* Set GDDRAM X address counter
                                   register */
#define SSD2119_CMD_GDDRAMY 0x4f /* Set GDDRAM Y address counter
                                   register
```

A detailed description of the above mentioned command registers can be found in the SSD2119 datasheet.

void ssd2119_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the SSD2119 controller.

Parameters:

index command register index
data to be written.

unsigned short ssd2119_rdreg(unsigned char index)

Reads the contents of a command register of the SSD2119 controller.

Parameters:

index command register index.

void ssd2119_wrdata(unsigned short data)

Writes data to the SSD2119 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short ssd2119_rddata(void)

Reads data from the SSD2119 controller's Graphic Display RAM.

The `glcd_ssd2119.h` header file also contains the definition of the `GLCDINIT_t` type specific for the SSD2119 controller, used as parameter for the `glcd_init` function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char first_out_gate:1; /* selects the first output gate
                                     GD bit of Driver Output Control
                                     register
                                     =0 Gate 1 on left side of
                                     display
                                     =1 Gate 2 on left side of
                                     display */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */

    /* power control registers bits */
    unsigned char stepup_factor:3; /* step-up factor of the step-up
                                     circuit, see BT0..BT2 bits in
                                     the datasheet */
    unsigned char stepup_cycle:4; /* controls the cycle for the
                                     step-up circuit */
    unsigned char crt_source:3; /* adjusts the amount of current
                                   from the constant current source
                                   in the internal op. amplifier
                                   circuit (AP0..AP2 bits) */
    unsigned char vcix2:3; /* adjusts the VCIX2 voltage */
    unsigned char vlcd63:4; /* adjusts the VLCD63 voltage */
    unsigned char vcoml:5; /* adjusts the amplitude of the
                             VcomL alternating drive voltage */
    unsigned char vcomh:5; /* adjusts the amplitude of the VcomH
                             voltage
                              $VcomH = VLCD63 * (0.35 + vcomh * 0.01)$  [V] */
    unsigned char frame_freq:4; /* LCD frame frequency */
    /* positive gamma control registers bits */
    unsigned char pkp00:3; /* PKP00..PKP02 positive gamma micro adj. */
    unsigned char pkp10:3; /* PKP10..PKP12 positive gamma micro adj. */
    unsigned char pkp20:3; /* PKP20..PKP22 positive gamma micro adj. */
    unsigned char pkp30:3; /* PKP30..PKP32 positive gamma micro adj. */
    unsigned char pkp40:3; /* PKP40..PKP42 positive gamma micro adj. */
    unsigned char pkp50:3; /* PKP50..PKP52 positive gamma micro adj. */
    unsigned char prp00:3; /* PRP00..PRP02 positive gamma gradient
                             adj. */
    unsigned char prp10:3; /* PRP10..PRP12 positive gamma gradient
                             adj. */
    unsigned char vrp00:4; /* VRP00..VRP03 positive gamma amplification
                             adj. */
    unsigned char vrp10:5; /* VRP10..VRP14 positive gamma amplification
                             adj. */
}
```

```
/* negative gamma control registers bits */
    unsigned char pkn00:3; /* PKN00..PKN02 negative gamma micro adj. */
    unsigned char pkn10:3; /* PKN10..PKN12 negative gamma micro adj. */
    unsigned char pkn20:3; /* PKN20..PKN22 positive gamma micro adj. */
    unsigned char pkn30:3; /* PKN30..PKN32 positive gamma micro adj. */
    unsigned char pkn40:3; /* PKN40..PKN42 negative gamma micro adj. */
    unsigned char pkn50:3; /* PKN50..PKN52 negative gamma micro adj. */
    unsigned char prn00:3; /* PRN00..PRN02 negative gamma gradient
                           adj. */
    unsigned char prn10:3; /* PRN10..PRN12 negative gamma gradient
                           adj. */
    unsigned char vrn00:4; /* VRN00..VRN03 negative gamma amplification
                           adj. */
    unsigned char vrn10:5; /* VRN10..VRN14 negative gamma
                           amplification adj. */

} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define SSD2119_REVX_NORM 0 /* No horizontal reverse */
#define SSD2119_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define SSD2119_REVY_NORM 0 /* No vertical reverse */
#define SSD2119_REVY_REV 1 /* Vertical reverse */

/* Initialization values for first_out_gate */
#define SSD2119_FIRST_OUT_GATE1 0 /* Gate 1 on left side of display */
#define SSD2119_FIRST_OUT_GATE2 1 /* Gate 2 on left side of display */

/* Initialization values for cl_bits_order */
#define SSD2119_CL_BITS_RGB 0 /* Write color bits to display RAM
                              in RGB order */
#define SSD2119_CL_BITS_BGR 1 /* Write color bits to display RAM
                              in BGR order */

/* Initilization values for dc30 step-up circuit cycle */
#define SSD2119_STEPUP_FLINE24 0 /* Fline *24 */
#define SSD2119_STEPUP_FLINE16 1 /* Fline *16 */
#define SSD2119_STEPUP_FLINE12 2 /* Fline *12 */
#define SSD2119_STEPUP_FLINE8 3 /* Fline *8 */
#define SSD2119_STEPUP_FLINE6 4 /* Fline *6 */
#define SSD2119_STEPUP_FLINE5 5 /* Fline *5 */
#define SSD2119_STEPUP_FLINE4 6 /* Fline *4 */
#define SSD2119_STEPUP_FLINE3 7 /* Fline *3 */
#define SSD2119_STEPUP_FLINE2 8 /* Fline *2 */
#define SSD2119_STEPUP_FLINE1 9 /* Fline *1 */
#define SSD2119_STEPUP_FOSC4 10 /* Fosc /4 (Fosc=510kHz) */
#define SSD2119_STEPUP_FOSC6 11 /* Fosc /6 */
#define SSD2119_STEPUP_FOSC8 12 /* Fosc /8 */
#define SSD2119_STEPUP_FOSC10 13 /* Fosc /10 */
#define SSD2119_STEPUP_FOSC12 14 /* Fosc /12 */
#define SSD2119_STEPUP_FOSC16 15 /* Fosc /16 */
```

```
/* Initialization values for the VCIX2 voltage
   (Power Control Reg. 2) */
#define SSD2119_VCIX2_5V1 0 /* 5.1V */
#define SSD2119_VCIX2_5V3 1 /* 5.3V */
#define SSD2119_VCIX2_5V5 2 /* 5.5V */
#define SSD2119_VCIX2_5V7 3 /* 5.7V */
#define SSD2119_VCIX2_5V9 4 /* 5.9V */
#define SSD2119_VCIX2_6V1 5 /* 6.1V */

/* Initialization values for the VLCD63 voltage
   (bits VRH0..3 from Power Control Reg. 3) */
#define SSD2119_VLCD63_3V56 3 /* VLCD63=3.56V */
#define SSD2119_VLCD63_3V70 4 /* VLCD63=3.70V */
#define SSD2119_VLCD63_3V86 5 /* VLCD63=3.86V */
#define SSD2119_VLCD63_4V04 6 /* VLCD63=4.04V */
#define SSD2119_VLCD63_4V18 7 /* VLCD63=4.18V */
#define SSD2119_VLCD63_4V33 8 /* VLCD63=4.33V */
#define SSD2119_VLCD63_4V49 9 /* VLCD63=4.49V */
#define SSD2119_VLCD63_4V67 10 /* VLCD63=4.67V */
#define SSD2119_VLCD63_4V80 11 /* VLCD63=4.80V */
#define SSD2119_VLCD63_5V00 12 /* VLCD63=5.00V */
#define SSD2119_VLCD63_5V14 13 /* VLCD63=5.14V */
#define SSD2119_VLCD63_5V29 14 /* VLCD63=5.29V */
#define SSD2119_VLCD63_5V45 15 /* VLCD63=5.45V */
#define SSD2119_VLCD63_5V62 0 /* VLCD63=5.62V */
#define SSD2119_VLCD63_5V80 1 /* VLCD63=5.80V */
#define SSD2119_VLCD63_6V00 2 /* VLCD63=6.00V */

/* Initialization values for the VcomL voltage
   (bits VDV0..4 from Power Control Reg. 4) */
#define SSD2119_VCOML_0_60 0 /* VcomL=VLCD63*0.60 */
#define SSD2119_VCOML_0_63 1 /* VcomL=VLCD63*0.63 */
#define SSD2119_VCOML_0_66 2 /* VcomL=VLCD63*0.66 */
#define SSD2119_VCOML_0_69 3 /* VcomL=VLCD63*0.69 */
#define SSD2119_VCOML_0_72 4 /* VcomL=VLCD63*0.72 */
#define SSD2119_VCOML_0_75 5 /* VcomL=VLCD63*0.75 */
#define SSD2119_VCOML_0_78 6 /* VcomL=VLCD63*0.78 */
#define SSD2119_VCOML_0_81 7 /* VcomL=VLCD63*0.81 */
#define SSD2119_VCOML_0_84 8 /* VcomL=VLCD63*0.84 */
#define SSD2119_VCOML_0_87 9 /* VcomL=VLCD63*0.87 */
#define SSD2119_VCOML_0_90 10 /* VcomL=VLCD63*0.90 */
#define SSD2119_VCOML_0_93 11 /* VcomL=VLCD63*0.93 */
#define SSD2119_VCOML_0_96 12 /* VcomL=VLCD63*0.96 */
#define SSD2119_VCOML_0_99 13 /* VcomL=VLCD63*0.99 */
#define SSD2119_VCOML_1_02 14 /* VcomL=VLCD63*1.02 */
#define SSD2119_VCOML_EXT_RES 15 /* VcomL is set by an external
                                   variable resistor */
#define SSD2119_VCOML_1_05 16 /* VcomL=VLCD63*1.05 */
#define SSD2119_VCOML_1_08 17 /* VcomL=VLCD63*1.08 */
#define SSD2119_VCOML_1_11 18 /* VcomL=VLCD63*1.11 */
#define SSD2119_VCOML_1_14 19 /* VcomL=VLCD63*1.14 */
#define SSD2119_VCOML_1_17 20 /* VcomL=VLCD63*1.17 */
#define SSD2119_VCOML_1_20 21 /* VcomL=VLCD63*1.20 */
#define SSD2119_VCOML_1_23 22 /* VcomL=VLCD63*1.23 */
```

CodeVisionAVR

```
/* Initialization values for frame_freq */
#define SSD2119_FRAME50 0 /* 50Hz */
#define SSD2119_FRAME55 2 /* 55Hz */
#define SSD2119_FRAME60 5 /* 60Hz */
#define SSD2119_FRAME65 8 /* 65Hz */
#define SSD2119_FRAME70 0x0A /* 70Hz */
#define SSD2119_FRAME75 0x0C /* 75Hz */
#define SSD2119_FRAME80 0x0E /* 80Hz */

/* Default value for reverse_x */
#define SSD2119_DEFAULT_REVX SSD2119_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define SSD2119_DEFAULT_REVY SSD2119_REVY_NORM /* No vertical reverse */

/* Default value for first_out_gate
   Gate 2 on left side of display */
#define SSD2119_DEFAULT_FIRST_OUT_GATE SSD2119_FIRST_OUT_GATE2

/* Default value for cl_bits_order
   (color bits writing order to display RAM),
   write in RGB order */
#define SSD2119_DEFAULT_CL_BITS SSD2119_CL_BITS_RGB

/* Power control 1 BT0..BT2 step-up factor of the step-up circuit */
#define SSD2119_DEFAULT_STEPUP_FACTOR 4
/* Power control 1 DC0..DC3 step-up circuit cycle */
#define SSD2119_DEFAULT_STEPUP_CYCLE SSD2119_STEPUP_FOSC4
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the internal operational
   amplifier circuit */
#define SSD2119_DEFAULT_CRT_SOURCE 2
/* Default value for VCIX2 voltage */
#define SSD2119_DEFAULT_VCIX2 SSD2119_VCIX2_5V1
/* Default value for VLCD63 voltage */
#define SSD2119_DEFAULT_VLCD63 SSD2119_VLCD63_4V80
/* Default value for VcomL alternating drive voltage */
#define SSD2119_DEFAULT_VCOML SSD2119_VCOML_0_72
/* Default value for VcomH=VLCD63*(0.35+0x1A*0.01) */
#define SSD2119_DEFAULT_VCOMH 0x1A
/* Default value for driving waveform control FLD bit,
   splits one frame into 3 fields to reduce flicker */
#define SSD2119_DEFAULT_FLD 1
/* Default value for LCD frame frequency */
#define SSD2119_DEFAULT_FRAME_FREQ SSD2119_FRAME80

/* Default initialization values for the gamma control register bits */
/* PKP00..PKP02 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKP00 7
/* PKP10..PKP12 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKP10 7
/* PKP20..PKP22 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKP20 4
/* PKP30..PKP32 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKP30 2
/* PKP40..PKP42 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKP40 4
/* PKP50..PKP52 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKP50 2
/* PRP00..PRP02 positive gamma gradient adj. */
#define SSD2119_DEFAULT_PRP00 2
```

```
/* PRP10..PRP12 positive gamma gradient adj. */
#define SSD2119_DEFAULT_PRP10 5
/* VRP00..VRP03 positive gamma amplification adj. */
#define SSD2119_DEFAULT_VRP00 2
/* VRP10..VRP14 positive gamma amplification adj. */
#define SSD2119_DEFAULT_VRP10 3
/* PKN00..PKN02 negative gamma micro adj. */
#define SSD2119_DEFAULT_PKN00 7
/* PKN10..PKN12 negative gamma micro adj. */
#define SSD2119_DEFAULT_PKN10 5
/* PKN20..PKN22 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKN20 4
/* PKN30..PKN32 positive gamma micro adj. */
#define SSD2119_DEFAULT_PKN30 2
/* PKN40..PKN42 negative gamma micro adj. */
#define SSD2119_DEFAULT_PKN40 4
/* PKN50..PKN52 negative gamma micro adj. */
#define SSD2119_DEFAULT_PKN50 2
/* PRN00..PRN02 negative gamma gradient adj. */
#define SSD2119_DEFAULT_PRN00 2
/* PRN10..PRN12 negative gamma gradient adj. */
#define SSD2119_DEFAULT_PRN10 5
/* VRN00..VRN03 negative gamma amplification adj. */
#define SSD2119_DEFAULT_VRN00 2
/* VRN10..VRN14 negative gamma amplification adj. */
#define SSD2119_DEFAULT_VRN10 3
```

The following colors are predefined in the **glcd_ssd2119.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The SSD2119 library functions can operate the display in 256 or 64k color modes.
For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_ssd2119.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_ssd2119.h**.
- The **..\EXAMPLES\Graphic Displays\SSD2119** directory contains fully functional code samples that may be used as references for SSD2119 initialization and usage.

5.12.24 Graphic LCD Functions Specific to the ST7565 Controller

The ST7565 library functions supplied with the CodeVisionAVR, can operate the controller in 8-bit parallel, bit-banged and hardware SPI serial modes.

In order to take full advantage of the ST7565 controller's features, the following specific functions, declared in the **glcd_st7565.h** header file, were implemented:

void st7565_wrcmd(unsigned char cmd)

Writes a command to the ST7565 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_st7565.h** header file:

```
#define ST7565_CMD_START_LINE 0x40 /* set display start line */
#define ST7565_CMD_SET_PAGE 0xB0 /* set display page address */
#define ST7565_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define ST7565_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define ST7565_CMD_ADC_SELECT_NORM 0xA0 /* set relationship between RAM
column address and display
driver: normal */
#define ST7565_CMD_ADC_SELECT_REV 0xA1 /* set relationship between RAM
column address and display
driver: reversed */
#define ST7565_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define ST7565_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define ST7565_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
contents */
#define ST7565_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define ST7565_CMD_STATIC_INDICATOR_OFF 0xAC /* turn off static
indicator */
#define ST7565_CMD_STATIC_INDICATOR_ON 0xAD /* turn on static indicator */
#define ST7565_CMD_DISP_OFF 0xAE /* display off */
#define ST7565_CMD_DISP_ON 0xAF /* display on */
#define ST7565_CMD_LCD_BIAS_LOW 0xA2 /* sets voltage ratio for LCD bias to
1/9 (duty cycle=1/65),
1/8 (duty cycle=1/49),
1/6 (duty cycle=1/33),
1/8 (duty cycle=1/55),
1/8 (duty cycle=1/53) */
#define ST7565_CMD_LCD_BIAS_HIGH 0xA3 /* sets voltage ratio for LCD bias to
1/7 (duty cycle=1/65),
1/6 (duty cycle=1/49),
1/5 (duty cycle=1/33),
1/6 (duty cycle=1/55),
1/6 (duty cycle=1/53) */
#define ST7565_CMD_COM0_63 0xC0 /* sets the COM output scan
direction 0->63 */
#define ST7565_CMD_COM63_0 0xC8 /* sets the COM output scan
direction 63->0 */
```



```
#define ST7565_CMD_POWER_CTRL 0x28 /* turns on/off the
                                     voltage follower (| bit 0),
                                     voltage regulator (| bit 1),
                                     voltage booster (| bit 2) */
#define ST7565_VOLT_FOLLOWER_ON (1<<0) /* enable voltage follower */
#define ST7565_VOLT_REGULATOR_ON (1<<1) /* enable voltage regulator */
#define ST7565_VOLT_BOOSTER_ON (1<<2) /* enable voltage booster */

#define ST7565_CMD_VOLT_REG_V5 0x20 /* sets the V5 voltage regulator
                                     internal resistor ratio */
#define ST7565_CMD_ELECTRONIC_VOLUME 0x81 /* sets the electronic volume
                                     register in order to control
                                     the V5 LCD drive voltage */
#define ST7565_CMD_SET_DRIVING_MODE 0xD2 /* used to set the LCD driving
                                     mode */
#define ST7565_CMD_RESET 0xE2 /* resets the controller */
```

A detailed description of the above mentioned commands can be found in the ST7565 datasheet.

void st7565_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the V5 LCD drive voltage, allowed range is 0..63.

The **glcd_st7565.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ST7565 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char lcd_bias:1; /* =0 LCD bias ratio low,
                               =1 LCD bias ratio high */
    unsigned char reverse_x:1; /* reverse display horizontally (ADC) */
    unsigned char rev132_x0:1; /* set to 1 for displays that use
                               reversed RAM column address
                               (reverse_x=1) driver and the pixel
                               with x=0 is connected to column
                               driver #132 */
    unsigned char reverse_y:1; /* reverse display vertically (COM) */
    unsigned char volt_reg_v5:3; /* set V5 voltage regulator
                               internal resistor ratio [0..7] */
    unsigned char driving_mode:2; /* set LCD driving mode:
                                0 - mode 1, 1 - mode 2,
                                2 - mode 3, 3 - mode 4 */
    unsigned char lcd_contrast:5; /* LCD contrast voltage: [0..63] */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for lcd_bias initialization */
#define ST7565_LCD_BIAS_19 0 /* sets LCD bias drive ratio 1/9, 1/8, 1/7 */
#define ST7565_LCD_BIAS_17 1 /* sets LCD bias drive ratio 1/7, 1/6, 1/5 */

/* values used for reverse_x initialization */
#define ST7565_REVX_NORM 0 /* set relationship between RAM column address
and display driver: normal (ADC=0) */
#define ST7565_REVX_REV 1 /* set relationship between RAM column address
and display driver: reversed (ADC=1) */

/* values used for rev132_x0 initialization,
effective only when reverse_x=1 (ST7565_REVX_REV) */
#define ST7565_REV132_X0NC 0 /* pixel with x=0 is not connected to column
driver #132 when ADC=1 */
#define ST7565_REV132_X0CON 1 /* pixel with x=0 is connected to column
driver #132 when ADC=1 */

/* values used for reverse_y initialization */
#define ST7565_REVY_NORM 0 /* sets the vertical COM output scan
direction 0->63 */
#define ST7565_REVY_REV 1 /* sets the vertical COM output scan
direction 63->0 */

/* values used for driving_mode initialization */
#define ST7565_DRIVING_MODE1 0 /* driving mode 1 */
#define ST7565_DRIVING_MODE2 1 /* driving mode 2 */
#define ST7565_DRIVING_MODE3 2 /* driving mode 3 */
#define ST7565_DRIVING_MODE4 3 /* driving mode 4 */

/* default initialization values */
/* default value for LCD bias */
#define ST7565_DEFAULT_LCD_BIAS ST7565_LCD_BIAS_LOW
/* default value for reverse_x */
#define ST7565_DEFAULT_REVX ST7565_REVX_NORM
/* default value for rev132_x0,
effective only when reverse_x=1 (ST7565_REVX_REV) */
#define ST7565_DEFAULT_REV132_X0 ST7565_REV132_X0NC
/* default value for reverse_y */
#define ST7565_DEFAULT_REVY ST7565_REVY_NORM
/* default V5 voltage regulator internal resistor ratio */
#define ST7565_DEFAULT_VOLT_REG_V5 6
/* default LCD driving mode */
#define ST7565_DEFAULT_DRIVING_MODE ST7565_DRIVING_MODE1
/* default contrast */
#define ST7565_DEFAULT_CONTRAST 7
```

The detailed description of the above mentioned initialization parameters can be found in the ST7565 datasheet.

Notes:

- The **glcd_st7565.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_st7565.h**.
- The **..\EXAMPLES\Graphic Displays\ST7565** directory contains fully functional code samples that may be used as references for ST7565 initialization and usage.

5.12.25 Graphic LCD Functions Specific to the ST7567 Controller

The ST7567 library functions supplied with the CodeVisionAVR, can operate the controller in 8-bit parallel, bit-banged and hardware SPI serial modes.

In order to take full advantage of the ST7567 controller's features, the following specific functions, declared in the **glcd_st7567.h** header file, were implemented:

void st7567_wrcmd(unsigned char cmd)

Writes a command to the ST7567 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_st7567.h** header file:

```
#define ST7567_CMD_START_LINE 0x40 /* set display start line */
#define ST7567_CMD_SET_PAGE 0xB0 /* set display page address */
#define ST7567_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define ST7567_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define ST7567_CMD_MX_SELECT_NORM 0xA0 /* set relationship between RAM
                                         column address and display
                                         driver: normal */
#define ST7567_CMD_MX_SELECT_REV 0xA1 /* set relationship between RAM
                                         column address and display
                                         driver: reversed */
#define ST7567_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define ST7567_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define ST7567_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
                                         contents */
#define ST7567_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define ST7567_CMD_STATIC_INDICATOR_OFF 0xAC /* turn off static
                                                indicator */
#define ST7567_CMD_STATIC_INDICATOR_ON 0xAD /* turn on static indicator */
#define ST7567_CMD_DISP_OFF 0xAE /* display off */
#define ST7567_CMD_DISP_ON 0xAF /* display on */
#define ST7567_CMD_LCD_BIAS_LOW 0xA2 /* sets voltage ratio for LCD bias to
                                         1/9 (duty cycle=1/65),
                                         1/8 (duty cycle=1/49),
                                         1/6 (duty cycle=1/33),
                                         1/8 (duty cycle=1/55) */
#define ST7567_CMD_LCD_BIAS_HIGH 0xA3 /* sets voltage ratio for LCD bias to
                                         1/7 (duty cycle=1/65),
                                         1/6 (duty cycle=1/49),
                                         1/5 (duty cycle=1/33),
                                         1/6 (duty cycle=1/55) */
#define ST7567_CMD_COM0_63 0xC0 /* sets the COM output scan
                                         direction 0->63 */
#define ST7567_CMD_COM63_0 0xC8 /* sets the COM output scan
                                         direction 63->0 */
```

```
#define ST7567_CMD_POWER_CTRL 0x28 /* turns on/off the
                                   voltage follower (| bit 0),
                                   voltage regulator (| bit 1),
                                   voltage booster (| bit 2) */
#define ST7567_VOLT_FOLLOWER_ON (1<<0) /* enable voltage follower */
#define ST7567_VOLT_REGULATOR_ON (1<<1) /* enable voltage regulator */
#define ST7567_VOLT_BOOSTER_ON (1<<2) /* enable voltage booster */

#define ST7567_CMD_VOLT_REG_RATIO 0x20 /* sets the resistor ratio of
                                         the internal voltage regulator */
#define ST7567_CMD_ELECTRONIC_VOLUME 0x81 /* sets the electronic volume
                                             register in order to control
                                             the V0 LCD drive voltage */
#define ST7567_CMD_SET_BOOSTER_LEVEL 0xF8 /* sets the booster level */
#define ST7567_CMD_RESET 0xE2 /* resets the controller */
#define ST7567_CMD_NOP 0xE3 /* no operation */
```

A detailed description of the above mentioned commands can be found in the ST7567 datasheet.

void st7567_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the V0 LCD drive voltage, allowed range is 0..63.

The **glcd_st7567.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ST7567 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char lcd_bias:1; /* =0 LCD bias ratio low,
                               =1 LCD bias ratio high */
    unsigned char reverse_x:1; /* reverse display horizontally (MX) */
    unsigned char rev132_x0:1; /* set to 1 for displays that use
                               reversed RAM column address
                               (reverse_x=1) driver and the pixel
                               with x=0 is connected to column
                               driver #132 */
    unsigned char reverse_y:1; /* reverse display vertically (COM) */
    unsigned char volt_reg_ratio:3; /* sets the resistor ratio of
                                    the internal voltage regulator
                                    */
    unsigned char booster_level:1; /* sets the booster level:
                                    0 - x4, 1 - x5 */
    unsigned char lcd_contrast:6; /* LCD contrast voltage: [0..63] */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for lcd_bias initialization */
#define ST7567_LCD_BIAS_19 0 /* sets LCD bias drive ratio 1/9, 1/8, 1/7 */
#define ST7567_LCD_BIAS_17 1 /* sets LCD bias drive ratio 1/7, 1/6, 1/5 */

/* values used for reverse_x initialization */
#define ST7567_REVX_NORM 0 /* set relationship between RAM column address
and display driver: normal (MX=0) */
#define ST7567_REVX_REV 1 /* set relationship between RAM column address
and display driver: reversed (MX=1) */

/* values used for rev132_x0 initilization,
effective only when reverse_x=1 (ST7567_REVX_REV) */
#define ST7567_REV132_X0NC 0 /* pixel with x=0 is not connected to column
driver #132 when MX=1 */
#define ST7567_REV132_X0CON 1 /* pixel with x=0 is connected to column
driver #132 when MX=1 */

/* values used for reverse_y initialization */
#define ST7567_REVY_NORM 0 /* sets the vertical COM output scan
direction 0->63 */
#define ST7567_REVY_REV 1 /* sets the vertical COM output scan
direction 63->0 */

/* values used for volt_reg_ratio initialization */
#define ST7567_VOLT_REG_RATIO_3_0 0 /* 3.0 */
#define ST7567_VOLT_REG_RATIO_3_5 1 /* 3.5 */
#define ST7567_VOLT_REG_RATIO_4_0 2 /* 4.0 */
#define ST7567_VOLT_REG_RATIO_4_5 3 /* 4.5 */
#define ST7567_VOLT_REG_RATIO_5_0 4 /* 5.0 */
#define ST7567_VOLT_REG_RATIO_5_5 5 /* 5.5 */
#define ST7567_VOLT_REG_RATIO_6_0 6 /* 6.0 */
#define ST7567_VOLT_REG_RATIO_6_5 7 /* 6.5 */

/* values used for booster_level initialization */
#define ST7567_BOOSTER_LEVEL_4X 0 /* 4x */
#define ST7567_BOOSTER_LEVEL_5X 1 /* 5x */

/* default initialization values */
/* default value for LCD bias */
#define ST7567_DEFAULT_LCD_BIAS ST7567_LCD_BIAS_LOW
/* default value for reverse_x */
#define ST7567_DEFAULT_REVX ST7567_REVX_NORM
/* default value for rev132_x0,
effective only when reverse_x=1 (ST7567_REVX_REV) */
#define ST7567_DEFAULT_REV132_X0 ST7567_REV132_X0NC
/* default value for reverse_y */
#define ST7567_DEFAULT_REVY ST7567_REVY_NORM
/* default internal voltage regulator ratio */
#define ST7567_DEFAULT_VOLT_REG_RATIO ST7567_VOLT_REG_RATIO_6_0
/* default booster level */
#define ST7567_DEFAULT_BOOSTER_LEVEL ST7567_BOOSTER_LEVEL_4X
/* default contrast */
#define ST7567_DEFAULT_CONTRAST 32
```

The detailed description of the above mentioned initialization parameters can be found in the ST7567 datasheet.

Notes:

- The **glcd_st7567.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_st7567.h**.
- The **..\EXAMPLES\Graphic Displays\ST7567** directory contains fully functional code samples that may be used as references for ST7567 initialization and usage.

5.12.26 Graphic LCD Functions Specific to the ST7781 Controller

The ST7781 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8 and 16 bit interface modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ST7781 controller's features, the following specific functions, declared in the **glcd_st7781.h** header file, were implemented:

void st7781_wrcmd(unsigned char cmd)

Writes a command to the ST7781 controller, used to access a specific command register.

Parameter:

cmd command register index to be sent to the controller.

This index may take one of the values defined in the following macros from the **glcd_st7781.h** header file:

```
/* ST7781 command register definitions */
#define ST7781_CMD_OSC 0x00 /* Oscillator register */
#define ST7781_CMD_DRIVER_OUT 0x01 /* Driver output control */
#define ST7781_CMD_DRIVING_WAVEFORM 0x02 /* LCD driving waveform control */
#define ST7781_CMD_ENTRY_MODE 0x03 /* Entry mode control */
#define ST7781_RESIZE_CONTROL 0x04 /* Resizing control register */
#define ST7781_CMD_DISPLAY_CONTROL1 0x07 /* Display control register 1 */
#define ST7781_CMD_DISPLAY_CONTROL2 0x08 /* Display control register 2 */
#define ST7781_CMD_DISPLAY_CONTROL3 0x09 /* Display control register 3 */
#define ST7781_CMD_DISPLAY_CONTROL4 0x0a /* Display control register 4 */
#define ST7781_CMD_RGB_IF_CONTROL1 0x0c /* RGB display interface control register 1 */
#define ST7781_FRAME_MARKER_POS 0x0d /* Frame marker position */
#define ST7781_CMD_RGB_IF_CONTROL2 0x0f /* RGB display interface control register 2 */
#define ST7781_CMD_POWER_CONTROL1 0x10 /* Power control 1 register */
#define ST7781_CMD_POWER_CONTROL2 0x11 /* Power control 2 register */
#define ST7781_CMD_POWER_CONTROL3 0x12 /* Power control 3 register */
#define ST7781_CMD_POWER_CONTROL4 0x13 /* Power control 4 register */
#define ST7781_CMD_GDDRAMX 0x20 /* Set GRAM X address counter register */
#define ST7781_CMD_GDDRAMY 0x21 /* Set GRAM Y address counter register */
#define ST7781_CMD_GDDRAM_DATA 0x22 /* GRAM read/write data register */
#define ST7781_CMD_POWER_CONTROL7 0x29 /* Power control 7 register */
#define ST7781_CMD_FRAME_RATE 0x2b /* Frame rate frequency control register */
#define ST7781_CMD_GAMMA_CONTROL1 0x30 /* Gamma control 1 */
#define ST7781_CMD_GAMMA_CONTROL2 0x31 /* Gamma control 2 */
#define ST7781_CMD_GAMMA_CONTROL3 0x32 /* Gamma control 3 */
#define ST7781_CMD_GAMMA_CONTROL4 0x35 /* Gamma control 4 */
#define ST7781_CMD_GAMMA_CONTROL5 0x36 /* Gamma control 5 */
```

```
#define ST7781_CMD_GAMMA_CONTROL6 0x37 /* Gamma control 6 */
#define ST7781_CMD_GAMMA_CONTROL7 0x38 /* Gamma control 7 */
#define ST7781_CMD_GAMMA_CONTROL8 0x39 /* Gamma control 8 */
#define ST7781_CMD_GAMMA_CONTROL9 0x3c /* Gamma control 9 */
#define ST7781_CMD_GAMMA_CONTROL10 0x3d /* Gamma control 10 */
#define ST7781_CMD_HORIZ_RAM_ADDR_START 0x50 /* Address of horizontal start
window positions */
#define ST7781_CMD_HORIZ_RAM_ADDR_END 0x51 /* Address of horizontal end
window positions */
#define ST7781_CMD_VERT_RAM_ADDR_START 0x52 /* Address of vertical start
window positions */
#define ST7781_CMD_VERT_RAM_ADDR_END 0x53 /* Address of vertical end
window positions */
#define ST7781_CMD_DRIVER_OUT_CONTROL2 0x60 /* Driver output control */
#define ST7781_CMD_BASE_IMG_DISPLAY_CONTROL 0x61 /* Base image display
control */
#define ST7781_CMD_VERT_SCROLL_CONTROL 0x6a /* Vertical scroll control */
#define ST7781_CMD_PARTIAL_IMG1_DISPLAY_POS 0x80 /* Partial image 1 display
position */
#define ST7781_CMD_PARTIAL_IMG1_START_LINE 0x81 /* Partial image 1 display
start line */
#define ST7781_CMD_PARTIAL_IMG1_END_LINE 0x82 /* Partial image 1 display
end line */
#define ST7781_CMD_PARTIAL_IMG2_DISPLAY_POS 0x83 /* Partial image 2 display
position */
#define ST7781_CMD_PARTIAL_IMG2_START_LINE 0x84 /* Partial image 2 display
start line */
#define ST7781_CMD_PARTIAL_IMG2_END_LINE 0x85 /* Partial image 2 display
end line */
#define ST7781_CMD_PANEL_IF_CONTROL1 0x90 /* Panel interface control 1 */
#define ST7781_CMD_PANEL_IF_CONTROL2 0x92 /* Panel interface control 2 */
#define ST7781_CMD_EEPROM_ID_CODE 0xD2 /* EEPROM ID Code */
#define ST7781_CMD_EEPROM_CTRL_STATUS 0xD9 /* EEPROM Control Status */
#define ST7781_CMD_EEPROM_WR 0xDF /* EEPROM Write Command */
#define ST7781_CMD_EEPROM_ENABLE 0xFA /* EEPROM Enable */
#define ST7781_CMD_EEPROM_VCOM_OFFSET 0xFE /* EEPROM VCOM Offset */
#define ST7781_CMD_FA_FE_ENABLE 0xFF /* FAh/FEh Commands Enable */
```

A detailed description of the above mentioned command registers can be found in the ST7781 datasheet.

void st7781_wrreg(unsigned char index, unsigned short data)

Writes data to a command register of the ST7781 controller.

Parameters:

index command register index
data to be written.

unsigned short st7781_rdreg(unsigned char index)

Reads the contents of a command register of the ST7781 controller.

Parameters:

index command register index.

void st7781_wrdata(unsigned short data)

Writes data to the ST7781 controller's Graphic Display RAM.

Parameters:

data to be written.

unsigned short st7781_rddata(void)

Reads data from the ST7781 controller's Graphic Display RAM.

The **glcd_st7781.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ST7781 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */

    /* power control registers bits */
    unsigned char stepup_factor:3; /* step-up factor of the step-up
                                     circuit, see BT0..BT2 bits in
                                     the datasheet */

    unsigned char stepup_freq1:3; /* controls the frequency for the
                                     step-up circuit 1 */
    unsigned char stepup_freq2:3; /* controls the frequency for the
                                     step-up circuit 2 */

    unsigned char crt_source:3; /* adjusts the amount of current
                                   from the constant current source
                                   in the internal op. amplifier
                                   circuit (AP0..AP2 bits) */

    unsigned char vreglout:4; /* adjusts the VREG1OUT voltage */
    unsigned char vcom:5; /* adjusts the amplitude of the Vcom
                           alternating drive voltage based on
                           VREG1OUT voltage */

    unsigned char vcomh:6; /* adjusts the amplitude of the VcomH
                           voltage based on VREG1OUT voltage
                           VcomH=VREG1OUT*(vcomh*0.005+0.685) [V] */

    unsigned char frame_freq:4; /* LCD frame frequency */
    /* positive gamma control registers bits */
    unsigned char kp00:3; /* KP00..KP02 positive gamma micro adj. */
    unsigned char kp10:3; /* KP10..KP12 positive gamma micro adj. */
    unsigned char kp20:3; /* KP20..KP22 positive gamma micro adj. */
    unsigned char kp30:3; /* KP30..KP32 positive gamma micro adj. */
    unsigned char kp40:3; /* KP40..KP42 positive gamma micro adj. */
    unsigned char kp50:3; /* KP50..KP52 positive gamma micro adj. */
}
```



```
unsigned char rp00:3; /* RP00..RP02 positive gamma gradient adj. */
unsigned char rp10:3; /* RP10..RP12 positive gamma gradient adj. */
unsigned char vrp00:4; /* VRP00..VRP03 positive gamma amplification
adj. */
unsigned char vrp10:5; /* VRP10..VRP14 positive gamma amplification
adj. */
/* negative gamma control registers bits */
unsigned char kn00:3; /* KN00..KN02 negative gamma micro adj. */
unsigned char kn10:3; /* KN10..KN12 negative gamma micro adj. */
unsigned char kn20:3; /* KN20..KN22 positive gamma micro adj. */
unsigned char kn30:3; /* KN30..KN32 positive gamma micro adj. */
unsigned char kn40:3; /* KN40..KN42 negative gamma micro adj. */
unsigned char kn50:3; /* KN50..KN52 negative gamma micro adj. */
unsigned char rn00:3; /* RN00..RN02 negative gamma gradient adj. */
unsigned char rn10:3; /* RN10..RN12 negative gamma gradient adj. */
unsigned char vrn00:4; /* VRN00..VRN03 negative gamma amplification
adj. */
unsigned char vrn10:5; /* VRN10..VRN14 negative gamma
amplification adj. */

} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ST7781_REVX_NORM 0 /* No horizontal reverse */
#define ST7781_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ST7781_REVY_NORM 0 /* No vertical reverse */
#define ST7781_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ST7781_CL_BITS_RGB 0 /* Write color bits to display RAM
in RGB order */
#define ST7781_CL_BITS_BGR 1 /* Write color bits to display RAM
in BGR order */

/* Initialization values for the VREG1OUT voltage */
#define ST7781_VREG1OUT_4V000 8 /* 4.000 V */
#define ST7781_VREG1OUT_4V125 9 /* 4.125 V */
#define ST7781_VREG1OUT_4V250 10 /* 4.250 V */
#define ST7781_VREG1OUT_4V375 11 /* 4.375 V */
#define ST7781_VREG1OUT_4V500 12 /* 4.500 V */
#define ST7781_VREG1OUT_4V625 13 /* 4.625 V */
#define ST7781_VREG1OUT_4V750 14 /* 4.750 V */
#define ST7781_VREG1OUT_4V875 15 /* 4.875 V */
#define ST7781_VREG1OUT_5V000 1 /* 5.000 V */
#define ST7781_VREG1OUT_5V125 2 /* 5.125 V */
#define ST7781_VREG1OUT_5V250 3 /* 5.250 V */
#define ST7781_VREG1OUT_5V500 4 /* 5.500 V */
#define ST7781_VREG1OUT_5V750 5 /* 5.750 V */
#define ST7781_VREG1OUT_6V000 6 /* 6.000 V */

/* Initialization values for the Vcom voltage */
#define ST7781_VCOM_0_70 0 /* Vcom=VREG1OUT*0.70 */
#define ST7781_VCOM_0_72 1 /* Vcom=VREG1OUT*0.72 */
#define ST7781_VCOM_0_74 2 /* Vcom=VREG1OUT*0.74 */
#define ST7781_VCOM_0_76 3 /* Vcom=VREG1OUT*0.76 */
#define ST7781_VCOM_0_78 4 /* Vcom=VREG1OUT*0.78 */
```

```
#define ST7781_VCOM_0_80 5 /* Vcom=VREG1OUT*0.80 */
#define ST7781_VCOM_0_82 6 /* Vcom=VREG1OUT*0.82 */
#define ST7781_VCOM_0_84 7 /* Vcom=VREG1OUT*0.84 */
#define ST7781_VCOM_0_86 8 /* Vcom=VREG1OUT*0.86 */
#define ST7781_VCOM_0_88 9 /* Vcom=VREG1OUT*0.88 */
#define ST7781_VCOM_0_90 10 /* Vcom=VREG1OUT*0.90 */
#define ST7781_VCOM_0_92 11 /* Vcom=VREG1OUT*0.92 */
#define ST7781_VCOM_0_94 12 /* Vcom=VREG1OUT*0.94 */
#define ST7781_VCOM_0_96 13 /* Vcom=VREG1OUT*0.96 */
#define ST7781_VCOM_0_98 14 /* Vcom=VREG1OUT*0.98 */
#define ST7781_VCOM_1_00 15 /* Vcom=VREG1OUT*1.00 */
#define ST7781_VCOM_1_02 0x14 /* Vcom=VREG1OUT*1.02 */
#define ST7781_VCOM_1_04 0x15 /* Vcom=VREG1OUT*1.04 */
#define ST7781_VCOM_1_06 0x16 /* Vcom=VREG1OUT*1.06 */
#define ST7781_VCOM_1_08 0x17 /* Vcom=VREG1OUT*1.08 */
#define ST7781_VCOM_1_10 0x18 /* Vcom=VREG1OUT*1.10 */
#define ST7781_VCOM_1_12 0x19 /* Vcom=VREG1OUT*1.12 */
#define ST7781_VCOM_1_14 0x1A /* Vcom=VREG1OUT*1.14 */
#define ST7781_VCOM_1_16 0x1B /* Vcom=VREG1OUT*1.16 */
#define ST7781_VCOM_1_18 0x1C /* Vcom=VREG1OUT*1.18 */
#define ST7781_VCOM_1_20 0x1D /* Vcom=VREG1OUT*1.20 */
#define ST7781_VCOM_1_22 0x1E /* Vcom=VREG1OUT*1.22 */
#define ST7781_VCOM_1_24 0x1F /* Vcom=VREG1OUT*1.24 */

/* Initialization value for VcomH
VcomH=VREG1OUT*(VREG1OUT_MULT1000/1000)
VREG1OUT_MULT1000=685..1000 */
#define ST7781_VCOMH(VREG1OUT_MULT1000) ((VREG1OUT_MULT1000-685)/5)

/* Initialization values for stepup_freq1 */
#define ST7781_STEPUP1_FOSC 0 /* FDCDC1=Fosc */
#define ST7781_STEPUP1_FOSC2 1 /* FDCDC1=Fosc/2 */
#define ST7781_STEPUP1_FOSC4 2 /* FDCDC1=Fosc/4 */
#define ST7781_STEPUP1_FOSC8 3 /* FDCDC1=Fosc/8 */
#define ST7781_STEPUP1_FOSC16 4 /* FDCDC1=Fosc/16 */
#define ST7781_STEPUP1_FOSC32 5 /* FDCDC1=Fosc/32 */
#define ST7781_STEPUP1_FOSC64 6 /* FDCDC1=Fosc/64 */
#define ST7781_STEPUP1_HALT 7 /* Halt step-up circuit 1 */

/* Initialization values for stepup_freq2 */
#define ST7781_STEPUP2_FOSC4 0 /* FDCDC2=Fosc/4 */
#define ST7781_STEPUP2_FOSC8 1 /* FDCDC2=Fosc/8 */
#define ST7781_STEPUP2_FOSC16 2 /* FDCDC2=Fosc/16 */
#define ST7781_STEPUP2_FOSC32 3 /* FDCDC2=Fosc/32 */
#define ST7781_STEPUP2_FOSC64 4 /* FDCDC2=Fosc/64 */
#define ST7781_STEPUP2_FOSC128 5 /* FDCDC2=Fosc/128 */
#define ST7781_STEPUP2_FOSC256 6 /* FDCDC2=Fosc/256 */
#define ST7781_STEPUP2_HALT 7 /* Halt step-up circuit 2 */

/* Initialization values for frame_freq */
#define ST7781_FRAME40 0 /* 40Hz */
#define ST7781_FRAME43 1 /* 43Hz */
#define ST7781_FRAME45 2 /* 45Hz */
#define ST7781_FRAME48 3 /* 48Hz */
#define ST7781_FRAME51 4 /* 51Hz */
#define ST7781_FRAME55 5 /* 55Hz */
#define ST7781_FRAME59 6 /* 59Hz */
#define ST7781_FRAME64 7 /* 64Hz */
#define ST7781_FRAME70 8 /* 70Hz */
```

```
#define ST7781_FRAME77 9 /* 77Hz */
#define ST7781_FRAME85 10 /* 85Hz */
#define ST7781_FRAME96 11 /* 96Hz */
#define ST7781_FRAME110 12 /* 110Hz */
#define ST7781_FRAME128 13 /* 128Hz */

/* Default value for reverse_x */
#define ST7781_DEFAULT_REVX ST7781_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ST7781_DEFAULT_REVY ST7781_REVY_NORM /* No vertical reverse */

/* Default value for cl_bits_order
   (color bits writing order to display RAM),
   write in RGB order */
#define ST7781_DEFAULT_CL_BITS ST7781_CL_BITS_RGB

/* Power control 1 BT0..BT2 step-up factor of the step-up circuit
   DDVDH=Vci1*2, VCL=-Vci1, VGH=Vci1*6, VGL=-Vci1*3 */
#define ST7781_DEFAULT_STEPUP_FACTOR 2
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the
   internal op. amplifier circuit */
#define ST7781_DEFAULT_CRT_SOURCE 2
/* Power control 2 DC00..DC02 step-up circuit 1 frequency */
#define ST7781_DEFAULT_STEPUP1_FREQ ST7781_STEPUP1_FOSC4
/* Power control 2 DC10..DC12 step-up circuit 2 frequency */
#define ST7781_DEFAULT_STEPUP2_FREQ ST7781_STEPUP2_FOSC128
/* Default value for VREG1OUT voltage */
#define ST7781_DEFAULT_VREG1OUT ST7781_VREG1OUT_4V000
/* Default value for Vcom alternating drive voltage */
#define ST7781_DEFAULT_VCOM ST7781_VCOM_0_94
/* Default value for VcomH voltage
   VcomH=VREG1OUT*0.835 */
#define ST7781_DEFAULT_VCOMH ST7781_VCOMH(835)
/* Default value for LCD frame frequency */
#define ST7781_DEFAULT_FRAME_FREQ ST7781_FRAME96

/* Default initialization values for the gamma control register bits */
/* KP00..KP02 positive gamma micro adj. */
#define ST7781_DEFAULT_KP00 7
/* KP10..KP12 positive gamma micro adj. */
#define ST7781_DEFAULT_KP10 7
/* KP20..KP22 positive gamma micro adj. */
#define ST7781_DEFAULT_KP20 4
/* KP30..KP32 positive gamma micro adj. */
#define ST7781_DEFAULT_KP30 2
/* KP40..KP42 positive gamma micro adj. */
#define ST7781_DEFAULT_KP40 4
/* KP50..KP52 positive gamma micro adj. */
#define ST7781_DEFAULT_KP50 2
/* RP00..RP02 positive gamma gradient adj. */
#define ST7781_DEFAULT_RP00 2
/* RP10..RP12 positive gamma gradient adj. */
#define ST7781_DEFAULT_RP10 5
/* VRP00..VRP03 positive gamma amplification adj. */
#define ST7781_DEFAULT_VRP00 2
/* VRP10..VRP14 positive gamma amplification adj. */
#define ST7781_DEFAULT_VRP10 3
```

```
/* KN00..KN02 negative gamma micro adj. */
#define ST7781_DEFAULT_KN00 7
/* KN10..KN12 negative gamma micro adj. */
#define ST7781_DEFAULT_KN10 5
/* KN20..KN22 positive gamma micro adj. */
#define ST7781_DEFAULT_KN20 4
/* KN30..KN32 positive gamma micro adj. */
#define ST7781_DEFAULT_KN30 2
/* KN40..KN42 negative gamma micro adj. */
#define ST7781_DEFAULT_KN40 4
/* KN50..KN52 negative gamma micro adj. */
#define ST7781_DEFAULT_KN50 2
/* RN00..RN02 negative gamma gradient adj. */
#define ST7781_DEFAULT_RN00 2
/* RN10..RN12 negative gamma gradient adj. */
#define ST7781_DEFAULT_RN10 5
/* VRN00..VRN03 negative gamma amplification adj. */
#define ST7781_DEFAULT_VRN00 2
/* VRN10..VRN14 negative gamma amplification adj. */
#define ST7781_DEFAULT_VRN10 3
```

The following colors are redefined in the **glcd_st7781.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ST7781 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_st7781.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_st7781.h**.
- The **..\EXAMPLES\Graphic Displays\ST7781** directory contains fully functional code samples that may be used as references for ST7781 initialization and usage.

5.12.27 Graphic LCD Functions Specific to the ST7789 Controller

The ST7789 library functions supplied with the CodeVisionAVR Advanced license, can operate the controller in 8/16 bit parallel interface and SPI serial modes with 256 or 64k colors.

To obtain higher display speed, the 16 bit interface mode is recommended.

Both 240x320 (portrait) and 320x240 (landscape) display modes are supported.

In order to take full advantage of the ST7789 controller's features, the following specific functions, declared in the **glcd_st7789.h** header file, were implemented:

void st7789_wrcmd(unsigned char cmd)

Writes a command to the ST7789 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_st7789.h** header file:

```
#define ST7789_CMD_NOP 0x00 /* No operation */
#define ST7789_CMD_SOFT_RESET 0x01 /* Software reset */
#define ST7789_CMD_GET_DISPLAY_ID 0x04 /* Get display identification
                                         information:
                                         LCD module manufacturer ID,
                                         module/driver version ID,
                                         /* module/driver ID */
#define ST7789_CMD_GET_DISPLAY_STATUS 0x09 /* Get display status */
#define ST7789_CMD_GET_PWR_MODE 0x0A /* Get the current power mode */
#define ST7789_CMD_GET_MADCTL 0x0B /* Get the Memory Address Control status
                                     bits: MX, MY, MH, MV, ML */
#define ST7789_CMD_GET_PIXEL_FORMAT 0x0C /* Get the display pixel format */
#define ST7789_CMD_GET_DISPLAY_MODE 0x0D /* Returns the display image mode
                                             status */
#define ST7789_CMD_GET_SIGNAL_MODE 0x0E /* Get the current display signal
                                             mode from the peripheral */
#define ST7789_CMD_GET_SELF_DIAGNOSTIC 0x0F /* Returns the display self-
                                                diagnostic result */
#define ST7789_CMD_ENT_SLEEP 0x10 /* Enter sleep mode */
#define ST7789_CMD_EXIT_SLEEP 0x11 /* Exit from sleep mode */
#define ST7789_CMD_ENT_PARTIAL_MODE 0x12 /* Enter partial display mode */
#define ST7789_CMD_ENT_NORMAL_MODE 0x13 /* Enter normal display mode */
#define ST7789_CMD_EXIT_INVERT_MODE 0x20 /* Exit from inverted
                                             display mode */
#define ST7789_CMD_ENT_INVERT_MODE 0x21 /* Enter inverted display mode */
#define ST7789_CMD_SET_GAMMA 0x26 /* Selects the gamma curve used by the
                                     display device */
#define ST7789_CMD_BLANK_DISPLAY 0x28 /* Set display off, without clearing
                                         the frame buffer */
```

```
#define ST7789_CMD_ON_DISPLAY 0x29 /* Set display on */
#define ST7789_CMD_SET_COLUMN_ADDR 0x2A /* Set the column extent of the
                                         frame buffer accessed with the
                                         ST7789_CMD_RD_MEM_CONT and
                                         ST7789_CMD_WR_MEM_CONT
                                         commands */
#define ST7789_CMD_SET_ROW_ADDR 0x2B /* Set the row extent of the frame
                                         buffer accessed with the
                                         ST7789_CMD_RD_MEM_CONT and
                                         ST7789_CMD_WR_MEM_CONT commands */
#define ST7789_CMD_WR_MEM_START 0x2C /* Transfer image information from uC
                                         to ST7789 starting with the
                                         location specified by
                                         ST7789_CMD_SET_COLUMN_ADDR and
                                         ST7789_CMD_SET_ROW_ADDR */
#define ST7789_CMD_RD_MEM_START 0x2E /* Transfer image information from
                                         ST7789 to uC starting with the
                                         location specified by
                                         ST7789_CMD_SET_COLUMN_ADDR and
                                         ST7789_CMD_SET_ROW_ADDR */
#define ST7789_CMD_SET_PARTIAL_AREA 0x30 /* Defines the partial display
                                         mode area */
#define ST7789_CMD_SET_SCROLL_AREA 0x33 /* Defines the vertical scrolling
                                         and fixed areas */
#define ST7789_CMD_SET_TEAR_OFF 0x34 /* Disable sending synchronization
                                         information from the display */
#define ST7789_CMD_SET_TEAR_ON 0x35 /* Enable sending synchronization
                                         information from the display */
#define ST7789_CMD_SET_ADDR_MODE 0x36 /* Set read order from uC to frame
                                         buffer and from frame buffer to
                                         the display panel */
#define ST7789_CMD_SET_SCROLL_START 0x37 /* Set the start of the vertical
                                         scrolling area in the frame
                                         buffer */
#define ST7789_CMD_EXIT_IDLE_MODE 0x38 /* Exit idle mode */
#define ST7789_CMD_ENT_IDLE_MODE 0x39 /* Enter idle mode */
#define ST7789_CMD_SET_PIXEL_FORMAT 0x3A /* Set pixel format */
#define ST7789_CMD_WR_MEM_CONT 0x3C /* Transfer image data from uC to
                                         ST7789 continuing from the
                                         last ST7789_CMD_WR_MEM_START or
                                         ST7789_CMD_WR_MEM_CONT */
#define ST7789_CMD_RD_MEM_CONT 0x3E /* Transfer image data from ST7789 to
                                         uC continuing from the
                                         last ST7789_CMD_RD_MEM_START or
                                         ST7789_CMD_RD_MEM_CONT */
#define ST7789_CMD_SET_TEAR_SCANLINE 0x44 /* Enable sending the TE signal
                                         to the uC when the
                                         display refresh reaches the
                                         provided scan line */
#define ST7789_CMD_GET_TEAR_SCANLINE 0x45 /* Get the current scan line */
#define ST7789_CMD_SET_BRIGHTNESS 0x51 /* Set display brightness */
#define ST7789_CMD_GET_BRIGHTNESS 0x52 /* Get the display brightness */
#define ST7789_CMD_SET_CTRL_DISPLAY 0x53 /* Set the brightness control
                                         block, display dimming and
                                         backlight */
#define ST7789_CMD_GET_CTRL_DISPLAY 0x54 /* Get the brightness control
                                         block, display dimming and
                                         backlight status */
```

CodeVisionAVR

```
/* Set the parameters for the content adaptive brightness */
#define ST7789_CMD_SET_CONTENT_ADAPTIVE_BRIGHTNESS 0x55
/* Get the parameters for the content adaptive brightness */
#define ST7789_CMD_GET_CONTENT_ADAPTIVE_BRIGHTNESS 0x56
/* Set the minimum display brightness for the content adaptive brightness
function */
#define ST7789_CMD_SET_CABC_MIN_BRIGHTNESS 0x5E
/* Get the minimum display brightness for the content adaptive brightness
function */
#define ST7789_CMD_GET_CABC_MIN_BRIGHTNESS 0x5F
#define ST7789_CMD_RAM_CTRL 0xB0 /* RAM control */
#define ST7789_CMD_RGB_CTRL 0xB1 /* RGB control */
#define ST7789_CMD_PORCH_CTRL 0xB2 /* Porch control */
#define ST7789_CMD_FRAME_RATE_CTRL1 0xB3 /* Frame rate control 1 in
partial/idle mode */
#define ST7789_CMD_GATE_CTRL_VGH_VGL 0xB7 /* Gate control voltages
VGH and VGL */
#define ST7789_CMD_DIGITAL_GAMMA_ENABLE 0xBA /* Digital gamma enable */
#define ST7789_CMD_SET_VCOM 0xBB /* Set VCOM */
#define ST7789_CMD_LCM_CTRL 0xC0 /* LCM control */
#define ST7789_CMD_SET_ID 0xC1 /* Set ID */
#define ST7789_CMD_VDV_VRH_CMD_ENABLE 0xC2 /* VDV and VRH command enable */
#define ST7789_CMD_SET_VRH 0xC3 /* Set VRH */
#define ST7789_CMD_SET_VDV 0xC4 /* Set VDV */
#define ST7789_CMD_SET_VCOM_OFFSET 0xC5 /* Set VCOM offset */
#define ST7789_CMD_FRAME_RATE_CTRL2 0xC6 /* Frame rate control 2 in
normal mode */
#define ST7789_CMD_CABC_CTRL 0xC7 /* CABC control */
#define ST7789_CMD_REG_VAL_SEL1 0xC8 /* Register value selection 1 */
#define ST7789_CMD_REG_VAL_SEL2 0xCA /* Register value selection 2 */
#define ST7789_CMD_POWER_CTRL1 0xD0 /* Power control 1 */
#define ST7789_CMD_VAP_VAN_ENABLE 0xD2 /* Enable VAP/VAN signal output */
#define ST7789_CMD_GET_ID1 0xDA /* Get the LCD manufacturer ID */
#define ST7789_CMD_GET_ID2 0xDB /* Get the LCD module/driver IC version */
#define ST7789_CMD_GET_ID3 0xDC /* Get the LCD module/driver ID */
/* Set positive gamma correction control parameters */
#define ST7789_CMD_SET_POSITIVE_GAMMA_CTRL 0xE0
/* Set negative gamma correction control parameters */
#define ST7789_CMD_SET_NEGATIVE_GAMMA_CTRL 0xE1
/* Set digital gamma look-up table for red color */
#define ST7789_CMD_SET_DIGITAL_GAMMA_LOOK_UP_RED 0xE2
/* Set digital gamma look-up table for blue color */
#define ST7789_CMD_SET_DIGITAL_GAMMA_LOOK_UP_BLUE 0xE3
#define ST7789_CMD_GATE_CTRL 0xE4 /* Gate control */
#define ST7789_CMD_POWER_CTRL2 0xE8 /* Power control 2 */
#define ST7789_CMD_EQ_TIME_CTRL 0xE9 /* Equalize time control */
#define ST7789_CMD_PGM_CTRL 0xEC /* Program control */
#define ST7789_CMD_PGM_MODE_ENABLE 0xFA /* Program mode enable */
#define ST7789_CMD_NVM_SET 0xFC /* NVM setting */
#define ST7789_CMD_PGM_ACTION 0xFE /* Program action */
```

void st7789_wldata(unsigned char data)

Writes data byte(s) to the ST7789 controller after a command was issued using the **st7789_wrcmd** function.

Parameter:

data to be sent to the controller.

unsigned char st7789_rddata(void)

Reads result data byte(s) from the ST7789 controller after a command was issued using the **st7789_wrcmd** function.

Note: When used immediately after **st7789_wrcmd**, this function must be called twice. The result of the first call is a dummy read and it is not valid.

void st7789_wrdram(GLCDCOL_t color)

Writes color data for 1 pixel to the ST7789 controller's display RAM.

Parameter:

color data to be sent to the controller.

Note: Before calling this function a **ST7789_CMD_WR_MEM_START** or **ST7789_CMD_WR_MEM_CONT** command must be issued to the controller using the **st7789_wrcmd** function.

GLCDCOL_t st7789_rddram(void)

Reads color data for 1 pixel from the ST7789 controller's display RAM.

Note: Before calling this function a **ST7789_CMD_RD_MEM_START** or **ST7789_CMD_RD_MEM_CONT** command must be issued to the controller using the **st7789_wrcmd** function.

void st7789_sleep(bool on)

Puts the ST7789 controller in sleep mode or exit from sleep mode.

Parameter:

on when **true** puts the controller in sleep mode, when **false** exits the sleep mode.

Notes:

- A delay of minimum 120ms must be present after exiting the sleep mode and entering sleep mode again.

The **glcd_st7789.h** header file also contains the definition of the **GLCDINIT_t** type specific for the ST7789 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to
       external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char cl_bits_order:1; /* selects the color bits writing
                                     order to the display RAM
                                     =0 -> RGB, =1 ->BGR */
    unsigned char vgl:3; /* set VGL (see the datasheet) */
    unsigned char vgh:3; /* set VGH (see the datasheet) */
    unsigned char vrh:6; /* set VRH (see the datasheet) */
    unsigned char vdv:6; /* set VDV (see the datasheet) */
    unsigned char vcom:6; /* set VCOM (see the datasheet) */
    unsigned char frame_rate:5; /* set vertical frame rate
                                   39..119Hz */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* Initialization values for reverse_x */
#define ST7789_REVX_NORM 0 /* No horizontal reverse */
#define ST7789_REVX_REV 1 /* Horizontal reverse */

/* Initialization values for reverse_y */
#define ST7789_REVY_NORM 0 /* No vertical reverse */
#define ST7789_REVY_REV 1 /* Vertical reverse */

/* Initialization values for cl_bits_order */
#define ST7789_CL_BITS_RGB 0 /* RGB */
#define ST7789_CL_BITS_BGR 1 /* BGR */

/* Initialization values for frame_rate
#define ST7789_FRAME_RATE_39 0x1F /* 39Hz */
#define ST7789_FRAME_RATE_40 0x1E /* 40Hz */
#define ST7789_FRAME_RATE_41 0x1D /* 41Hz */
#define ST7789_FRAME_RATE_42 0x1C /* 42Hz */
#define ST7789_FRAME_RATE_43 0x1B /* 43Hz */
#define ST7789_FRAME_RATE_44 0x1A /* 44Hz */
#define ST7789_FRAME_RATE_45 0x19 /* 45Hz */
#define ST7789_FRAME_RATE_46 0x18 /* 46Hz */
#define ST7789_FRAME_RATE_48 0x17 /* 48Hz */
#define ST7789_FRAME_RATE_49 0x16 /* 49Hz */
#define ST7789_FRAME_RATE_50 0x15 /* 50Hz */
#define ST7789_FRAME_RATE_52 0x14 /* 52Hz */
#define ST7789_FRAME_RATE_53 0x13 /* 53Hz */
#define ST7789_FRAME_RATE_55 0x12 /* 55Hz */
#define ST7789_FRAME_RATE_57 0x11 /* 57Hz */
#define ST7789_FRAME_RATE_58 0x10 /* 58Hz */
#define ST7789_FRAME_RATE_60 0x0F /* 60Hz */
#define ST7789_FRAME_RATE_62 0x0E /* 62Hz */
#define ST7789_FRAME_RATE_64 0x0D /* 64Hz */
```

```
#define ST7789_FRAME_RATE_67 0x0C /* 67Hz */
#define ST7789_FRAME_RATE_69 0x0B /* 69Hz */
#define ST7789_FRAME_RATE_72 0x0A /* 72Hz */
#define ST7789_FRAME_RATE_75 0x09 /* 75Hz */
#define ST7789_FRAME_RATE_78 0x08 /* 78Hz */
#define ST7789_FRAME_RATE_82 0x07 /* 82Hz */
#define ST7789_FRAME_RATE_86 0x06 /* 86Hz */
#define ST7789_FRAME_RATE_90 0x05 /* 90Hz */
#define ST7789_FRAME_RATE_94 0x04 /* 94Hz */
#define ST7789_FRAME_RATE_99 0x03 /* 99Hz */
#define ST7789_FRAME_RATE_105 0x02 /* 105Hz */
#define ST7789_FRAME_RATE_111 0x01 /* 111Hz */
#define ST7789_FRAME_RATE_119 0x00 /* 119Hz */

/* Default initialization values for GLCDINIT_t */
/* Default value for reverse_x */
#define ST7789_DEFAULT_REVX ST7789_REVX_NORM /* No horizontal reverse */
/* Default value for reverse_y */
#define ST7789_DEFAULT_REVY ST7789_REVY_NORM /* No vertical reverse */
/* Default value for cl_bits_order */
#define ST7789_DEFAULT_CL_BITS ST7789_CL_BITS_RGB /* write in RGB order */
/* Default value for vgl */
#define ST7789_DEFAULT_VGL 0x05 /* -10.43V */
/* Default value for vgh */
#define ST7789_DEFAULT_VGH 0x03 /* 13.26V */
/* Default value for vrh */
#define ST7789_DEFAULT_VRH 0x11
/* Default value for vdv */
#define ST7789_DEFAULT_VDV 0x20
/* Default value for vcom */
#define ST7789_DEFAULT_VCOM 0x2B /* 1.175V */
/* Default value for frame_rate */
#define ST7789_DEFAULT_FRAME_RATE ST7789_FRAME_RATE_60 /* 60Hz */
```

The following colors are predefined in the **glcd_st7789.h** header file:

```
GLCD_CL_BLACK
GLCD_CL_WHITE
GLCD_CL_GRAY
GLCD_CL_LIGHT_GRAY
GLCD_CL_GREEN
GLCD_CL_LIME
GLCD_CL_BLUE
GLCD_CL_RED
GLCD_CL_AQUA
GLCD_CL_YELLOW
GLCD_CL_MAGENTA
GLCD_CL_CYAN
GLCD_CL_DARK_CYAN
GLCD_CL_ORANGE
GLCD_CL_PINK
GLCD_CL_BROWN
GLCD_CL_VIOLET
GLCD_CL_SILVER
GLCD_CL_GOLD
GLCD_CL_NAVY
GLCD_CL_MAROON
GLCD_CL_PURPLE
GLCD_CL_OLIVE
```

The ST7789 library functions can operate the display in 256 or 64k color modes. For 256 color mode the following color bit allocation in a data byte is used:

- Bits 0..2 - Blue color bits 0..2
- Bits 3..5 - Green color bits 0..2
- Bits 6..7 - Red color bits 0..1.

For 64k color mode the following color bit allocation in a 16bit data word is used:

- Bits 0..4 - Blue color bits 0..4
- Bits 5..10 - Green color bits 0..5
- Bits 11..15 - Red color bits 0..4.

Notes:

- In order to reduce image storage size and improve speed, it is recommended to use the 256 color mode, if possible.
- The **glcd_st7789.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_st7789.h**.
- The **..\EXAMPLES\Graphic Displays\ST7789** directory contains fully functional code samples that may be used as references for ST7789 initialization and usage.

5.12.28 Graphic LCD Functions Specific to the ST7920 Controller

In order to take full advantage of the ST7920 controller's features, the following specific functions, declared in the **glcd_st7920.h** header file, were implemented:

void st7920_wrcmd(unsigned char cmd)

Writes a command to the ST7920 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_st7920.h** header file:

```
/* Basic command set */
/* clear display */
#define ST7920_DISPLAY_CLEAR 0x01

/* return cursor to origin */
#define ST7920_RETURN_HOME 0x02

/* set cursor position & display shift when doing write or read */
#define ST7920_ENTRY_MODE_SET 0x04
/* entry mode bits: */
/* cursor moves right, address counter+=1 */
#define ST7920_ENTRY_CURSOR_RIGHT 0x02
/* shift entire display */
#define ST7920_ENTRY_SHIFT_DISPL 0x01

/* display control */
#define ST7920_DISPLAY_CTRL 0x08
/* display control bits: */
/* display on */
#define ST7920_DISPLAY_ON 0x04
/* cursor on */
#define ST7920_CURSOR_ON 0x02
/* character blinks at cursor position */
#define ST7920_BLINK 0x01

/* cursor/display shift control */
#define ST7920_CURSOR_DISPLAY_SHIFT_CTRL 0x10
/* cursor/display shift control bits: */
/* shift display */
#define ST7920_SHIFT_DISPLAY 0x08
/* shifts right */
#define ST7920_SHIFT_RIGHT 0x04
```

```
/* function set */
#define ST7920_FUNC_SET 0x20
/* function set control bits:
   must not be applied at the same time!
   change ST7920_8BIT or ST7920_GRAPHICS_ON first, then ST7920_EXTENDED */
/* 8 bit interface */
#define ST7920_8BIT 0x10
/* select the extended command set */
#define ST7920_EXTENDED 0x04
/* turn graphics display on */
#define ST7920_GRAPHICS_ON 0x02

/* writes CGRAM address into address counter AC */
#define ST7920_SET_CGRAM_ADDR 0x40

/* writes DDRAM address into address counter AC:
   start for line #1 of text AC=0x00
   start for line #2 of text AC=0x10
   start for line #3 of text AC=horizontal_display_resolution/16
   start for line #4 of text AC=0x10+horizontal_display_resolution/16 */
#define ST7920_SET_DDRAM_ADDR 0x80

/* Extended command set */
#define ST7920_STANDBY 0x01 /* enter standby mode */

/* enable the ST7920_SET_CGRAM_ADDR command */
#define ST7920_ENABLE_SET_CGRAM_ADDR 0x02

/* enable vertical scroll mode and disable the
   ST7920_SET_CGRAM_ADDR command */
#define ST7920_VERT_SCROLL 0x03

/* toggle reverse condition for a line of text */
#define ST7920_REVERSE_LINE 0x04

/* set vertical scroll displacement address */
#define ST7920_SET_SCROLL_ADDR 0x40

/* set the vertical and horizontal addresses
   for the graphic display RAM into address counter */
#define ST7920_SET_GDRAM_ADDR 0x80
```

A detailed description of the above mentioned commands can be found in the ST7920 datasheet.

void st7920_wrddata(unsigned char data)

Writes a data byte to the ST7920 controller.

Parameter:

data byte to be sent to the controller.

unsigned char st7920_rddata(void)

Reads a data byte from the ST7920 controller.

void glcd_cleartext(void)

Clears the text overlay area when the character generator is used and sets the text display position at row 0 and column 0.

void glcd_cleargraphics(void)

Clears the LCD graphics overlay area by setting it's color to the current background color.

The ST7920 controller has a built-in alphanumeric character font generator which can be used for displaying text over the graphics.

In order to take advantage of this capability, the following high level functions, compatible with the alphanumeric LCDs, were implemented:

void lcd_clear(void)

Clears the text on the LCD and sets the text display position at row 0 and column 0.

Note: This function is equivalent to **glcd_cleartext** and was defined for compatibility.

void lcd_gotoxy(unsigned char x, unsigned char y)

Sets the current text display position at column x and row y. The row and column numbering starts from 0.

void lcd_putchar(char c)

Displays the character c at the current display position.

For displaying ASCII set characters, c may take the values: 0x02..0x7F. These characters are displayed in a 8x16 pixel matrix.

For displaying a Chinese BIG5 character the function must be called twice, first with the MSB of the character code, then with the LSB.

Example:

```
/* display the Chinese BIG5 character with code: 0xA140 */
lcd_putchar(0xA1);
lcd_putchar(0x40);
```

The Chinese BIG5 characters may take the values: 0xA140..0xD75F.

For displaying an user defined character the **lcd_putchar** function must be also called twice, first with the parameter 0, then with the character code which may be 0, 2, 4 or 6.

Example:

```
lcd_putchar(0);
lcd_putchar(4); /* display the user defined character with code: 4 */
```

Note: Chinese BIG 5 and user defined characters use a 16x16 pixel matrix, therefore may be displayed only on even horizontal text x coordinates.

void glcd_definechar(unsigned char c,flash unsigned char *data)

Defines a character in the LCD controller's character generator RAM.

Parameters:

c specifies the defined character's code, must be 0, 2, 4 or 6 for the ST7920 controller
data points to a 32 byte array located in FLASH that contains the character's definition.

The data in the array is organized as 16 horizontal rows, each row containing 2 bytes of pixels:

byte 0, bit 0 -> pixel 7, on row 0
byte 0, bit 1 -> pixel 6, on row 0
..
byte 0, bit 7 -> pixel 0, on row 0
byte 1, bit 0 -> pixel 15, on row 0
byte 1, bit 1 -> pixel 14, on row 0
..
byte 1, bit 7 -> pixel 8, on row 0

byte 2, bit 0 -> pixel 7, on row 1
byte 2, bit 1 -> pixel 6, on row 1
..
byte 2, bit 7 -> pixel 0, on row 1
byte 3, bit 0 -> pixel 15, on row 1
byte 3, bit 1 -> pixel 14, on row 1
..
byte 3, bit 7 -> pixel 8, on row 1
..

Example:

```
#include <glcd.h>
#include <delay.h>

/* User defined characters */
flash char user_def_char[4][32]=
{
/* Character with code: 0 */
{
0b00000000,0b11111111,
0b00000000,0b00000011,
0b00000000,0b00000101,
0b00000000,0b00001001,
0b00000000,0b00010001,
0b00000000,0b00100001,
0b00000000,0b01000001,
0b00000000,0b10000001,
0b00000001,0b00000000,
0b00000010,0b00000000,
0b00000100,0b00000000,
0b00001000,0b00000000,
0b00010000,0b00000000,
0b00100000,0b00000000,
0b01000000,0b00000000,
0b10000000,0b00000000
},

```

```
/* Character with code: 2 */
{
0b00000000,0b00000001,
0b00000000,0b00000010,
0b00000000,0b00000100,
0b00000000,0b00001000,
0b00000000,0b00010000,
0b00000000,0b00100000,
0b00000000,0b01000000,
0b00000000,0b10000000,
0b10000001,0b00000000,
0b10000010,0b00000000,
0b10000100,0b00000000,
0b10001000,0b00000000,
0b10010000,0b00000000,
0b10100000,0b00000000,
0b11000000,0b00000000,
0b11111111,0b00000000
},

/* Character with code: 4 */
{
0b11111111,0b11111111,
0b10000000,0b00000011,
0b10000000,0b00000101,
0b10000000,0b00001001,
0b10000000,0b00010001,
0b10000000,0b00100001,
0b10000000,0b01000001,
0b10000000,0b10000001,
0b10000001,0b00000001,
0b10000010,0b00000001,
0b10000100,0b00000001,
0b10001000,0b00000001,
0b10010000,0b00000001,
0b10100000,0b00000001,
0b11000000,0b00000001,
0b11111111,0b11111111
},

/* Character with code: 6 */
{
0b11111111,0b11111111,
0b11000000,0b00000001,
0b10100000,0b00000001,
0b10010000,0b00000001,
0b10001000,0b00000001,
0b10000100,0b00000001,
0b10000010,0b00000001,
0b10000001,0b00000001,
0b10000000,0b10000001,
0b10000000,0b01000001,
0b10000000,0b00100001,
0b10000000,0b00010001,
0b10000000,0b00001001,
0b10000000,0b00000101,
0b10000000,0b00000011,
0b11111111,0b11111111
}
};
```



```
void main()
{
    unsigned char c;
    GLCDINIT_t init;

    /* No font is used */
    init.font=NULL;

    /* No need for reading data from external memory */
    init.readxmem=NULL;

    /* No need for reading data from external memory */
    init.writexmem=NULL;

    /* Initialize the LCD controller and graphics */
    glcd_init(&init);

    /* Display text using the built-in character generator */
    lcd_putsf("Sitronix ST7920\nCodeVisionAVR\nDemo");

    /* 2 seconds delay */
    delay_ms(2000);
    lcd_clear();

    /* Define 4 characters with codes: 0, 2, 4, 6 */
    for (c=0; c<=3; c++)
        glcd_definechar(c*2,user_def_char[c]);

    lcd_putsf("User defined\n"
              "characters:\n");

    /* User defined characters must be located on even x coordinates */
    /* Display user defined characters with codes: 0, 2, 4, 6 */
    for (c=0; c<=6; c+=2)
    {
        lcd_putchar(0); /* Always first write MSB=0 */
        lcd_putchar(c); /* Write LSB=character code */
    }
}
```

void lcd_puts(char *str)

Displays at the current display position the string str, located in RAM.

void lcd_putsf(char flash *str)

Displays at the current display position the string str, located in FLASH.

void lcd_putse(char eeprom *str)

Displays at the current display position the string str, located in EEPROM.

Notes:

- The **glcd_st7920.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_st7920.h**.
- The **..\EXAMPLES\Graphic Displays\ST7920** directory contains fully functional code samples that may be used as references for ST7920 initialization and usage.

5.12.29 Graphic LCD Functions Specific to the T6963C Controller

In order to take full advantage of the T6963C controller's features, the following specific functions, declared in the `glcd_t6963.h` header file, were implemented:

void t6963_busy(void)

Waits for the T6963 controller to become ready for reading or writing data by polling the STA0 and STA1 flags. Also sets C/D=1.

void t6963_wrcmd(unsigned char cmd)

Writes a command to the T6963C controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the `glcd_t6963.h` header file:

```
#define T6963_SET_CURSOR_PTR 0x21 /* Set cursor pointer */
#define T6963_SET_OFFSETS_REG 0x22 /* Set offset register */
#define T6963_SET_ADDR_PTR 0x24 /* Set address pointer */

#define T6963_SET_TXT_HOME_ADDR 0x40 /* Set text RAM starting address */
#define T6963_SET_TXT_AREA 0x41 /* Set the number of text columns */
#define T6963_SET_GFX_HOME_ADDR 0x42 /* Set graphics RAM starting
                                     address */
#define T6963_SET_GFX_AREA 0x43 /* Set the number of columns for
                                  graphic mode */

#define T6963_SET_MODE_OR 0x80
#define T6963_SET_MODE_XOR 0x81
#define T6963_SET_MODE_AND 0x83
#define T6963_SET_MODE_TXT_ATTR 0x84 /* Set text attributes */
#define T6963_SET_MODE_INTCG 0x80 /* Use internal character generator */
#define T6963_SET_MODE_EXTCG 0x88 /* Use external character generator */

#define T6963_DISPLAY_OFF 0x90 /* Display off */
#define T6963_CURSORON_BLINKOFF 0x92 /* Cusror on, blink off */
#define T6963_CURSORON_BLINKON 0x93 /* Cusror on, blink on */
#define T6963_TXTON_GFXOFF 0x94 /* Text on, graphics off */
#define T6963_TXTOFF_GFXON 0x98 /* Text off, graphics on */
#define T6963_TXTON_GFXON 0x9C /* Text on, graphics on */

#define T6963_CURSOR_1LINE 0xA0 /* Selects 1 line cursor */
#define T6963_CURSOR_2LINE 0xA1 /* Selects 2 lines cursor */
#define T6963_CURSOR_3LINE 0xA2 /* Selects 3 lines cursor */
#define T6963_CURSOR_4LINE 0xA3 /* Selects 4 lines cursor */
#define T6963_CURSOR_5LINE 0xA4 /* Selects 5 lines cursor */
#define T6963_CURSOR_6LINE 0xA5 /* Selects 6 lines cursor */
#define T6963_CURSOR_7LINE 0xA6 /* Selects 7 lines cursor */
#define T6963_CURSOR_8LINE 0xA7 /* Selects 8 lines cursor */

#define T6963_DATA_AUTO_WR 0xB0 /* Data auto write */
#define T6963_DATA_AUTO_RD 0xB1 /* Data auto read */
#define T6963_AUTO_RESET 0xB2 /* Use to exit from auto mode */
```

```
#define T6963_DATA_WR_INC 0xC0 /* Write data and increment ADP */
#define T6963_DATA_RD_INC 0xC1 /* Read data and increment ADP */
#define T6963_DATA_WR 0xC4 /* Write data without modifying ADP */
#define T6963_DATA_RD 0xC5 /* Read data without modifying ADP */

#define T6963_SCREEN_PEEK 0xE0 /* Transfers 1 byte of displayed data
                                to the data stack */
#define T6963_SCREEN_COPY 0xE8 /* Copies a single raster line of data
                                to the graphic area */
```

A detailed description of the above mentioned commands can be found in the T6963C datasheet.

void t6963_wrdata(unsigned char data)

Writes a data byte to the T6963C controller.

Parameter:

data byte to be sent to the controller.

unsigned char t6963_rddata(void)

Reads a data byte from the T6963C controller.

void glcd_cleartext(void)

Clears the text overlay area when the character generator is used and sets the text display position at row 0 and column 0.

void glcd_cleargraphics(void)

Clears the LCD graphics overlay area by setting it's color to the current background color.

void glcd_definechar(unsigned char c,flash unsigned char *data)

Defines a character in the LCD controller's character generator external RAM.

Parameters:

c specifies the defined character's code, must be $\geq 0x80$

data points to a byte array that contains the character's definition.

The array dimension depends on the height of the character generator font and is 8.

Notes:

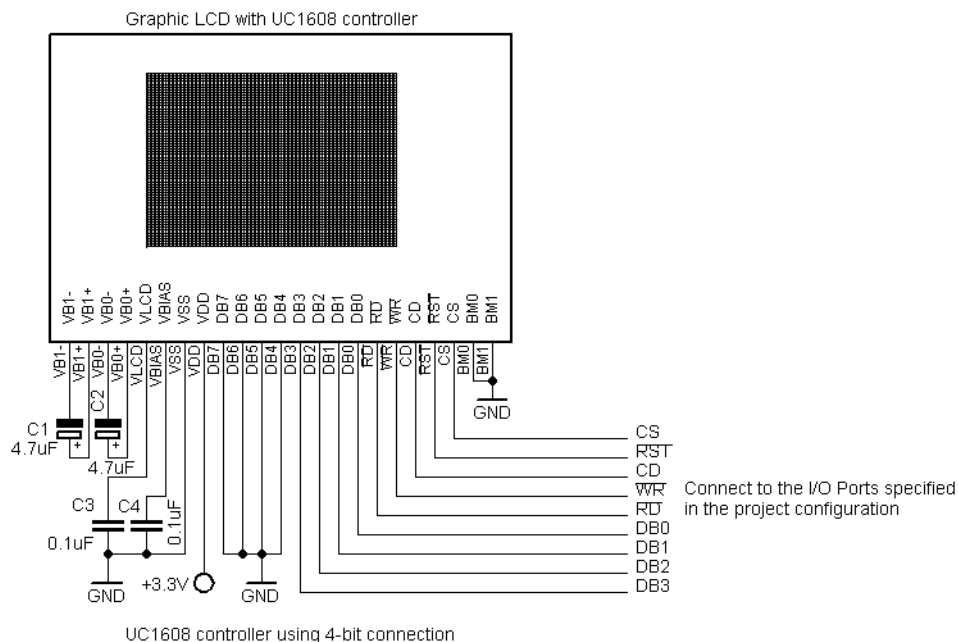
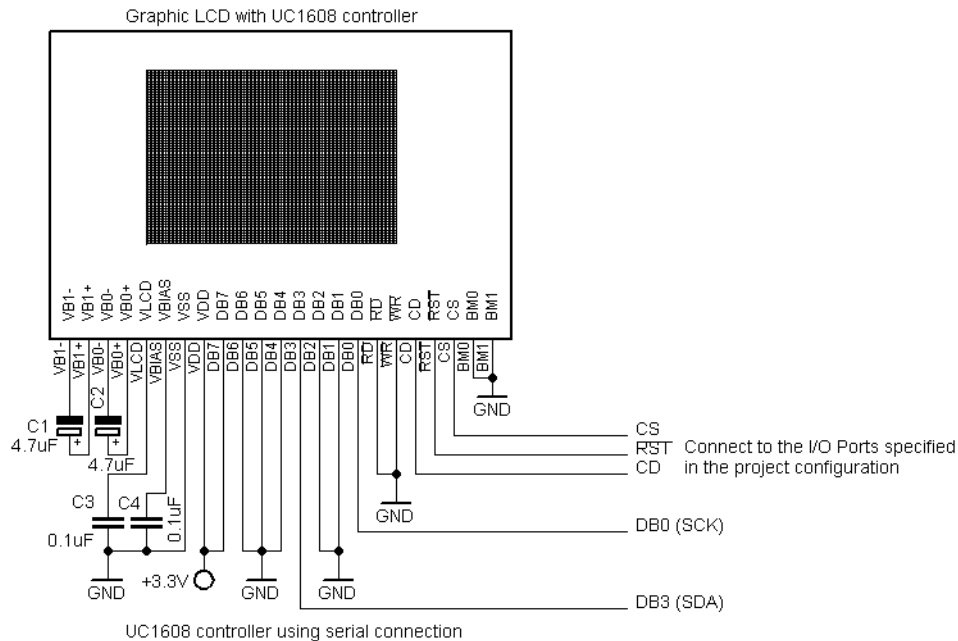
- The **glcd_t6963.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_t6963.h**.
- The **..\EXAMPLES\Graphic Displays\T6963C** directory contains fully functional code samples that may be used as references for T6963C initialization and usage.

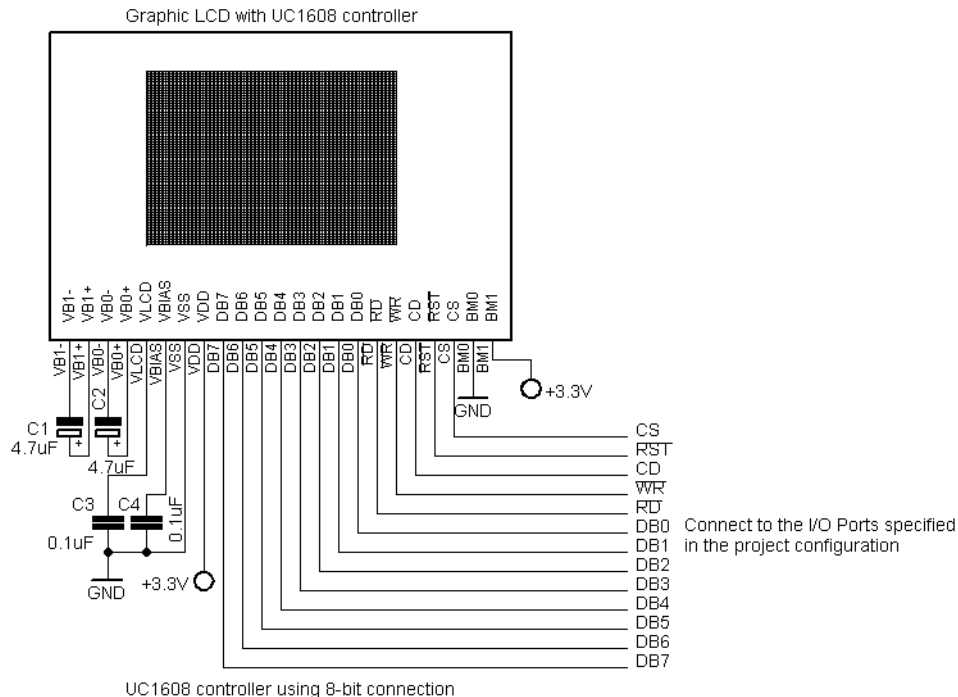
5.12.30 Graphic LCD Functions Specific to the UC1608 Controller

The UC1608 library functions supplied with the CodeVisionAVR, can operate the controller in serial, 4 and 8 bit interface modes.

To obtain higher display speed, the 8 bit interface mode is recommended.

The controller's connections for each operation mode are specified in the following pictures:





In order to take full advantage of the UC1608 controller's features, the following specific functions, declared in the **glcd_uc1608.h** header file, were implemented:

void uc1608_wrcmd(unsigned char cmd)

Writes a command to the UC1608 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_uc1608.h** header file:

```
#define UC1608_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define UC1608_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define UC1608_CMD_MUX_RATE_TC 0x20 /* sets the multiplex rate (# of rows)
                                     and temperature compensation */
#define UC1608_96ROWS (0<<2) /* 96 rows */
#define UC1608_128ROWS (1<<2) /* 128 rows (default) */

#define UC1608_CMD_POWER_CTRL 0x28 /* sets the usage of external or
                                     internal VLCD and panel loading
                                     capacitance */
#define UC1608_EXT_VLCD (0<<2) /* use external VLCD source */
#define UC1608_INT_VLCD (1<<2) /* use internal VLCD source (default) */

#define UC1608_CMD_START_LINE 0x40 /* set display start line */
#define UC1608_CMD_GAIN_POTENTIOMETER 0x81 /* sets gain and
                                               potentiometer */
#define UC1608_CMD_RAM_ADDR_CTRL 0x88 /* controls the automatic column/page
                                       wrap-around and page address auto
                                       increment direction: */
#define UC1608_WRAP_AROUND (1<<0) /* enable automatic column/page
                                       wrap-around on reaching boundary */
```

```
#define UC1608_PA_AUTOINC (0<<2) /* Page Address auto increment on reaching
                                   boundary */
#define UC1608_PA_AUTODEC (1<<2) /* Page Address auto decrement on reaching
                                   boundary */

#define UC1608_CMD_SET_FIXED_LINES 0x90 /* set the number of fixed display
                                         lines */
#define UC1608_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
                                         contents */
#define UC1608_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define UC1608_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define UC1608_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define UC1608_CMD_DISP_OFF 0xAE /* display off */
#define UC1608_CMD_DISP_ON 0xAF /* display on */
#define UC1608_CMD_SET_PAGE 0xB0 /* set display page address */
#define UC1608_CMD_LCD_MAPPING_CTRL 0xC0 /* set display horizontal and
                                         vertical mapping reversing */

#define UC1608_CMD_RESET 0xE2 /* resets the controller */
#define UC1608_CMD_NOP 0xE3 /* no operation */
#define UC1608_CMD_BIAS_RATIO 0xE8 /* set LCD voltage bias ratio */
#define UC1608_RESET_CURSOR_MODE 0xEE /* turns off the cursor update
                                         function */
#define UC1608_SET_CURSOR_MODE 0xEF /* turns on the cursor update
                                       function */
```

A detailed description of the above mentioned commands can be found in the UC1608 datasheet.

void uc1608_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the LCD bias voltage, allowed range is 0..63.

The **glcd_uc1608.h** header file also contains the definition of the **GLCDINIT_t** type specific for the UC1608 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
       memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
       memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char temp_comp:2; /* temperature compensation */
    unsigned char panel_cap:2; /* LCD panel capacitance */
    unsigned char lcd_bias:2; /* LCD bias voltage ratio */
    unsigned char contrast:6; /* LCD contrast value 0..63 */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for reverse_x initialization */
/* set relationship between RAM column addr. & display driver: normal */
#define UC1608_REVX_NORM 0
/* set relationship between RAM column addr. & display driver: reversed */
#define UC1608_REVX_REV 1

/* values used for reverse_y initialization */
/* sets the vertical output scan direction 0->127 */
#define UC1608_REVY_NORM 0
/* sets the vertical output scan direction 127->0 */
#define UC1608_REVY_REV 1

/* values used for temp_comp initialization */
#define UC1608_TC000 (0<<0) /* -0.00%/C (default) */
#define UC1608_TC005 (1<<0) /* -0.05%/C */
#define UC1608_TC010 (2<<0) /* -0.10%/C */
#define UC1608_TC020 (3<<0) /* -0.20%/C */

/* values used for panel_cap initialization */
/* panel loading capacitance =< 26nF */
#define UC1608_PANEL_CAP_26NF (0<<0)
/* 26nF < panel loading capacitance =< 43nF (default) */
#define UC1608_PANEL_CAP_43NF (1<<0)
/* 43nF < panel loading capacitance =< 60nF */
#define UC1608_PANEL_CAP_60NF (2<<0)
/* 60nF < panel loading capacitance =< 90nF */
#define UC1608_PANEL_CAP_90NF (3<<0)

/* values used for lcd_bias initialization */
#define UC1608_BIAS_10_7 0 /* 10.7 */
#define UC1608_BIAS_11_3 1 /* 11.3 */
#define UC1608_BIAS_12_0 2 /* 12.0 (default) */
#define UC1608_BIAS_12_7 3 /* 12.7 */

/* default initialization values */
/* default value for reverse_x */
#define UC1608_DEFAULT_REVX UC1608_REVX_NORM
/* default value for reverse_y */
#define UC1608_DEFAULT_REVY UC1608_REVY_NORM
/* default value for LCD temperature compensation */
#define UC1608_DEFAULT_TEMP_COMP UC1608_TC000
/* default LCD panel loading capacitance */
#define UC1608_DEFAULT_PANEL_CAP UC1608_PANEL_CAP_43NF
/* default LCD bias ratio */
#define UC1608_DEFAULT_LCD_BIAS UC1608_BIAS_12_0
/* default LCD contrast 0..63 */
#define UC1608_DEFAULT_LCD_CONTRAST 18
/* default gain */
#define UC1608_DEFAULT_GAIN 1
```

The detailed description of the above mentioned initialization parameters can be found in the UC1608 datasheet.

Notes:

- The **glcd_uc1608.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_uc1608.h**.
- The **..\EXAMPLES\Graphic Displays\UC1608** directory contains fully functional code samples that may be used as references for UC1608 initialization and usage.

5.12.31 Graphic LCD Functions Specific to the UC1610 Controller

The UC1610 library functions supplied with the CodeVisionAVR, can operate the controller in 4-wire bit-banged serial and hardware SPI modes.

Two display resolutions can be selected from the **Project|Configure|C Compiler|Libraries|Graphic Displays** menu:

- 160x104 for the Electronic Assembly DOGXL160-7 displays
- 160x128 the native resolution of the UC1610 controller.

The UC1610 hardware configuration for the 4-wire serial mode is obtained by connecting the following signals:

- BM0 - GND
- BM1 - GND
- WR0 - +3.3V
- WR1 - +3.3V
- D0 (SCK) - microcontroller I/O port, specified in the Project|Configure|C Compiler|Libraries|Graphic Displays menu
- D3 (SDA) - microcontroller I/O port, specified in the Project|Configure|C Compiler|Libraries|Graphic Displays menu
- D6 - GND
- D7 - +3.3V
- CD - microcontroller I/O port, specified in the Project|Configure|C Compiler|Libraries|Graphic Displays menu
- /CS0 - microcontroller I/O port, specified in the Project|Configure|C Compiler|Libraries|Graphic Displays menu
- CS1 - +3.3V
- /RST - microcontroller I/O port, specified in the Project|Configure|C Compiler|Libraries|Graphic Displays menu.

In order to take full advantage of the UC1610 controller's features, the following specific functions, declared in the **glcd_uc1610.h** header file, were implemented:

void uc1610_wrcmd(unsigned char cmd)

Writes a command to the UC1610 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_uc1610.h** header file:

```
#define UC1610_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define UC1610_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define UC1610_CMD_TEMP_COMP 0x24 /* set Vbias temperature compensation */
#define UC1610_CMD_PANEL_LOADING 0x28 /* set panel loading capacitance */
#define UC1610_CMD_PUMP_CTRL 0x2C /* programs the build-in charge pump stages: */
#define UC1610_EXT_VLCD 0 /* uses external Vlcd */
#define UC1610_7X_PUMP 1 /* uses internal Vlcd, 7x pump */
#define UC1610_6X_PUMP 2 /* uses internal Vlcd, 6x pump */
#define UC1610_8X_PUMP 3 /* uses internal Vlcd, 8x pump */

#define UC1610_CMD_SCROLL_LINE_LSB 0x40 /* set scroll line bits 0..3 */
#define UC1610_CMD_SCROLL_LINE_MSB 0x50 /* set scroll line bits 4..6 */
#define UC1610_CMD_SET_PAGE 0x60 /* set display page address */
```



```
#define UC1610_CMD_VBIAS 0x81 /* set Vbias potentiometer */
#define UC1610_CMD_PARTIAL_CTRL 0x84 /* set partial display function */
#define UC1610_CMD_RAM_ADDR_CTRL 0x88 /* controls the automatic
column/page wrap around and
page address auto increment
direction: */

#define UC1610_WRAP_AROUND (1<<0) /* enable automatic column/page
wrap-around on reaching
boundary */

#define UC1610_CA_AUTOINC_FIRST (0<<1) /* column address first auto
increments on reaching
boundary */

#define UC1610_PA_AUTOINC_FIRST (1<<1) /* page address first auto
increments on reaching
boundary */

#define UC1610_PA_AUTOINC (0<<2) /* page address auto increment
on reaching boundary */

#define UC1610_PA_AUTODEC (1<<2) /* page address auto decrement
on reaching boundary */

#define UC1610_CMD_SET_FIXED_LINES 0x90 /* set the number of fixed
display lines */
#define UC1610_CMD_SET_LINE_RATE 0xA0 /* set the Line Rate (Frame Rate =
Line Rate/Mux Rate) */
#define UC1610_LINE_RATE_12_1 0 /* Line Rate= 12.1 kLines/s */
#define UC1610_LINE_RATE_13_4 1 /* Line Rate= 13.4 kLines/s */
#define UC1610_LINE_RATE_14_7 2 /* Line Rate= 14.7 kLines/s */
#define UC1610_LINE_RATE_16_6 3 /* Line Rate= 16.6 kLines/s */

#define UC1610_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
contents */
#define UC1610_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define UC1610_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define UC1610_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define UC1610_CMD_DISP_OFF 0xAE /* display off */
#define UC1610_CMD_DISP_ON 0xAF /* display on */
#define UC1610_CMD_LCD_MAPPING_CTRL 0xC0 /* set display horizontal and
vertical mapping reversing */
#define UC1610_CMD_LCD_GRAY_SHADE 0xD0 /* set the voltage RMS separation
between the two gray shade
levels */

#define UC1610_CMD_RESET 0xE2 /* resets the controller */
#define UC1610_CMD_NOP 0xE3 /* no operation */
#define UC1610_CMD_BIAS_RATIO 0xE8 /* set the LCD voltage bias ratio */
#define UC1610_CMD_RESET_CURSOR_MODE 0xEE /* turns off the cursor
update function */
#define UC1610_CMD_SET_CURSOR_MODE 0xEF /* turns on the cursor
update function */
#define UC1610_CMD_COM_END 0xF1 /* set the number of used COM
electrodes -1 */
#define UC1610_CMD_DISP_START 0xF2 /* set the starting COM electrode,
which has been assigned a full
scanning period, and which will
output an active COM scanning
pulse */
#define UC1610_CMD_DISP_END 0xF3 /* set the ending COM electrode,
which has been assigned a full
scanning period, and which will
output an active COM scanning
pulse */
```

```
#define UC1610_CMD_WINDOW_START_COL 0xF4 /* set the display window start
column address */
#define UC1610_CMD_WINDOW_START_PAGE 0xF5 /* set the display window start
page address */
#define UC1610_CMD_WINDOW_END_COL 0xF6 /* set the display window end
column address */
#define UC1610_CMD_WINDOW_END_PAGE 0xF7 /* set the display window end
page address */
#define UC1610_CMD_WINDOW_PGM_EN 0xF8 /* enables the window program
function */
```

A detailed description of the above mentioned commands can be found in the UC1610 datasheet.

void uc1610_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the LCD bias voltage, allowed range is 0..255.

The **glcd_uc1610.h** header file also contains the definition of the **GLCDINIT_t** type specific for the UC1610 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte from external
memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte to external
memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);

    unsigned char reverse_x:1; /* reverse display horizontally */
    unsigned char reverse_y:1; /* reverse display vertically */
    unsigned char temp_comp:2; /* temperature compensation */
    unsigned char panel_cap:2; /* LCD panel capacitance */
    unsigned char lcd_bias:2; /* LCD bias voltage ratio */
    unsigned char contrast; /* LCD contrast value 0..255 */
} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for reverse_x initialization */
/* set relationship between RAM column address and display driver: normal
*/
#define UC1610_REVX_NORM 0
/* set relationship between RAM column address and display driver: reversed
*/
#define UC1610_REVX_REV 1

/* values used for reverse_y initialization */
/* sets the vertical output scan direction 0->127 (0->103) */
#define UC1610_REVY_NORM 0
/* sets the vertical output scan direction 127->0 (103->0) */
#define UC1610_REVY_REV 1
```

```
/* values used for temp_comp initialization */
#define UC1610_TC005 0 /* -0.05%/C */
#define UC1610_TC010 1 /* -0.10%/C */
#define UC1610_TC015 2 /* -0.15%/C */
#define UC1610_TC020 3 /* -0.20%/C */

/* values used for panel_cap initialization */
#define UC1610_PANEL_CAP_16NF 0 /* Cpanel <= 16nF */
#define UC1610_PANEL_CAP_21NF 1 /* 16nF < Cpanel <= 21nF */
#define UC1610_PANEL_CAP_28NF 2 /* 21nF < Cpanel <= 28nF */
#define UC1610_PANEL_CAP_38NF 3 /* 28nF < Cpanel <= 38nF */

/* values used for lcd_bias initialization */
#define UC1610_BIAS_1_5 0 /* 1/5 */
#define UC1610_BIAS_1_10 1 /* 1/10 */
#define UC1610_BIAS_1_11 2 /* 1/11 */
#define UC1610_BIAS_1_12 3 /* 1/12 */

/* default initialization values */
/* default value for reverse_x */
#define UC1610_DEFAULT_REVX UC1610_REVX_NORM
/* default value for reverse_y */
#define UC1610_DEFAULT_REVY UC1610_REVY_NORM
/* default value for LCD temperature compensation */
#define UC1610_DEFAULT_TEMP_COMP UC1610_TC005
/* default LCD panel loading capacitance */
#define UC1610_DEFAULT_PANEL_CAP UC1610_PANEL_CAP_38NF
/* default LCD bias ratio */
#define UC1610_DEFAULT_LCD_BIAS UC1610_BIAS_1_12
/* default LCD contrast */
#define UC1610_DEFAULT_LCD_CONTRAST 0x5F
```

The detailed description of the above mentioned initialization parameters can be found in the UC1610 datasheet.

Notes:

- The **glcd_uc1610.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_uc1610.h**.
- The **..\EXAMPLES\Graphic Displays\UC1610 EA DOGXL160-7** directory contains fully functional code samples that may be used as references for UC1610 initialization and usage.

5.12.32 Graphic LCD Functions Specific to the UC1701 Controller

In order to take full advantage of the UC1701 controller's features, the following specific functions, declared in the **glcd_uc1701.h** header file, were implemented:

void uc1701_wrcmd(unsigned char cmd)

Writes a command to the UC1701 controller.

Parameter:

cmd command to be sent to the controller.

This command may take one of the values defined in the following macros from the **glcd_uc1701.h** header file:

```
#define UC1701_CMD_SET_SCROLL_LINE 0x40 /* set the scroll line number */
#define UC1701_CMD_SET_PAGE 0xB0 /* set display page address */
#define UC1701_CMD_SET_ADDR_LOW 0x00 /* set column address bits 0..3 */
#define UC1701_CMD_SET_ADDR_HIGH 0x10 /* set column address bits 4..7 */
#define UC1701_CMD_SEG_DIR_NORM 0xA0 /* set relationship between RAM column
                                     address and display driver:
                                     normal (MX=0) */
#define UC1701_CMD_SEG_DIR_REV 0xA1 /* set relationship between RAM column
                                     address and display driver:
                                     reversed (MX=1) */
#define UC1701_CMD_DISP_NORMAL 0xA6 /* set normal display mode */
#define UC1701_CMD_DISP_REVERSE 0xA7 /* set reversed display mode */
#define UC1701_CMD_PIXELS_NORMAL 0xA4 /* display the graphic RAM
                                     contents */
#define UC1701_CMD_ALL_PIXELS_ON 0xA5 /* all display pixels are on */
#define UC1701_CMD_STATIC_INDICATOR_OFF 0xAC /* turn off static
                                              indicator */
#define UC1701_CMD_STATIC_INDICATOR_ON 0xAD /* turn on static indicator */
#define UC1701_CMD_DISP_OFF 0xAE /* turn display off */
#define UC1701_CMD_DISP_ON 0xAF /* turn display on */
#define UC1701_CMD_LCD_BIAS_LOW 0xA2 /* sets voltage ratio for LCD bias to
                                     1/9 (duty cycle=1/65),
                                     1/8 (duty cycle=1/49),
                                     1/6 (duty cycle=1/33),
                                     1/8 (duty cycle=1/55),
                                     1/8 (duty cycle=1/53) */
#define UC1701_CMD_LCD_BIAS_HIGH 0xA3 /* sets voltage ratio for LCD bias to
                                     1/7 (duty cycle=1/65),
                                     1/6 (duty cycle=1/49),
                                     1/5 (duty cycle=1/33),
                                     1/6 (duty cycle=1/55),
                                     1/6 (duty cycle=1/53) */
#define UC1701_CMD_COM0_63 0xC0 /* sets the COM output scan
                                  direction 0->63 (MY=0) */
#define UC1701_CMD_COM63_0 0xC8 /* sets the COM output scan
                                  direction 63->0 (MY=1) */
#define UC1701_CMD_POWER_CTRL 0x28 /* turns on/off the voltage follower
                                     (| bit 0),
                                     voltage regulator (| bit 1),
                                     voltage booster (| bit 2) */
#define UC1701_VOLT_FOLLOWER_ON (1<<0) /* enable voltage follower */
#define UC1701_VOLT_REGULATOR_ON (1<<1) /* enable voltage regulator */
#define UC1701_VOLT_BOOSTER_ON (1<<2) /* enable voltage booster */
```

```
#define UC1701_CMD_VLCD_RES 0x20 /* sets the VLCD voltage regulator
                                   internal resistor ratio */
#define UC1701_CMD_ELECTRONIC_VOLUME 0x81 /* sets the electronic
                                             volume register in order
                                             to control the VLCD
                                             drive voltage */

#define UC1701_CMD_ADV_PGM_CTRL0 0xFA /* advanced program control 0,
                                         used to set LCD temperature
                                         compensation coefficient (TC) */

#define UC1701_CMD_RESET 0xE2 /* resets the controller */

/* set cursor update mode when writing to display RAM,
   reading from display RAM doesn't affect the column address
   register CA */
#define UC1701_CMD_CURSOR_UPDATE_ON 0xE0 /* the column address CA will be
                                             incremented when writing to
                                             display RAM */
#define UC1701_CMD_CURSOR_UPDATE_OFF 0xEE /* the column address CA will
                                             not be incremented when
                                             writing to display RAM */
```

A detailed description of the above mentioned commands can be found in the UC1701 datasheet.

void uc1701_setcontrast(unsigned char contrast)

Controls the LCD contrast.

Parameter:

contrast sets the value of the VLCD drive voltage, allowed range is 0..63.

The **glcd_uc1701.h** header file also contains the definition of the **GLCDINIT_t** type specific for the UC1701 controller, used as parameter for the **glcd_init** function:

```
typedef struct
{
    flash unsigned char *font; /* default font after initialization */
    /* pointer to the function used for reading a byte
       from external memory */
    unsigned char (*readxmem) (GLCDMEMADDR_t addr);
    /* pointer to the function used for writing a byte
       to external memory */
    void (*writexmem) (GLCDMEMADDR_t addr, unsigned char data);
    unsigned char lcd_bias:1; /* =0 LCD bias voltage ratio low,
                               =1 LCD bias voltage ratio high */
    unsigned char reverse_x:1; /* reverse display horizontally (MX) */
    unsigned char rev132_x0:1; /* set to 1 for displays that use
                                reversed RAM column address
                                (reverse_x=1) driver and the pixel
                                with x=0 is connected to column
                                driver #132 */
    unsigned char reverse_y:1; /* reverse display vertically (MY) */
};
```

```
    unsigned char volt_reg_vlcd:3; /* set VLCD voltage regulator
                                   internal resistor ratio [0..7] */
    unsigned char lcd_contrast:5; /* LCD contrast voltage: [0..63] */
    unsigned char lcd_temp_comp:1; /* LCD temperature compensation
                                   coefficient (TC)
                                   (=0 -0.05%/C, =1 -0.11%/C) */

} GLCDINIT_t;
```

The following macros are defined for initializing the members of the **GLCDINIT_t** structure:

```
/* values used for lcd_bias initialization */
#define UC1701_LCD_BIAS_19 0 /* sets LCD bias drive ratio 1/9, 1/8, 1/7 */
#define UC1701_LCD_BIAS_17 1 /* sets LCD bias drive ratio 1/7, 1/6, 1/5 */

/* values used for reverse_x initialization */
#define UC1701_REVX_NORM 0 /* set relationship between RAM column address
                           and display driver: normal (MX=0) */
#define UC1701_REVX_REV 1 /* set relationship between RAM column address
                           and display driver: reversed (MX=1) */

/* values used for rev132_x0 initialization,
   effective only when reverse_x=1 (UC1701_REVX_REV) */
#define UC1701_REV132_X0NC 0 /* pixel with x=0 is not connected to column
                              driver #132 when MX=1 */
#define UC1701_REV132_X0CON 1 /* pixel with x=0 is connected to column
                               driver #132 when MX=1 */

/* values used for reverse_y initialization */
/* sets the vertical output scan direction 0->63 */
#define UC1701_REVY_NORM 0
/* sets the vertical output scan direction 63->0 */
#define UC1701_REVY_REV 1

/* values used for lcd_temp_comp initialization */
#define UC1701_LCD_TEMP_COMP_005 0 /* -0.05%/C */
#define UC1701_LCD_TEMP_COMP_011 1 /* -0.11%/C */

/* default initialization values */
/* default value for LCD bias */
#define UC1701_DEFAULT_LCD_BIAS UC1701_LCD_BIAS_LOW
/* default value for reverse_x */
#define UC1701_DEFAULT_REVX UC1701_REVX_NORM
/* default value for rev132_x0,
   effective only when reverse_x=1 (UC1701_REVX_REV) */
#define UC1701_DEFAULT_REV132_X0 UC1701_REV132_X0NC
/* default value for reverse_y */
#define UC1701_DEFAULT_REVY UC1701_REVY_NORM
/* default VLCD voltage regulator internal resistor ratio */
#define UC1701_DEFAULT_VLCD_RES 6
/* default contrast */
#define UC1701_DEFAULT_CONTRAST 7
/* default LCD temperature compensation coefficient */
#define UC1701_DEFAULT_LCD_TEMP_COMP UC1701_LCD_TEMP_COMP_011
```

The detailed description of the above mentioned initialization parameters can be found in the UC1701 datasheet.

Note:

- The **glcd_uc1701.h** header file is automatically **#included** when the main **glcd.h** header file is **#included**. Therefore there is no need to explicitly **#include glcd_uc1701.h**.

5.13 Resistive Touchscreen Functions

The Resistive Touchscreen Functions are intended for easy interfacing between C programs and graphic LCD and TFT modules that use the Texas Instruments ADS7843 and ADS7846 touchscreen controllers.

The prototypes for these functions are placed in the file **rtouch.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

Before using these functions, the I/O port signals employed for communication with the touchscreen controller must be specified in the **Project|Configure|C Compiler|Libraries|Resistive Touchscreen** menu.

The coordinate system employed by these functions has the origin (0,0) in the upper left corner of the display, with the x-coordinates increasing from left to right, and the y-coordinates increasing from top to bottom.

The following helper data types and variables are defined in the header file **rtouch.h**:

```
/* Touchscreen point coordinates */
typedef struct
{
    unsigned short x; /* horizontal coordinate */
    unsigned short y; /* vertical coordinate */
} RTPOINT_t;

/* Touchscreen calibration points coordinates */
typedef struct
{
    RTPOINT_t left_top; /* screen horizontal left-vertical top point */
    RTPOINT_t right_center; /* screen horizontal right-vertical center point */
    RTPOINT_t center_bottom; /* screen horizontal center-vertical bottom point */
} RTCALP_t;

/* Signal that the screen was touched and the point's coordinates
   can be read using the rt_getxy function */
extern bit rt_touched;
```

The following low level resistive touchscreen functions are available:

void rt_timerproc(void)

This function needs to be called every 10ms by a timer interrupt service routine in order to sense the state of the **/PENIRQ** output of the touch screen controller.

Example:

```
/* Timer/counter TCC0 Overflow interrupt
   service routine called every 10ms */
interrupt [TCC0_OVF_vect] void tcc0_overflow_isr(void)
{
    /* Called to detect the ADS7846 controller's /PENIRQ signal
       becoming 0 when the screen was touched */
    rt_timerproc();

    /* Other code needed to be executed every 10ms may follow... */
}
```

Note:

- If the screen was touched, **rt_timerproc** will set the global variable **rt_touched** to 1. The variable will be reset to 0 when reading the point's coordinates using the **rt_readctrl** and **rt_getxy** functions.

void rt_readctrl(unsigned short *xt, unsigned short *yt)

Waits for the screen to be touched and returns the **xt**, **yt** touchscreen coordinate values read from the controller.

Parameters:

xt - pointer to the variable that will hold the 12-bit *noise filtered* value read from the controller's ADC for the horizontal coordinate

yt - pointer to the variable that will hold the 12-bit *noise filtered* value read from the controller's ADC for the vertical coordinate.

Note:

- **xt** and **yt** don't represent graphic display coordinates.

The following high level resistive touchscreen functions are available:

bool rt_init(bool single_ended)

Initializes the resistive touchscreen controller.

Parameter:

single_ended - specifies the operating mode for the ADS7843/ADS7846 controller: set **true** for *single-ended* and **false** for *differential* connection.

Return values:

true if the touchscreen calibration data, stored in the chip's EEPROM is valid;
false if not.

Notes:

- After calling **rt_init**, please make sure that the timer that is used for generating the 10ms interrupt which calls **rt_timerproc**, is also initialized and that global interrupts are enabled using **#asm("sei")**.
- In order to simplify the usage of the **rt_init** function, the following macros are defined in the **rtouch.h** header file:

```
#define RTOUCH_MODE_DIFFERENTIAL false
#define RTOUCH_MODE_SINGLE_ENDED true
```

bool rt_calibrate(RTCALP_t *touchscreen, flash RTCALP_t *display)

Calibrates the resistive touchscreen controller and stores the calibration data in the chip's EEPROM.

Parameters:

touchscreen - points to the **RTCALP_t** structure that holds the ADC values read by the touchscreen controller, corresponding to the display coordinates of the calibration points
display - points to the **RTCALP_t** structure, stored in FLASH memory, that holds the coordinates of the calibration points to be displayed.

Return values:

true if the touchscreen calibration was successful,
false if not.

Note:

- **rt_calibrate** stores the calibration data redundantly in the chip's EEPROM, special routines are also used in **rt_init** in order to prevent this data to be corrupted and eventually correct it in such cases.

Example:

/ The example is designed to run on the STK600 development board with an ATxmega128A1 chip using the internal 32 MHz oscillator as clock source.*

A 240x320 HY32D 3.2" TFT LCD module with the SSD1289 controller is used.

*The connections must be specified by accessing the Project|Configure|C Compiler|Libraries|Graphic Display and Project|Configure|C Compiler|Libraries|Resistive Touchscreen menus. */*

```
#include <io.h>
#include <glcd.h>
#include <font5x7.h>
#include <stdio.h>
#include <delay.h>
#include <rtouch.h>
```

```
/* (x,y) Coordinates of the three touch screen calibration points */
flash RTCALP_t display_calibration_points=
{{10,30},/* horizontal left-vertical top point */
{220,159}, /* horizontal right-vertical center point */
{119,310}}; /* horizontal center-vertical bottom point */
```

```
/* Display buffer */
char display_buf[];
```

```
/* Timer/counter TCC0 Overflow/Underflow interrupt service routine called every 10ms */
interrupt [TCC0_OVF_vect] void tcc0_overflow_isr(void)
{
/* Called to detect the ADS7846 controller's /PENIRQ signal becoming 0 when the screen was touched */
rt_timerproc();
}
```

```
/* Display a cross using the current foreground color */
void display_cross(RTPOINT_t p)
{
short text_width,xt;
short text_height,yt,t;
/* Display the cross */
glcd_line(p.x-5,p.y,p.x+5,p.y);
glcd_line(p.x,p.y-5,p.x,p.y+5);
/* Prepare to display cross center coordinates */
sprintf(display_buf,"(%d,%d)",p.x,p.y);
```

```
/* Establish displayed text size */
text_width=glcd_textwidth(display_buf);
text_height=glcd_textheight();

/* Try to display the text centered under the cross */
if ((t=p.y+5+text_height)<_GLCD_MAXY_) goto l0;
/* Try to display the text centered above the cross */
if ((t=p.y-5-text_height)>=0)
{
    l0:
    yt=t;
    /* Ensure the text fits the screen horizontally */
    xt=p.x-text_width/2;
    if (xt<0) xt=0;
    else if ((xt+text_width)>=_GLCD_MAXX_) xt=_GLCD_MAXX_-1-text_width;
}
/* If not possible, display on the same line with the cross */
else
{
    yt=p.y-text_height/2;
    /* Try to display the text to the right of the cross */
    if ((t=p.x+5+text_width)<_GLCD_MAXX_) xt=t;
    /* Try to display the text to the left of the cross */
    else if ((t=p.x-5-text_width)>=0) xt=t;
    else xt=p.x-5;
}
/* Display the cross center coordinates */
glcd_outtextxy(xt,yt,display_buf);
}

/* Display a cross for a calibration point */
void display_rt_point(RTPOINT_t p)
{
    glcd_setcolor(GLCD_CL_WHITE);
    /* Draw the cross with white color */
    display_cross(p);
}

/* Erase the cross for a calibration point */
void erase_rt_point(RTPOINT_t p)
{
    GLCDCOL_t c;
    /* Save foreground color */
    c=glcd_getcolor();
    /* Set foreground color same as background */
    glcd_setcolor(glcd_getbkcolor());
    /* Draw the cross with the background color (erase it) */
    display_cross(p);
    /* Restore the foreground color */
    glcd_setcolor(c);
}
```

```
/* Calibrate the touch screen*/
bool calibrate_touchscreen(void)
{
    RTCALP_t rt_calibration_points;

    /* Display calibration points and read the touchscreen result for each of
    them */

    /* horizontal left-vertical top point */
    display_rt_point(display_calibration_points.left_top);
    rt_readctrl(&rt_calibration_points.left_top.x,&rt_calibration_points.left_top.y);
    erase_rt_point(display_calibration_points.left_top);

    delay_ms(1000);

    /* horizontal right-vertical center point */
    display_rt_point(display_calibration_points.right_center);
    rt_readctrl(&rt_calibration_points.right_center.x,&rt_calibration_points.right_center.y);
    erase_rt_point(display_calibration_points.right_center);

    delay_ms(1000);

    /* horizontal center-vertical bottom point */
    display_rt_point(display_calibration_points.center_bottom);
    rt_readctrl(&rt_calibration_points.center_bottom.x,&rt_calibration_points.center_bottom.y);
    erase_rt_point(display_calibration_points.center_bottom);

    /* Calculate the calibration coefficients and store them to EEPROM */
    return rt_calibrate(&rt_calibration_points,&display_calibration_points);
}

void main()
{
    GLCDINIT_t glcd_init_data;
    unsigned char n;

    /* Set the ATxmega128A1 to run from the internal 32MHz oscillator */

    /* Optimize for speed */
    #pragma optimize-

    /* Internal 32 kHz RC oscillator initialization
    Enable the internal 32 kHz RC oscillator */
    OSC.CTRL|=OSC_RC32KEN_bm;
    /* Wait for the internal 32 kHz RC oscillator to stabilize */
    while ((OSC.STATUS & OSC_RC32KRDY_bm)==0);

    /* Internal 32 MHz RC oscillator initialization
    Enable the internal 32 MHz RC oscillator */
    OSC.CTRL|=OSC_RC32MEN_bm;

    /* System Clock prescaler A division factor: 1
    System Clock prescalers B & C division factors: B:1, C:1 */
    n=(CLK.PSCTRL & ~(CLK_PSADIV_gm | CLK_PSBCDIV1_bm | CLK_PSBCDIV0_bm)) |
    CLK_PSADIV_1_gc | CLK_PSBCDIV_1_1_gc;
    CCP=CCP_IOREG_gc;
    CLK.PSCTRL=n;
}
```

```
/* Internal 32 MHz RC osc. calibration reference
   clock source: 32.768 kHz Internal Osc. */
OSC.DFLLCTRL&= ~(OSC_RC32MCREF_bm | OSC_RC2MCREF_bm);
/* Enable the autocalibration of the internal 32 MHz RC oscillator */
DFLLRC32M.CTRL|=DFLL_ENABLE_bm;

/* Wait for the internal 32 MHz RC oscillator to stabilize */
while ((OSC.STATUS & OSC_RC32MRDY_bm)==0);

/* Select the system clock source: 32 MHz Internal RC Osc. */
n=(CLK.CTRL & (~CLK_SCLKSEL_gm)) | CLK_SCLKSEL_RC32M_gc;
CCP=CCP_IOREG_gc;
CLK.CTRL=n;

/* Initialize timer TCC0 */
/* Clock source: ClkPer/1 */
TCC0.CTRLA=(TCC0.CTRLA & (~TC0_CLKSEL_gm)) | TC_CLKSEL_DIV1_gc;

/* Mode: Normal Operation, Overflow Int./Event on TOP */
TCC0.CTRLB=(TCC0.CTRLB & (~(TC0_CCAEN_bm | TC0_CCBEN_bm | TC0_CCCEN_bm |
    TC0_CCDEN_bm | TC0_WGMODE_gm))) | TC_WGMODE_NORMAL_gc;

/* Capture event source: None
   Capture event action: None */
TCC0.CTRLD=(TCC0.CTRLD & (~(TC0_EVACT_gm | TC0_EVSEL_gm))) |
    TC_EVACT_OFF_gc | TC_EVSEL_OFF_gc;

/* Overflow interrupt: Low Level
   Error interrupt: Disabled */
TCC0.INTCTRLA=(TCC0.INTCTRLA & (~(TC0_ERRINTLVL_gm | TC0_OVFINTLVL_gm))) |
    TC_ERRINTLVL_OFF_gc | TC_OVFINTLVL_LO_gc;

/* Compare/Capture channel A interrupt: Disabled
   Compare/Capture channel B interrupt: Disabled
   Compare/Capture channel C interrupt: Disabled
   Compare/Capture channel D interrupt: Disabled */
TCC0.INTCTRLB=(TCC0.INTCTRLB & (~(TC0_CCDINTLVL_gm | TC0_CCCINTLVL_gm |
    TC0_CCBINTLVL_gm | TC0_CCAINTLVL_gm))) |
    TC_CCDINTLVL_OFF_gc | TC_CCCINTLVL_OFF_gc |
    TC_CCBINTLVL_OFF_gc | TC_CCAINTLVL_OFF_gc;

/* Clear the interrupt flags */
TCC0.INTFLAGS=TCC0.INTFLAGS;

/* Set period register for 10ms overflow @32MHz */
TCC0.PER=0x9C3F;

/* Interrupt system initialization in order to be able to sense /PENIRQ
   generated by the ADS7846, using TCC0 overflow interrupt */

/* Low level interrupt: On
   Round-robin scheduling for low level interrupt: Off
   Medium level interrupt: Off
   High level interrupt: Off
   The interrupt vectors will be placed at the start of the
   Application FLASH section */
n=(PMIC.CTRL & (~(PMIC_RREN_bm | PMIC_IVSEL_bm | PMIC_HILVLEN_bm |
    PMIC_MEDLVLEN_bm | PMIC_LOLVLEN_bm))) | PMIC_LOLVLEN_bm;
CCP=CCP_IOREG_gc;
PMIC.CTRL=n;
```

```
/* Set the default priority for round-robin scheduling */
PMIC.INTPRI=0x00;

/* Restore optimization for size if needed */
#pragma optsize_default

/* Initialize the LCD controller with the default values
   from glcd_ssd1289.h */

/* Specify the current font for displaying text */
glcd_init_data.font=font5x7;
/* No function is used for reading image data from external memory */
glcd_init_data.readxmem=NULL;
/* No function is used for writing image data to external memory */
glcd_init_data.writexmem=NULL;
/* Horizontal reverse for HY32D */
glcd_init_data.reverse_x=SSD1289_REVX_REV;
/* Normal display, no vertical reverse */
glcd_init_data.reverse_y=SSD1289_REVY_NORM;
/* Color bit writing order: BGR for HY32D ! */
glcd_init_data.cl_bits_order=SSD1289_CL_BITS_BGR;
/* Power control 1 BT0..BT2 step-up factor of the step-up circuit */
glcd_init_data.stepup_factor=SSD1289_DEFAULT_STEPUP_FACTOR;
/* Power control 1 DC0..DC3, DCT0..DCT3 step-up circuit cycle */
glcd_init_data.stepup_cycle=SSD1289_DEFAULT_STEPUP_CYCLE;
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the
   internal op. amplifier circuit */
glcd_init_data.crt_source=SSD1289_DEFAULT_CRT_SOURCE;
/* Default value for VCIX2 voltage */
glcd_init_data.vcix2=SSD1289_DEFAULT_VCIX2;
/* Default value for VLCD63 voltage */
glcd_init_data.vlcd63=SSD1289_DEFAULT_VLCD63;
// Default value for VcomL alternating drive voltage
glcd_init_data.vcoml=SSD1289_DEFAULT_VCOML;
/* Default value for VcomH voltage */
glcd_init_data.vcomh=SSD1289_DEFAULT_VCOMH;
/* Frame frequency */
glcd_init_data.frame_freq=SSD1289_DEFAULT_FRAME_FREQ;
/* PKP00..PKP02 positive gamma micro adj. */
glcd_init_data.pkp00=SSD1289_DEFAULT_PKP00;
/* PKP10..PKP12 positive gamma micro adj. */
glcd_init_data.pkp10=SSD1289_DEFAULT_PKP10;
/* PKP20..PKP22 positive gamma micro adj. */
glcd_init_data.pkp20=SSD1289_DEFAULT_PKP20;
/* PKP30..PKP32 positive gamma micro adj. */
glcd_init_data.pkp30=SSD1289_DEFAULT_PKP30;
/* PKP40..PKP42 positive gamma micro adj. */
glcd_init_data.pkp40=SSD1289_DEFAULT_PKP40;
/* PKP50..PKP52 positive gamma micro adj. */
glcd_init_data.pkp50=SSD1289_DEFAULT_PKP50;
/* PRP00..PRP02 positive gamma gradient adj. */
glcd_init_data.prp00=SSD1289_DEFAULT_PRP00;
/* PRP10..PRP12 positive gamma gradient adj. */
glcd_init_data.prp10=SSD1289_DEFAULT_PRP10;
/* VRP00..VRP03 positive gamma amplification adj. */
glcd_init_data.vrp00=SSD1289_DEFAULT_VRP00;
/* VRP10..VRP14 positive gamma amplification adj. */
glcd_init_data.vrp10=SSD1289_DEFAULT_VRP10;
```

```
/* PKN00..PKN02 negative gamma micro adj. */
glcd_init_data.pkn00=SSD1289_DEFAULT_PKN00;
/* PKN10..PKN12 negative gamma micro adj. */
glcd_init_data.pkn10=SSD1289_DEFAULT_PKN10;
/* PKN20..PKN22 positive gamma micro adj. */
glcd_init_data.pkn20=SSD1289_DEFAULT_PKN20;
/* PKN30..PKN32 positive gamma micro adj. */
glcd_init_data.pkn30=SSD1289_DEFAULT_PKN30;
/* PKN40..PKN42 negative gamma micro adj. */
glcd_init_data.pkn40=SSD1289_DEFAULT_PKN40;
/* PKN50..PKN52 negative gamma micro adj. */
glcd_init_data.pkn50=SSD1289_DEFAULT_PKN50;
/* PRN00..PRN02 negative gamma gradient adj. */
glcd_init_data.prn00=SSD1289_DEFAULT_PRN00;
/* PRN10..PRN12 negative gamma gradient adj. */
glcd_init_data.prn10=SSD1289_DEFAULT_PRN10;
/* VRN00..VRN03 negative gamma amplification adj. */
glcd_init_data.vrn00=SSD1289_DEFAULT_VRN00;
/* VRN10..VRN14 negative gamma amplification adj. */
glcd_init_data.vrn10=SSD1289_DEFAULT_VRN10;

glcd_init(&glcd_init_data);

/* Initialize the ADS7846 resistive touch controller
   in differential mode */
if (rt_init(RTOUCH_MODE_DIFFERENTIAL))
{
    glcd_outtextf("Touchscreen controller initialized OK");

    /* Globally enable interrupts in order to be able to sense /PENIRQ */
    #asm("sei")
}
else
{
    /* Globally enable interrupts in order to be able to sense /PENIRQ */
    #asm("sei")

    /* No valid touch controller calibration data found in EEPROM,
       so we need to calibrate it now */
    glcd_outtextf("Touch cross center to calibrate");

    if (calibrate_touchscreen())
        glcd_outtextxyf(0,20,"Touchscreen controller calibrated OK");
    else
        glcd_outtextxyf(0,20,"Touchscreen controller calibration\n"
                        "failed");
}

/* Stop here */
while (1);
}
```

bool rt_getxy(unsigned short *xd, unsigned short *yd)

Waits for the screen to be touched and returns the **xd**, **yd** display coordinates calculated using the calibration data stored in the chip's EEPROM.

Parameters:

xd - pointer to the variable that will hold the read horizontal X display coordinate
yd - pointer to the variable that will hold the read vertical Y display coordinate.

Return values:

true if the coordinates are valid,
false if the coordinates are not valid or no calibration data is present in chip's EEPROM.

Example:

```
/* The example is designed to run on the STK600
development board with an ATxmega128A1
chip using the internal 32 MHz oscillator
as clock source.
```

```
A 240x320 HY32D 3.2" TFT LCD module with the SSD1289
controller is used.
```

```
The connections must be specified by accessing the
Project|Configure|C Compiler|Libraries|Graphic Display and
Project|Configure|C Compiler|Libraries|Resistive Touchscreen
menus. */
```

```
#include <io.h>
#include <glcd.h>
#include <font5x7.h>
#include <stdio.h>
#include <delay.h>
#include <rtouch.h>
```

```
/* (x,y) Coordinates of the three touch screen calibration points */
flash RTCALP_t display_calibration_points=
{{10,30},/* horizontal left-vertical top point */
{220,159}, /* horizontal right-vertical center point */
{119,310}}; /* horizontal center-vertical bottom point */
```

```
/* Display buffer */
char display_buf[];
```

```
/* Timer/counter TCC0 Overflow/Underflow interrupt service
routine called every 10ms */
interrupt [TCC0_OVF_vect] void tcc0_overflow_isr(void)
{
/* Called to detect the ADS7846 controller's
/PENIRQ signal becoming 0 when the screen was touched */
rt_timerproc();
}
```

```
/* Display a cross using the current foreground color */
void display_cross(RTPPOINT_t p)
{
    short text_width,xt;
    short text_height,yt,t;
    /* Display the cross */
    glcd_line(p.x-5,p.y,p.x+5,p.y);
    glcd_line(p.x,p.y-5,p.x,p.y+5);
    /* Prepare to display cross center coordinates */
    sprintf(display_buf,"%d,%d",p.x,p.y);
    /* Establish displayed text size */
    text_width=glcd_textwidth(display_buf);
    text_height=glcd_textheight();
    /* Try to display the text centered under the cross */
    if ((t=p.y+5+text_height)<_GLCD_MAXY_) goto l0;
    /* Try to display the text centered above the cross */
    if ((t=p.y-5-text_height)>=0)
    {
        l0:
        yt=t;
        /* Ensure the text fits the screen horizontally */
        xt=p.x-text_width/2;
        if (xt<0) xt=0;
        else if ((xt+text_width)>=_GLCD_MAXX_) xt=_GLCD_MAXX_-1-text_width;
    }
    /* If not possible, display on the same line with the cross */
    else
    {
        yt=p.y-text_height/2;
        /* Try to display the text to the right of the cross */
        if ((t=p.x+5+text_width)<_GLCD_MAXX_) xt=t;
        /* Try to display the text to the left of the cross */
        else if ((t=p.x-5-text_width)>=0) xt=t;
        else xt=p.x-5;
    }
    /* Display the cross center coordinates */
    glcd_outtextxy(xt,yt,display_buf);
}

/* Display a cross for a calibration point */
void display_rt_point(RTPPOINT_t p)
{
    glcd_setcolor(GLCD_CL_WHITE);
    /* Draw the cross with white color */
    display_cross(p);
}

/* Erase the cross for a calibration point */
void erase_rt_point(RTPPOINT_t p)
{
    GLCDCOL_t c;
    /* Save foreground color */
    c=glcd_getcolor();
    /* Set foreground color same as background */
    glcd_setcolor(glcd_getbkcolor());
    /* Draw the cross with the background color (erase it) */
    display_cross(p);
    /* Restore the foreground color */
    glcd_setcolor(c);
}
```



```
/* Calibrate the touch screen*/
bool calibrate_touchscreen(void)
{
    RTCALP_t rt_calibration_points;

    /* Display calibration points and read the touchscreen result for each of
    them */

    /* horizontal left-vertical top point */
    display_rt_point(display_calibration_points.left_top);
    rt_readctrl(&rt_calibration_points.left_top.x,&rt_calibration_points.left_top.y);
    erase_rt_point(display_calibration_points.left_top);

    delay_ms(1000);

    /* horizontal right-vertical center point */
    display_rt_point(display_calibration_points.right_center);
    rt_readctrl(&rt_calibration_points.right_center.x,&rt_calibration_points.right_center.y);
    erase_rt_point(display_calibration_points.right_center);

    delay_ms(1000);

    /* horizontal center-vertical bottom point */
    display_rt_point(display_calibration_points.center_bottom);
    rt_readctrl(&rt_calibration_points.center_bottom.x,&rt_calibration_points.center_bottom.y);
    erase_rt_point(display_calibration_points.center_bottom);

    /* Calculate the calibration coefficients and store them to EEPROM */
    return rt_calibrate(&rt_calibration_points,&display_calibration_points);
}

void main()
{
    GLCDINIT_t glcd_init_data;
    unsigned char n;
    short x,y;

    /* Set the ATxmega128A1 to run from the internal 32MHz oscillator */

    /* Optimize for speed */
    #pragma optimize-

    /* Internal 32 kHz RC oscillator initialization
    Enable the internal 32 kHz RC oscillator */
    OSC_CTRL|=OSC_RC32KEN_bm;
    /* Wait for the internal 32 kHz RC oscillator to stabilize */
    while ((OSC.STATUS & OSC_RC32KRDY_bm)==0);

    /* Internal 32 MHz RC oscillator initialization
    Enable the internal 32 MHz RC oscillator */
    OSC_CTRL|=OSC_RC32MEN_bm;
```

```
/* System Clock prescaler A division factor: 1
   System Clock prescalers B & C division factors: B:1, C:1 */
n=(CLK.PSCTRL & ~(CLK_PSADIV_gm | CLK_PSBCDIV1_bm | CLK_PSBCDIV0_bm)) |
  CLK_PSADIV_1_gc | CLK_PSBCDIV_1_1_gc;
CCP=CCP_IOREG_gc;
CLK.PSCTRL=n;

/* Internal 32 MHz RC osc. calibration reference
   clock source: 32.768 kHz Internal Osc. */
OSC.DFLLCTRL&= ~(OSC_RC32MCREF_bm | OSC_RC2MCREF_bm);
/* Enable the autocalibration of the internal 32 MHz RC oscillator */
DFLLRC32M.CTRL|=DFLL_ENABLE_bm;

/* Wait for the internal 32 MHz RC oscillator to stabilize */
while ((OSC.STATUS & OSC_RC32MRDY_bm)==0);

/* Select the system clock source: 32 MHz Internal RC Osc. */
n=(CLK.CTRL & ~(CLK_SCLKSEL_gm)) | CLK_SCLKSEL_RC32M_gc;
CCP=CCP_IOREG_gc;
CLK.CTRL=n;

/* Initialize timer TCC0 */
/* Clock source: ClkPer/1 */
TCC0.CTRLA=(TCC0.CTRLA & ~(TC0_CLKSEL_gm)) | TC_CLKSEL_DIV1_gc;

/* Mode: Normal Operation, Overflow Int./Event on TOP */
TCC0.CTRLB=(TCC0.CTRLB & ~(TC0_CCAEN_bm | TC0_CCBEN_bm | TC0_CCCEN_bm |
  TC0_CCDEN_bm | TC0_WGMODE_gm)) | TC_WGMODE_NORMAL_gc;

/* Capture event source: None
   Capture event action: None */
TCC0.CTRLD=(TCC0.CTRLD & ~(TC0_EVACT_gm | TC0_EVSEL_gm)) |
  TC_EVACT_OFF_gc | TC_EVSEL_OFF_gc;

/* Overflow interrupt: Low Level
   Error interrupt: Disabled */
TCC0.INTCTRLA=(TCC0.INTCTRLA & ~(TC0_ERRINTLVL_gm | TC0_OVFINTLVL_gm)) |
  TC_ERRINTLVL_OFF_gc | TC_OVFINTLVL_LO_gc;

/* Compare/Capture channel A interrupt: Disabled
   Compare/Capture channel B interrupt: Disabled
   Compare/Capture channel C interrupt: Disabled
   Compare/Capture channel D interrupt: Disabled */
TCC0.INTCTRLB=(TCC0.INTCTRLB & ~(TC0_CCDINTLVL_gm | TC0_CCCINTLVL_gm |
  TC0_CCBINTLVL_gm | TC0_CCAINTLVL_gm)) |
  TC_CCDINTLVL_OFF_gc | TC_CCCINTLVL_OFF_gc |
  TC_CCBINTLVL_OFF_gc | TC_CCAINTLVL_OFF_gc;

/* Clear the interrupt flags */
TCC0.INTFLAGS=TCC0.INTFLAGS;

/* Set period register for 10ms overflow @32MHz */
TCC0.PER=0x9C3F;
```

```
/* Interrupt system initialization in order to be able to sense /PENIRQ
   generated by the ADS7846, using TCC0 overflow interrupt */

/* Low level interrupt: On
   Round-robin scheduling for low level interrupt: Off
   Medium level interrupt: Off
   High level interrupt: Off
   The interrupt vectors will be placed at the start of the
   Application FLASH section */
n=(PMIC.CTRL & (~(PMIC_RREN_bm | PMIC_IVSEL_bm | PMIC_HILVLEN_bm |
   PMIC_MEDLVLEN_bm | PMIC_LOLVLEN_bm))) | PMIC_LOLVLEN_bm;
CCP=CCP_IOREG_gc;
PMIC.CTRL=n;
/* Set the default priority for round-robin scheduling */
PMIC.INTPRI=0x00;

/* Restore optimization for size if needed */
#pragma optsize_default

/* Initialize the LCD controller with the default values
   from glcd_ssd1289.h */

/* Specify the current font for displaying text */
glcd_init_data.font=font5x7;
/* No function is used for reading image data from external memory */
glcd_init_data.readxmem=NULL;
/* No function is used for writing image data to external memory */
glcd_init_data.writexmem=NULL;
/* Horizontal reverse for HY32D */
glcd_init_data.reverse_x=SSD1289_REVX_REV;
/* Normal display, no vertical reverse */
glcd_init_data.reverse_y=SSD1289_REVY_NORM;
/* Color bit writing order: BGR for HY32D ! */
glcd_init_data.cl_bits_order=SSD1289_CL_BITS_BGR;
/* Power control 1 BT0..BT2 step-up factor of the step-up circuit */
glcd_init_data.stepup_factor=SSD1289_DEFAULT_STEPUP_FACTOR;
/* Power control 1 DC0..DC3, DCT0..DCT3 step-up circuit cycle */
glcd_init_data.stepup_cycle=SSD1289_DEFAULT_STEPUP_CYCLE;
/* Power control 1 AP0..AP2 adjusts the amount of current
   from the constant current source in the
   internal op. amplifier circuit */
glcd_init_data.crt_source=SSD1289_DEFAULT_CRT_SOURCE;
/* Default value for VCIX2 voltage */
glcd_init_data.vcix2=SSD1289_DEFAULT_VCIX2;
/* Default value for VLCD63 voltage */
glcd_init_data.vlcd63=SSD1289_DEFAULT_VLCD63;
// Default value for VcomL alternating drive voltage
glcd_init_data.vcoml=SSD1289_DEFAULT_VCOML;
/* Default value for VcomH voltage */
glcd_init_data.vcomh=SSD1289_DEFAULT_VCOMH;
/* Frame frequency */
glcd_init_data.frame_freq=SSD1289_DEFAULT_FRAME_FREQ;
/* PKP00..PKP02 positive gamma micro adj. */
glcd_init_data.pkp00=SSD1289_DEFAULT_PKP00;
/* PKP10..PKP12 positive gamma micro adj. */
glcd_init_data.pkp10=SSD1289_DEFAULT_PKP10;
/* PKP20..PKP22 positive gamma micro adj. */
glcd_init_data.pkp20=SSD1289_DEFAULT_PKP20;
```

```
/* PKP30..PKP32 positive gamma micro adj. */
glcd_init_data.pkp30=SSD1289_DEFAULT_PKP30;
/* PKP40..PKP42 positive gamma micro adj. */
glcd_init_data.pkp40=SSD1289_DEFAULT_PKP40;
/* PKP50..PKP52 positive gamma micro adj. */
glcd_init_data.pkp50=SSD1289_DEFAULT_PKP50;
/* PRP00..PRP02 positive gamma gradient adj. */
glcd_init_data.prp00=SSD1289_DEFAULT_PRP00;
/* PRP10..PRP12 positive gamma gradient adj. */
glcd_init_data.prp10=SSD1289_DEFAULT_PRP10;
/* VRP00..VRP03 positive gamma amplification adj. */
glcd_init_data.vrp00=SSD1289_DEFAULT_VRP00;
/* VRP10..VRP14 positive gamma amplification adj. */
glcd_init_data.vrp10=SSD1289_DEFAULT_VRP10;
/* PKN00..PKN02 negative gamma micro adj. */
glcd_init_data.pkn00=SSD1289_DEFAULT_PKN00;
/* PKN10..PKN12 negative gamma micro adj. */
glcd_init_data.pkn10=SSD1289_DEFAULT_PKN10;
/* PKN20..PKN22 positive gamma micro adj. */
glcd_init_data.pkn20=SSD1289_DEFAULT_PKN20;
/* PKN30..PKN32 positive gamma micro adj. */
glcd_init_data.pkn30=SSD1289_DEFAULT_PKN30;
/* PKN40..PKN42 negative gamma micro adj. */
glcd_init_data.pkn40=SSD1289_DEFAULT_PKN40;
/* PKN50..PKN52 negative gamma micro adj. */
glcd_init_data.pkn50=SSD1289_DEFAULT_PKN50;
/* PRN00..PRN02 negative gamma gradient adj. */
glcd_init_data.prn00=SSD1289_DEFAULT_PRN00;
/* PRN10..PRN12 negative gamma gradient adj. */
glcd_init_data.prn10=SSD1289_DEFAULT_PRN10;
/* VRN00..VRN03 negative gamma amplification adj. */
glcd_init_data.vrn00=SSD1289_DEFAULT_VRN00;
/* VRN10..VRN14 negative gamma amplification adj. */
glcd_init_data.vrn10=SSD1289_DEFAULT_VRN10;

glcd_init(&glcd_init_data);

/* Initialize the ADS7846 resistive touch controller
in differential mode */
if (rt_init(RTOUCH_MODE_DIFFERENTIAL))
{
    glcd_outtextf("Touchscreen controller initialized OK");

    /* Globally enable interrupts in order to be able to sense /PENIRQ */
    #asm("sei")
}
else
{
    /* Globally enable interrupts in order to be able to sense /PENIRQ */
    #asm("sei")

    /* No valid touch controller calibration data found in EEPROM,
    so we need to calibrate it now */
    glcd_outtextf("Touch cross center to calibrate");
}
```

```
if (calibrate_touchscreen())
    glcd_outtextxyf(0,20,"Touchscreen controller calibrated OK");
else
{
    glcd_outtextxyf(0,20,"Touchscreen controller calibration\n"
                    "failed");

    /* Stop here */
    while (1);
}

delay_ms(2000);
glcd_clear();
glcd_outtextf("Touch the screen to draw...");

while (1)
{
    if (rt_getxy(&x,&y))
    {
        glcd_setpixel(x,y);
        delay_ms(10);
    }
}
```

short rt_readtemp(void)

Reads the temperature in °C using the ADS7846 controller.

Note:

- Due to the ADS7846 operating mode, the temperature measurement accuracy is only 2 °C.

unsigned short rt_readvbat(void)

Reads the battery voltage in mV on the **Vbat** input of the ADS7846 controller.

5.14 Capacitive Touchscreen Functions

The Capacitive Touchscreen Functions are intended for easy interfacing between C programs and graphic LCD and TFT modules that use the FocalTech Systems FT5206, FT5306 and FT5406 touchscreen controllers.

The prototypes for these functions are placed in the file **ft5x06.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

The communication between the touchscreen controller and the AVR chip is performed using the hardware **TWI**, so before using these functions, this interface must be properly configured for operation in *Master Mode*, as described in the **5.15 Two Wire Interface Functions for non-XMEGA Devices** and **5.16 Two Wire Interface Functions for XMEGA Devices** chapters.

The following connections must be performed for the touchscreen controller's signals:

- **SDA** signal must be connected to the AVR's TWI **SDA** signal. A 3.3k..10k pull-up resistor to +3.3V must be present on the SDA line.
- **SCL** signal must be connected to the AVR's TWI **SCL** signal. A 3.3k..10k pull-up resistor to +3.3V must be present on the SCL line.
- **/RES** signal must be connected to the corresponding **/RES (/RESET)** reset signal of the graphic display controller
- **/INT** signal must be connected to an I/O port input pin of the AVR chip that can sense a high to low transition and generate the corresponding **External Interrupt**
- **WAKE** signal must be connected to a logic high level. Alternatively, it can be connected to an I/O port output pin and set to low level by the user's program, forcing the controller to enter low power consumption mode.

The coordinate system employed by these functions has the origin (0,0) in the upper left corner of the display, with the x-coordinates increasing from left to right, and the y-coordinates increasing from top to bottom.

The following helper data types and variables are defined in the header file **ft5x06.h**:

```
/* Structure that holds the display screen coordinates
   of a touched point */
typedef struct
{
    unsigned short x;
    unsigned short y;
} CTPOINT_t;

/* Structure that holds the touched point data read from the controller */
typedef struct
{
    unsigned char touched_points:3; /* number of simultaneously touched points
                                     stored in the point buffer */
    unsigned char new_touch:1; /* signal that a new touch occurred
                                since the last read from the point buffer */
    CTPOINT_t point[5]; /* buffer with touched point display coordinates */
} CTSTATUS_t;

extern CTSTATUS_t ct_status;
```

Note: The FT5206, FT5306 and FT5406 controllers can detect up to 5 simultaneous touch points, the coordinates of which are stored in the **point** member of the **CTSTATUS_t** structure.

The number of detected points is stored in the **touched_points** member.

The following low level functions are available for interfacing with the capacitive touchscreen controller:

void ct_wrreg(unsigned char reg, unsigned char data)

Writes a byte of data to the capacitive controller register.

Parameters:

reg – controller's register where the data must be written

data – byte to be written.

The registers available for the FT5206, FT5306 and FT5406 controllers are defined in the **ft5x06.h** header file:

```
/* FT5X06 registers definitions for normal operating mode */
#define CT_DEVICE_MODE 0x00
#define CT_GEST_ID 0x01 /* Gesture ID */
#define CT_TD_STATUS 0x02 /* # of touch points */

#define CT_TOUCH1_XH 0x03 /* Bit[7]=1st event flag,
                          Bits[3:0]=1st touch X position [11:8] */
#define CT_TOUCH1_XL 0x04 /* 1st touch X position [7:0] */
#define CT_TOUCH1_YH 0x05 /* Bits[4:7]=1st touch ID [3:0],
                          Bits[3:0]=1st touch Y position [11:8] */
#define CT_TOUCH1_YL 0x06 /* 1st touch Y position [7:0] */

#define CT_TOUCH2_XH 0x09 /* Bit[7]=2nd event flag,
                          Bits[3:0]=2nd touch X position [11:8] */
#define CT_TOUCH2_XL 0x0A /* 2nd touch X position [7:0] */
#define CT_TOUCH2_YH 0x0B /* Bits[4:7]=2nd touch ID [3:0],
                          Bits[3:0]=2nd touch Y position [11:8] */
#define CT_TOUCH2_YL 0x0C /* 2nd touch Y position [7:0] */

#define CT_TOUCH3_XH 0x0F /* Bit[7]=3rd event flag,
                          Bits[3:0]=3rd touch X position [11:8] */
#define CT_TOUCH3_XL 0x10 /* 3rd touch X position [7:0] */
#define CT_TOUCH3_YH 0x11 /* Bits[4:7]=3rd touch ID [3:0],
                          Bits[3:0]=3rd touch Y position [11:8] */
#define CT_TOUCH3_YL 0x12 /* 3rd touch Y position [7:0] */

#define CT_TOUCH4_XH 0x15 /* Bit[7]=4th event flag,
                          Bits[3:0]=4th touch X position [11:8] */
#define CT_TOUCH4_XL 0x16 /* 4th touch X position [7:0] */
#define CT_TOUCH4_YH 0x17 /* Bits[4:7]=4th touch ID [3:0],
                          Bits[3:0]=4th touch Y position [11:8] */
#define CT_TOUCH4_YL 0x18 /* 4th touch Y position [7:0] */

#define CT_TOUCH5_XH 0x1B /* Bit[7]=5th event flag,
                          Bits[3:0]=5th touch X position [11:8] */
#define CT_TOUCH5_XL 0x1C /* 5th touch X position [7:0] */
#define CT_TOUCH5_YH 0x1D /* Bits[4:7]=5th touch ID [3:0],
                          Bits[3:0]=5th touch Y position [11:8] */
#define CT_TOUCH5_YL 0x1E /* 5th touch Y position [7:0] */

#define CT_ID_G_THGROUP 0x80 /* Valid touching detect threshold */
#define CT_ID_G_THPEAK 0x81 /* Valid touching peak detect threshold */
#define CT_ID_G_THCAL 0x82 /* Threshold when calculating the
                          focus of touching */
#define CT_ID_G_THWATER 0x83 /* Threshold when there's surface water */
```

CodeVisionAVR

```
#define CT_ID_G_THTEMP 0x84 /* Threshold of temperature compensation */
#define CT_ID_G_THDIFF 0x85 /* Threshold whether the coordinate is
                             different from the original */
#define CT_ID_G_CTRL 0x86 /* Power control mode [1:0] */
#define CT_ID_G_TIME_ENTER_MONITOR 0x87 /* Timer of entering monitor
                                         status */
#define CT_ID_G_PERIOD_ACTIVE 0x88 /* Active Period [3:0] */
#define CT_ID_G_PERIOD_MONITOR 0x89 /* Timer of entering idle while
                                     in monitor status */

#define CT_ID_G_AUTO_CLB_MODE 0xA0 /* Auto calibration mode */
#define CT_ID_G_LIB_VERSION_H 0xA1 /* Firmware version high byte */
#define CT_ID_G_LIB_VERSION_L 0xA2 /* Firmware version low byte */
#define CT_ID_G_CIPHER 0xA3 /* Chip vendor ID */
#define CT_ID_G_MODE 0xA4 /* Interrupt status to host */
#define CT_ID_G_PMODE 0xA5 /* Power consuming mode */
#define CT_ID_G_FIRMID 0xA6 /* Firmware ID */
#define CT_ID_G_STATE 0xA7 /* Running state */
#define CT_ID_G_FT5201ID 0xA8 /* CTPM Vendor ID */
#define CT_ID_G_ERR 0xA9 /* Error code */
#define CT_ID_G_CLB 0xAA /* Configure TP during calibration
                          in test mode */

#define CT_ID_G_B_AREA_TH 0xAE /* Threshold of large area */

#define CT_LOG_MSG_CNT 0xFE /* Log message count */
#define CT_LOG_CUR_CHA 0xFF /* Current character of log message.
                             After one char. is read, will point
                             to the next char. */
```

The touchscreen controller's registers are described in detail in its datasheet.

unsigned char ct_rdreg(unsigned char reg)

Reads a byte of data from the capacitive controller register.

Parameter:

reg – controller's register from which the data must be read.

Returns:

data byte read from **reg**.

void ct_inthandler(void)

Function to be called in the I/O port **External Interrupt Service Routine** when the capacitive touchscreen controller's **/INT** signal becomes active (high to low transition).

Example:

```
#include <io.h>
#include <glcd.h>
#include <ft5x06.h>

/* PORTC interrupt 0 service routine for an Atxmega128A1U chip */
interrupt [PORTC_INT0_vect] void portc_int0_isr(void)
{
    /* Process the touchscreen controller's /INT signal interrupt */
    ct_inthandler();
}
```


The following high level functions are available:

For non-XMEGA devices:

bool ct_init(void)

Initializes the capacitive touchscreen controller.

Returns: **true** on success.

For XMEGA devices:

bool ct_init(TWI_MASTER_INFO_t *twi_master)

Initializes the capacitive touchscreen controller.

Parameter:

twi_master - pointer to a structure that holds the information required by the TWI module used for communication with the touchscreen controller in master mode.

Returns: **true** on success.

Notes:

- The **ct_init** function must be called after the interrupt system, TWI and graphic display controllers were properly initialized.
- Interrupts must be globally enabled before calling the **ct_init** function.
- The FT5206, FT5306 and FT5406 touchscreen controllers come precalibrated along with the display, so further calibration by the user is not necessary.

Example for an ATmega2560 chip:

```
#include <io.h>
#include <iobits.h>
#include <glcd.h>
#include <ft5x06.h>

/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

/* Interrupt service routine called by the
   falling edge of the /INT signal connected
   to the INT4 external interrupt input (PORTE Pin 4) */
interrupt [EXT_INT4] void ext_int4_isr(void)
{
    /* Process the touchscreen controller's /INT signal interrupt */
    ct_inthandler();
}

void main(void)
{
    /* Initialization code for the graphic display controller */
    /* ... */

    /* Initialize the TWI in master mode */
    twi_master_init(TWI_CLK_RATE/1000);
}
```

```
/* Code to initialize the external interrupt INT4
   input used to detect the falling edge of the
   touchscreen controller's /INT signal */

/* Ensure PORTE Pin4 is an input */
CLRBIT(DDRE,4);

/* INT4 Mode: Falling Edge */
EICRB=(1<<ISC41) | (0<<ISC40);
EIMSK=(1<<INT4);
/* Clear the INT4 interrupt flag */
EIFR=(1<<INTF4);

/* Globally enable interrupts */
#asm("sei")

/* Initialize the capacitive touchscreen controller */
ct_init();

/* Follows the rest of the program */
/* ... */

}
```

Example for an ATxmega128A1U chip:

```
#include <io.h>
#include <iobits.h>
#include <glcd.h>
#include <ft5x06.h>

// TWI clock rate [bps]
#define TWI_CLK_RATE 100000

/* Structure that holds information used by the
   TWIC master peripheral for performing a TWI
   bus transaction */
TWI_MASTER_INFO_t twic_master;

/* Interrupt service routine for the TWIC peripheral
   operating in master mode */
interrupt [TWIC_TWIM_vect] void twic_master_isr(void)
{
    twi_master_int_handler(&twic_master);
}

/* PORTC Pin 2 interrupt 0 service routine */
interrupt [PORTC_INT0_vect] void portc_int0_isr(void)
{
    /* Process the touchscreen controller's /INT signal interrupt */
    ct_inthandler();
}
```

```
void main(void)
{
    unsigned char n;

    /* Initialization code for the graphic display controller */
    /* ... */

    /* General TWIC initialization:
       no external driver interface
       no SDA hold time */
    twi_init(&TWIC,false,false);

    /* Initialize the TWIC master
       Uses the Low priority level interrupt */
    twi_master_init(&twic_master,&TWIC,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* Code to initialize the I/O PORTC interrupt,
       used to detect the falling edge of the
       touchscreen controller's /INT signal,
       connected to Pin 2 */

    /* Set Pin 2 as input */
    CLRBIT(PORTC.DIR,2);
    /* Pin 2 Input/Sense configuration: Sense falling edge */
    PORTC.PIN2CTRL=PORT_ISC_FALLING_gc;
    /* Interrupt 0 level: Low
       Interrupt 1 level: Disabled */
    PORTC.INTCTRL=PORT_INT1LVL_OFF_gc | PORT_INT0LVL_LO_gc;
    /* Pin 2 Pin Change interrupt 0: On */
    PORTC.INT0MASK=(1<<2);

    /* Enable the Low priority level interrupt */
    n=PMIC_LOLVLEN_bm;
    CCP=CCP_IOREG_gc;
    PMIC.CTRL=n;

    /* Globally enable interrupts */
    #asm("sei")

    /* Initialize the capacitive touchscreen controller */
    ct_init(&twic_master);

    /* Follows the rest of the program */
    /* ... */
}
```

signed char ct_getxy(unsigned short *xd, unsigned short *yd)

Waits for the display screen to be touched and returns the coordinates of the first point.

Parameters:

xd – pointer to an unsigned short variable that will hold the horizontal display coordinate of the first touched point

yd – pointer to an unsigned short variable that will hold the vertical display coordinate of the first touched point.

Returns:

- a positive value representing the number of detected touched points: 1..5
- in case of error, the negative value **CT_RESULT_NO_INIT** (defined in the **ft5x06.h** header file), signaling that the function was called before the touchscreen controller was initialized, using the **ct_init** function.

Example for an ATxmega128A1U chip:

```
#include <io.h>
#include <iobits.h>
#include <stdio.h>
#include <glcd.h>
#include <ft5x06.h>

// TWI clock rate [bps]
#define TWI_CLK_RATE 100000

/* Structure that holds information used by the
   TWIC master peripheral for performing a TWI
   bus transaction */
TWI_MASTER_INFO_t twic_master;

/* Interrupt service routine for the TWIC peripheral
   operating in master mode */
interrupt [TWIC_TWIM_vect] void twic_master_isr(void)
{
    twi_master_int_handler(&twic_master);
}

/* PORTC Pin 2 interrupt 0 service routine */
interrupt [PORTC_INT0_vect] void portc_int0_isr(void)
{
    /* Process the touchscreen controller's /INT signal interrupt */
    ct_inthandler();
}

void main(void)
{
    signed char n;

    /* Display coordinates for the first touched point */
    unsigned short x,y;

    /* Display buffer */
    char display_buf[32];

    /* Initialization code for the graphic display controller */
    /* ... */

    /* General TWIC initialization:
       no external driver interface
       no SDA hold time */
    twi_init(&TWIC,false,false);

    /* Initialize the TWIC master
       Uses the Low priority level interrupt */
    twi_master_init(&twic_master,&TWIC,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));
```

```
/* Code to initialize the I/O PORTC interrupt,
   used to detect the falling edge of the
   touchscreen controller's /INT signal,
   connected to Pin 2 */

/* Set Pin 2 as input */
CLRBIT(PORTC.DIR,2);
/* Pin 2 Input/Sense configuration: Sense falling edge */
PORTC.PIN2CTRL=PORT_ISC_FALLING_gc;
/* Interrupt 0 level: Low
   Interrupt 1 level: Disabled */
PORTC.INTCTRL=PORT_INT1LVL_OFF_gc | PORT_INT0LVL_LO_gc;
/* Pin 2 Pin Change interrupt 0: On */
PORTC.INT0MASK=(1<<2);

/* Enable the Low priority level interrupt */
n=PMIC_LOLVLEN_bm;
CCP=CCP_IOREG_gc;
PMIC.CTRL=n;

/* Globally enable interrupts */
#asm("sei")

/* Initialize the capacitive touchscreen controller */
ct_init(&twic_master);

while (1)
{
    /* Wait for the display screen to be touched */
    n=ct_getxy(&x,&y);
    if (n>0)
    {
        /* Touched point(s) detected,
           clear the screen */
        glcd_clear();

        /* Display the # of touched points */
        sprintf(display_buf,"Touched point(s): %ld",n);
        glcd_outtextxy(0,0,display_buf);

        /* Display the coordinates of the first point */
        sprintf(display_buf,"Point 1, X=%3d, Y=%3d",x,y);
        glcd_outtextxy(0,10,display_buf);
    }
}
}
```

signed char ct_getxynw(unsigned short *xd, unsigned short *yd)

Checks, without waiting, if the display screen is touched and returns the coordinates of the first point.

Parameters:

xd – pointer to an unsigned short variable that will hold the horizontal display coordinate of the first touched point

yd – pointer to an unsigned short variable that will hold the vertical display coordinate of the first touched point.

Returns:

- the number of detected touched points: 0..5
- in case of error, the negative value **CT_RESULT_NO_INIT** (defined in the **ft5x06.h** header file), signaling that the function was called before the touchscreen controller was initialized, using the **ct_init** function.

signed char ct_getpoints(CTPOINT_t *points)

Waits for the display screen to be touched and returns the coordinates of all the touched points.

Parameters:

points – pointer to an array of **CTPOINT_t** types that will hold the horizontal display coordinate of the 5 touched points.

Returns:

- a positive value representing the number of detected touched points: 1..5
- in case of error, the negative value **CT_RESULT_NO_INIT** (defined in the **ft5x06.h** header file), signaling that the function was called before the touchscreen controller was initialized, using the **ct_init** function.

Example for an ATxmega128A1U chip:

```
#include <io.h>
#include <iobits.h>
#include <stdio.h>
#include <glcd.h>
#include <ft5x06.h>

// TWI clock rate [bps]
#define TWI_CLK_RATE 100000

/* Structure that holds information used by the
   TWIC master peripheral for performing a TWI
   bus transaction */
TWI_MASTER_INFO_t twic_master;

/* Interrupt service routine for the TWIC peripheral
   operating in master mode */
interrupt [TWIC_TWIM_vect] void twic_master_isr(void)
{
    twi_master_int_handler(&twic_master);
}
```

```
/* PORTC Pin 2 interrupt 0 service routine */
interrupt [PORTC_INT0_vect] void portc_int0_isr(void)
{
/* Process the touchscreen controller's /INT signal interrupt */
ct_inthandler();
}

void main(void)
{
signed char i,n;

/* Display buffer */
char display_buf[32];

/* Array that holds the display coordinates of the 5 touched points */
CTPOINT_t points[5];

/* Initialization code for the graphic display controller */
/* ... */

/* General TWIC initialization:
no external driver interface
no SDA hold time */
twi_init(&TWIC,false,false);

/* Initialize the TWIC master
Uses the Low priority level interrupt */
twi_master_init(&twic_master,&TWIC,TWI_MASTER_INTLVL_LO_gc,
TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

/* Code to initialize the I/O PORTC interrupt,
used to detect the falling edge of the
touchscreen controller's /INT signal,
connected to Pin 2 */

/* Set Pin 2 as input */
CLRBIT(PORTC.DIR,2);
/* Pin 2 Input/Sense configuration: Sense falling edge */
PORTC.PIN2CTRL=PORT_ISC_FALLING_gc;
/* Interrupt 0 level: Low
Interrupt 1 level: Disabled */
PORTC.INTCTRL=PORT_INT1LVL_OFF_gc | PORT_INT0LVL_LO_gc;
/* Pin 2 Pin Change interrupt 0: On */
PORTC.INT0MASK=(1<<2);

/* Enable the Low priority level interrupt */
n=PMIC_LOLVLEN_bm;
CCP=CCP_IOREG_gc;
PMIC.CTRL=n;

/* Globally enable interrupts */
asm("sei")
```

```
/* Initialize the capacitive touchscreen controller */
ct_init(&twic_master);

while (1)
{
    /* Wait for the display screen to be touched */
    n=ct_getpoints(points);
    if (n>0)
    {
        /* Touched point(s) detected,
           clear the screen */
        glcd_clear();

        /* Display the # of touched points */
        sprintf(display_buf, "Touched point(s): %ld", n);
        glcd_outtextxy(0,0,display_buf);

        /* Display each point's coordinates */
        for (i=0; i<n; i++)
        {
            sprintf(display_buf, "Point %ld, X=%3d, Y=%3d",
                    i, points[i].x, points[i].y);
            glcd_outtextxy(0,10+i*10,display_buf);
        }
    }
}
```

signed char ct_getpointsnw(CTPOINT_t *points)

Checks, without waiting, if the display screen is touched and returns the coordinates of all the touched points.

Parameters:

points – pointer to an array of **CTPOINT_t** types that will hold the horizontal display coordinate of the 5 touched points.

Returns:

- the number of detected touched points: 0..5
- in case of error, the negative value **CT_RESULT_NO_INIT** (defined in the **ft5x06.h** header file), signaling that the function was called before the touchscreen controller was initialized, using the **ct_init** function.

A fully functional code example for the FT5206 chip is provided in the **\Examples\Graphic Displays\Capacitive Touchscreen\FT5206** directory of the CodeVisionAVR installation.

5.15 1 Wire Protocol Functions

The 1 Wire Functions are intended for easy interfacing between C programs and various peripherals using the Maxim 1 Wire protocol.

These functions treat the microcontroller as a bus master and the peripherals as slaves.

The prototypes for these functions are placed in the file **1wire.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the functions.

The 1 Wire functions must be configured, by specifying the I/O port and bit used for communication through the 1 Wire protocol.

This is accomplished in the **Project|Configure|C Compiler|Libraries|1 Wire** menu:

- the **Enable 1 Wire Bus Interface Support** option must be activated
- the **I/O Port** and **Bit** must be specified in **Data Connection**.

Note: For compatibility with projects developed with CodeVisionAVR prior to V2.04.7, the 1 Wire functions can also be configured as outlined in the example below.

However in this case, the **Enable 1 Wire Bus Interface Support** option must be disabled in the **Project|Configure|C Compiler|Libraries|1 Wire** menu.

Example:

```
/* the 1 Wire bus is connected to ATmega8515 PORTB
   the data signal is bit 2 */
#asm
    .equ __w1_port=0x18
    .equ __w1_bit=2
#endasm

/* now you can include the 1 Wire Functions */
#include <1wire.h>
```

This method is not recommended for new projects and it also does not support the XMEGA chips.

Because the 1 Wire Functions require precision time delays for correct operation, the interrupts must be disabled during their execution.

Also it is very important to specify the correct AVR chip **Clock** frequency in the **Project|Configure|C Compiler|Code Generation** menu.

The 1 Wire Functions are:

unsigned char w1_init(void)

this function initializes the 1 Wire devices on the bus.
It returns 1 if there were devices present or 0 if not.

unsigned char w1_read(void)

this function reads a byte from the 1 Wire bus.

unsigned char w1_write(unsigned char data)

this function writes the byte **data** to the 1 Wire bus.
It returns 1 if the write process completed normally or 0 if not.

unsigned char w1_search(unsigned char cmd,void *p)

this function returns the number of devices connected to the 1 Wire bus.
If no devices were detected then it returns 0.
The byte **cmd** represents the Search ROM (F0h), Alarm Search (ECh) for the DS1820/DS18S20, or other similar commands, sent to the 1 Wire device.

The pointer **p** points to an area of RAM where are stored the 8 bytes ROM codes returned by the device. After the eighth byte, the function places a ninth status byte which contains a status bit returned by some 1 Wire devices (e.g. DS2405).

Thus the user must allocate 9 bytes of RAM for each device present on the 1 Wire bus.
If there is more than one device connected to the 1 Wire bus, than the user must first call the **w1_search** function to identify the ROM codes of the devices and to be able to address them at a later stage in the program.

Example:

```
#include <mega8515.h>

/* the ATmega8515 port and bit used for the 1 Wire bus must be specified in
   the Project|Configure|C Compiler|Libraries 1 Wire menu */

/* include the 1 Wire bus functions prototypes */
#include <1wire.h>

/* include the printf function prototype */
#include <stdio.h>

/* specify the maximum number of devices connected
   to the 1 Wire bus */
#define MAX_DEVICES 8

/* allocate RAM space for the ROM codes & status bit */
unsigned char rom_codes[MAX_DEVICES][9];

/* quartz crystal frequency [Hz] */
#define xtal 4000000L

/* Baud rate */
#define baud 9600

void main(void) {
    unsigned char i,j,devices;

    /* initialize the USART control register
       TX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x08;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/ baud-1) >> 8;
    UBRL=(xtal/16/ baud-1) & 0xFF;

    /* detect how many DS1820/DS18S20 devices
       are connected to the bus and
       store their ROM codes in the rom_codes array */
    devices=w1_search(0xf0,rom_codes);
```

```
/* display the ROM codes for each detected device */
printf("%-u DEVICE(S) DETECTED\n\r", devices);
if (devices) {
    for (i=0; i<devices; i++) {
        printf("DEVICE #%-u ROM CODE IS:", i+1);
        for (j=0; j<8; j++) printf("%-X ", rom_codes[i][j]);
        printf("\n\r");
    };
};
while (1); /* loop forever */
}
```

unsigned char w1_dow_crc8(void *p, unsigned char n)

this function checks the 8 bit DOW CRC for a block of bytes with the length **n**, pointed by **p**. It returns **0** if the DOW CRC of the first **n-1** bytes from the block equals the value of the **n**-th byte, or **1** if it doesn't.

5.16 Two Wire Interface Functions for non-XMEGA Devices

The **TWI Functions for non-XMEGA Devices** are intended for easy interfacing between C programs and various external peripherals using the I²C bus.

These functions can operate the AVR microcontroller as bus master or slave.

The function prototypes, along with helper variable and macro definitions, are placed in the header file **twi.h**, located in the .INC subdirectory.

This file must be **#include -d** before using the TWI functions.

Notes:

- The **twi.h** header file automatically includes the **io.h** header file that contains the I/O modules definitions for the AVR device selected in the project configuration.
- These functions operate using interrupts, so the **interrupts must be globally enabled** using the **#asm("sei")** inline assembly code before attempting any communication through the I²C bus.
- **For proper operation, the TWI Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V on the SCL and SDA signals.**

5.16.1 Two Wire Interface Functions for Master Mode Operation

The following functions are used for operating the TWI in master mode:

void twi_master_init(unsigned int bit_rate)

enables and initializes the TWI hardware for operating in master mode.

Parameters:

bit_rate specifies the SCL clock frequency in kHz.

**bool twi_master_trans(
 unsigned char slave_addr,
 unsigned char *tx_data,
 unsigned char tx_count,
 unsigned char *rx_data,
 unsigned char rx_count)**

performs a TWI transaction using the master module.

Parameters:

slave_addr specifies the 7 bit bus address of the slave with which the transaction should be performed.

tx_data represents a pointer to the buffer that holds the data that must be transmitted to the slave during the transaction.

tx_count specifies the number of bytes to transmit during the transaction. If no data must be transmitted to the slave, the **tx_data** parameter should be a NULL pointer and **tx_count** must be 0.

rx_data represents a pointer to the buffer that will hold the data received from the slave during the transaction.

rx_count specifies the number of bytes to be received from the slave during the transaction. If no data must be received from the slave, the **rx_data** parameter should be a NULL pointer and **rx_count** must be 0.

Return values:

true on success

false in case of error.

The nature of the error can be established by reading the value of the **twi_result** global variable, which can take the values defined in the following macros:

```
#define TWI_RES_OK 0
#define TWI_RES_BUFFER_OVERFLOW 1
#define TWI_RES_ARBITRATION_LOST 2
#define TWI_RES_BUS_ERROR 3
#define TWI_RES_NACK_RECEIVED 4
#define TWI_RES_BUS_TIMEOUT 5
#define TWI_RES_FAIL 6
#define TWI_RES_UNKNOWN 7
```

Note: Operating the TWI in master mode requires the interrupts to be globally enabled. This must be done by using the `#asm("sei")` inline assembly code, before attempting any communication through the I²C bus.

TWI master operation example:

```
/* accessing an external AT24C16B EEPROM using the
   TWI running in master mode */

/* TWI functions */
#include <twi.h>

/* delay functions */
#include <delay.h>

/* 7 bit TWI bus slave address of the AT24C16B 2kbyte EEPROM */
#define EEPROM_TWI_BUS_ADDRESS (0xA0 >> 1)

void main(void)
{
    struct
    {
        struct
        {
            unsigned char msb;
            unsigned char lsb;
        } addr;
        unsigned char data;
    } twi_eeprom;

    unsigned char eeprom_rd_data;

    /* the TWI master for SCL bit rate of 100 kHz */
    twi_master_init(100);

    /* globally enable interrupts */
    #asm("sei")

    /* write the byte 0x55 to the AT24C16B EEPROM address 0x210 */
    twi_eeprom.addr.msb=0x02;
    twi_eeprom.addr.lsb=0x10;
    twi_eeprom.data=0x55;
    twi_master_trans(EEPROM_TWI_BUS_ADDRESS, (unsigned char *)
    &twi_eeprom, 3, 0, 0);

    /* 10ms delay to complete the write operation */
    delay_ms(10);
}
```

```
/* read the byte back into the eeprom_rd_data variable */
twi_master_trans(EEPROM_TWI_BUS_ADDRESS, (unsigned char *)
&twi_eeprom, 2, &eeprom_rd_data, 1);

/* stop here */
while (1);
}
```

5.16.2 Two Wire Interface Functions for Slave Mode Operation

The following function is used for operating the TWI in slave mode:

```
void twi_slave_init(
    bool match_any_addr,
    unsigned char addr,
    unsigned char *rx_buffer,
    unsigned char rx_buffer_size,
    unsigned char *tx_buffer,
    bool (*slave_rx_handler) (bool rx_complete),
    unsigned char (*slave_tx_handler) (bool tx_complete));
```

enables and initializes the TWI hardware for operating in slave mode.

Parameters:

match_any_addr enables the TWI slave to respond to any slave address supplied by the master when starting a transaction.

addr represents the 7 bit slave address to which the slave will respond if the **match_any_addr** parameter is **false**.

rx_buffer represents a pointer to the buffer that will hold the data received by the slave during the transaction.

rx_buffer_size represents the size of the receive buffer, specified in bytes.

tx_buffer represents a pointer to the buffer that holds the data to be transmitted by the slave to the master during the transaction.

slave_rx_handler represents a pointer to the TWI slave receive processing function.

This function is called each time a byte is received from the master.

It can handle the received data from the receive buffer using the value from the **twi_rx_index** global variable.

The TWI interrupt service routine embedded in **twi.lib**, when calling this function, will pass the **rx_complete** argument as **true** when the master transmission to the slave has finished.

If the slave wishes to terminate the reception of bytes from the slave, the function pointed by the **slave_rx_handler** must return the value **false** when it is called.

If the slave can accept more data bytes from the master, this function should return the value **true**.

slave_tx_handler represents a pointer to the TWI slave transmission processing function.

This function is called twice by the TWI interrupt service routine embedded in **twi.lib**.

On its first call, when the master is ready to receive the data transmitted by the slave, this function is called with the **tx_complete** parameter set as **false** and should return the number of bytes from the transmit buffer that must be transmitted to the master during the ongoing transaction.

After the master has finished receiving the data bytes transmitted by the slave, this function is called for the second time with the **tx_complete** parameter set as **true**, signaling that the transaction on the bus has finished.

In this case the function should return the value 0, as there are no more bytes to be transmitted from the slave to the master.

After the transaction has finished, the **twi_tx_index** global variable will be the index of the last byte in the transmission buffer, that was transmitted by the slave to the master.

After a transaction between the master and the slave has finished, its status can be read from the `twi_result` global variable, which may take one of the values specified by these macros defined in the `twi.h` header file:

```
#define TWI_RES_OK 0
#define TWI_RES_BUFFER_OVERFLOW 1
#define TWI_RES_BUS_ERROR 3
#define TWI_RES_NACK_RECEIVED 4
#define TWI_RES_UNKNOWN 7
```

Note: Operating the TWI in slave mode requires the interrupts to be globally enabled. This must be done by using the `#asm("sei")` inline assembly code, before attempting any communication through the I²C bus.

TWI slave operation example:

```
/* The slave will receive the bytes sent by the master and
   will display them on the LCD in ASCII form.
   After a packet of bytes has been received, the slave
   will transmit the char string "Data packet received OK\n\r"
   back to the master.

   The LCD connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */

#include <io.h>
#include <stdio.h>
#include <twi.h>
#include <delay.h>
#include <alcd.h>
#include <string.h>

/* 7 bit slave I2C address */
#define TWI_SLAVE_ADDR 0x50

/* slave receive buffer */
char rx_buffer[32];

/* slave transmission buffer */
char tx_buffer[32];

/* flag that signals that the TWI slave reception was OK */
bit received_ok=false;

/* status messages */
flash char * flash_status_msg[8]=
{
    "OK",
    "Buffer overflow",
    "Arbitration lost",
    "Bus error",
    "NACK received",
    "Bus timeout",
    "Fail",
    "Unknown error"
};
```

```
bool slave_rx_handler(bool rx_complete)
{
    if (twi_result==TWI_RES_OK)
        received_ok=true; /* signal that data was received without errors */
    else
    {
        /* TWI receive error, display the twi_result value on the LCD */
        lcd_clear();
        lcd_putsf("Receive error:\n");
        lcd_putsf(status_msg[twi_result]);
        received_ok=false; /* signal that data was received with errors */
        return false; /* stop reception */
    }

    if (rx_complete)
        /* the TWI master has finished transmitting data */
        return false; /* no more bytes to receive */

    /* signal to the TWI master that the TWI slave is ready
       to accept more data as long as there is space in the
       receive buffer */
    return (twi_rx_index<sizeof(rx_buffer));
}

unsigned char slave_tx_handler(bool tx_complete)
{
    unsigned char i;
    if (tx_complete==false)
    {
        /* transmission from slave to master is about to start
           copy the text to transmit to the TWI master in the
           transmission buffer */
        strcpyf(tx_buffer,"Data packet received OK\n\nr");

        /* # of bytes to transmit from the TWI slave to the TWI master */
        return strlen(tx_buffer);
    }

    /* transmission from slave to master has already started,
       no more bytes to send in this transaction */
    if (received_ok)
    {
        /* no TWI receive error, display the received data on the LCD */
        lcd_clear();
        for (i=0;i<twi_rx_index;i++) lcd_putchar(rx_buffer[i]);
    }
    return 0;
}

void main(void)
{
    /* initialize the LCD */
    lcd_init(16);
    lcd_clear();
}
```



```
/* initialize the TWI slave */
twi_slave_init(false,TWI_SLAVE_ADDR,rx_buffer,sizeof(rx_buffer),
tx_buffer,slave_rx_handler,slave_tx_handler);

lcd_putsf("TWI slave OK");
delay_ms(2000);

/* enable interrupts to start TWI communication */
#asm("sei")

/* all processing is performed by TWI interrupts inside twi.lib */
while (1);
}
```

5.17 Two Wire Interface Functions for XMEGA Devices

The **TWI Functions for XMEGA Devices** are intended for easy interfacing between C programs and various external peripherals using the I²C bus and SMBus.

These functions can operate the XMEGA AVR microcontroller as both bus master and slave.

The function prototypes, along with helper structure and macro definitions, are placed in the header file **twix.h**, located in the .\INC subdirectory.

This file must be **#include -d** before using the TWI functions.

Notes:

- The **twix.h** header file automatically includes the **io.h** header file that contains the I/O modules definitions for the XMEGA device selected in the project configuration.
- The **TWI Functions for XMEGA Devices** operate using interrupts, so the interrupt priority level(s) used by them must be activated. Interrupts must be also globally enabled using the **#asm("sei")** inline assembly code.
- **For proper operation, the TWI Functions require the presence of 3.3k - 4.7k pull-up resistors to +3.3V on the SCL and SDA signals.**

General initialization of the TWI module associated with an XMEGA I/O port is performed by the

void twi_init(TWI_t *module, bool ext_driver_intf, unsigned char sda_hold)

function.

Parameters:

module represents a pointer to the TWI module associated with the I/O port.

ext_driver enables the external driver interface. In this situation, the internal TWI drivers with input filtering and slew rate control are bypassed and I/O pin direction must be configured by the user software.

sda_hold enables an internal hold time on the SDA signal with respect to the negative edge of SCL.

For XMEGA AU chips **sda_hold** can take one of the following predefined values:

TWI_SDAHOLD_OFF_gc	- SDA Hold Time off
TWI_SDAHOLD_50NS_gc	- SDA Hold Time 50 ns
TWI_SDAHOLD_300NS_gc	- SDA Hold Time 300 ns
TWI_SDAHOLD_400NS_gc	- SDA Hold Time 400 ns.

For the rest of XMEGA chips **sda_hold** can take one of the following values:

0	- SDA Hold Time off
TWI_SDAHOLD_bm	- SDA Hold Time on.

5.17.1 Two Wire Interface Functions for Master Mode Operation

The following structure data type is defined in the **twix.h** header file for operating the XMEGA TWI in master mode:

```
typedef struct
{
    TWI_t *module;           /* pointer to the used TWI interface module */
    unsigned char slave_address; /* I2C slave address */
    unsigned char *tx_buffer;  /* pointer to the transmit buffer */
    unsigned char bytes_to_tx; /* number of bytes to transmit to the slave */
    unsigned char tx_counter;  /* number of transmitted bytes */
    unsigned char *rx_buffer;  /* pointer to receive buffer */
    unsigned char bytes_to_rx; /* number of bytes to receive from the slave */
    unsigned char rx_counter;  /* number of received bytes */
    unsigned char result;      /* transaction result */
} TWI_MASTER_INFO_t;
```

The **TWI_MASTER_INFO_t** data type is used for declaring the structure variables, used to hold the information required by each TWI module when operating in master mode. These structure variables are updated automatically by the TWI functions during bus transactions.

The result of a TWI master transaction is returned in the **result** member of the **TWI_MASTER_INFO_t** structure data type, which may take the values defined by the following macros from **twix.h**:

```
#define TWIM_RES_UNKNOWN 0
#define TWIM_RES_OK 1
#define TWIM_RES_BUFFER_OVERFLOW 2
#define TWIM_RES_ARBITRATION_LOST 3
#define TWIM_RES_BUS_ERROR 4
#define TWIM_RES_NACK_RECEIVED 5
#define TWIM_RES_FAIL 6
```

The macro:

TWI_BAUD_REG(SYS_CLK, TWI_CLK_RATE)

is used for calculating the value of the TWI **MASTER.BAUD** register for the desired TWI clock rate **TWI_CLK_RATE**, expressed in Hz, based on the System Clock **SYS_CLK** value, expressed in Hz.

The following functions are used for operating the TWI in master mode:

```
void twi_master_init(
    TWI_MASTER_INFO_t *twi,
    TWI_t *module,
    TWI_MASTER_INTLVL_t int_level,
    unsigned char baud_reg)
```

enables and initializes a TWI module for operating in master mode.

Parameters:

twi represents a pointer to the **TWI_MASTER_INFO_t** data type variable, that will be used to hold all the required information for operating in master mode, for a particular TWI module.

module represents a pointer to the TWI module, associated with an XMEGA I/O port, that will be enabled and initialized for operation in master mode.

int_level specifies the interrupt priority level used by the TWI module when operating in master mode.

baud_reg specifies the value used for initializing the TWI module's **MASTER.BAUD** register. Usually the value of this parameter is calculated using the **TWI_BAUD_REG** macro.

void twi_master_int_handler(TWI_MASTER_INFO_t *twi)

represents the interrupt handler used for processing the interrupts generated by a TWI module operating in master mode.

Parameters:

twi represents a pointer to the **TWI_MASTER_INFO_t** data type variable, that is used to hold all the required information for master operation of a particular TWI module associated with an I/O port. The **TWI_MASTER_INFO_t** data type variable must have been first initialized by a call to **twi_master_init**.

The **twi_master_int_handler** function must be called inside the interrupt service routine associated with the master interrupt of a particular TWI module.

**bool twi_master_trans(
TWI_MASTER_INFO_t *twi,
unsigned char slave_addr,
unsigned char *tx_data,
unsigned char tx_count,
unsigned char *rx_data,
unsigned char rx_count)**

performs a TWI transaction using the master module.

Parameters:

twi represents a pointer to the **TWI_MASTER_INFO_t** data type variable, that is used to hold all the required information for master operation of a particular TWI module associated with an I/O port. The **TWI_MASTER_INFO_t** data type variable must have been first initialized by a call to **twi_master_init**.

slave_addr specifies the 7 bit bus address of the slave with which the transaction should be performed.

tx_data represents a pointer to the buffer that holds the data that must be transmitted to the slave during the transaction.

tx_count specifies the number of bytes to transmit during the transaction. If no data must be transmitted to the slave, the **tx_data** parameter should be a NULL pointer and **tx_count** must be 0.

rx_data represents a pointer to the buffer that will hold the data received from the slave during the transaction.

rx_count specifies the number of bytes to be received from the slave during the transaction. If no data must be received from the slave, the **rx_data** parameter should be a NULL pointer and **rx_count** must be 0.

Return values:

true on success

false in case of error.

The nature of the error can be established by reading the value of the **result** member of the **TWI_MASTER_INFO_t** structure data type variable pointed by **twi**.

TWI master operation example:

```
/* accessing an external AT24C16B EEPROM using the
   TWID module running in master mode */

/* TWI functions for XMEGA devices */
#include <twix.h>

/* delay functions */
#include <delay.h>

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000

/* 7 bit TWI bus slave address of the AT24C16B 2kbyte EEPROM */
#define EEPROM_TWI_BUS_ADDRESS (0xA0 >> 1)

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

void main(void)
{
    struct
    {
        struct
        {
            unsigned char msb;
            unsigned char lsb;
        } addr;
        unsigned char data;
    } twi_eeprom;

    unsigned char eeprom_rd_data;

    /* general TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* enable the Low interrupt level */
    PMIC.CTRL|=PMIC_LOLVLEN_bm;

    /* globally enable interrupts */
    #asm("sei")
}
```

```
/* write the byte 0x55 to the AT24C16B EEPROM address 0x210 */
twi_eeprom.addr.msb=0x02;
twi_eeprom.addr.lsb=0x10;
twi_eeprom.data=0x55;
twi_master_trans(&twid_master,EEPROM_TWI_BUS_ADDRESS,(unsigned char *)
&twi_eeprom,3,0,0);

/* 10ms delay to complete the write operation */
delay_ms(10);

/* read the byte back into the eeprom_rd_data variable */
twi_master_trans(&twid_master,EEPROM_TWI_BUS_ADDRESS,(unsigned char *)
&twi_eeprom,2,&eeprom_rd_data,1);

/* stop here */
while (1);
}
```

5.17.2 Two Wire Interface Functions for Slave Mode Operation

The following structure data type is defined in the **twix.h** header file for operating the XMEGA TWI in slave mode:

```
typedef struct
{
    TWI_t *module;           /* pointer to the used TWI interface module */
    unsigned char *rx_buffer; /* pointer to receive buffer */
    unsigned char rx_buffer_size; /* receive buffer size */
    unsigned char rx_index; /* index in the receive buffer of the last received byte */
    unsigned char *tx_buffer; /* pointer to transmit buffer */
    unsigned char tx_index; /* index in the transmit buffer of the last transmitted byte */
    unsigned char bytes_to_tx; /* number of bytes to transmit to the master */
    void (*twi_trans)(void); /* pointer to TWI slave transaction processing function */
    unsigned result; /* transaction result */
} TWI_SLAVE_INFO_t;
```

The **TWI_SLAVE_INFO_t** data type is used for declaring the structure variables used to hold the information required by each TWI module when operating in slave mode.

These structure variables are updated automatically by the TWI functions during bus transactions.

The result of a TWI slave transaction is returned in the **result** member of the **TWI_SLAVE_INFO_t** structure data type, which may take the values defined by the following macros from **twix.h**:

```
#define TWIS_RES_UNKNOWN 0
#define TWIS_RES_OK 1
#define TWIS_RES_ADDR_MATCH 2
#define TWIS_RES_BUFFER_OVERFLOW 3
#define TWIS_RES_TRANSMIT_COLLISION 4
#define TWIS_RES_BUS_ERROR 5
#define TWIS_RES_FAIL 6
#define TWIS_RES_HALT 7
```

The following functions are used for operating the TWI in slave mode:

```
void twi_slave_init(
    TWI_SLAVE_INFO_t *twi,
    TWI_t *module,
    TWI_SLAVE_INTLVL_t int_level,
    bool match_any_addr,
    unsigned char addr,
    unsigned char addr_mask_reg,
    unsigned char *rx_buffer,
    unsigned char rx_buffer_size,
    unsigned char *tx_buffer,
    void (*twi_slave_trans)(void));
```

enables and initializes the TWI module for operating in slave mode.

Parameters:

twi represents a pointer to the **TWI_SLAVE_INFO_t** data type variable, that will be used to hold all the required information for operating in slave mode, for a particular TWI module.

module represents a pointer to the TWI module, associated with an XMEGA I/O port, that will be enabled and initialized for operation in slave mode.

int_level specifies the interrupt priority level used by the TWI module when operating in slave mode.

match_any_addr enables the TWI slave to respond to any slave address supplied by the master when starting a transaction.

addr represents the 7 bit slave address to which the slave will respond if the **match_any_addr** parameter is **false**.

addr_mask_reg specifies the value used to initialize the TWI module's **SLAVE.ADDRMASK** register. If bit 0 of **addr_mask_reg** is 0, then bits 1 to 7 will represent the 7 bit slave address bit mask, otherwise these bits will represent a second 7 bit slave address to which the slave will respond. When address mask mode is used, if a bit in the address mask is set to 1, the address match between the incoming address bit and the corresponding bit from the slave address is ignored, i.e. masked bits will always match.

rx_buffer represents a pointer to the buffer that will hold the data received by the slave during the transaction.

rx_buffer_size represents the size of the receive buffer, specified in bytes.

tx_buffer represents a pointer to the buffer that holds the data to be transmitted by the slave to the master during the transaction.

twi_slave_trans represents a pointer to the TWI slave transaction processing function.

This function is called each time a byte is received from the master.

It will handle the received data from the receive buffer using the value from the **rx_index** member of **TWI_SLAVE_INFO_t**.

Also on its first call, when a transaction was started, it must initialize the **bytes_to_tx** member to the number of bytes from the transmit buffer that must be send to the master during the ongoing transaction.

After the current transaction is finished, **bytes_to_tx** will be automatically reset to 0, along with **rx_index**, by the *TWI slave interrupt handler*, so it can be ready to be initialized when the next transaction will start.

void twi_slave_int_handler(TWI_SLAVE_INFO_t *twi)

represents the interrupt handler used for processing the interrupts generated by a TWI module operating in master mode.

Parameters:

twi represents a pointer to the **TWI_SLAVE_INFO_t** data type variable, that is used to hold all the required information for slave operation of a particular TWI module associated with an I/O port. The **TWI_SLAVE_INFO_t** data type variable must have been first initialized by a call to **twi_slave_init**.

The **twi_slave_int_handler** function must be called inside the interrupt service routine associated with the slave interrupt of a particular TWI module.

void twi_slave_halt_trans(TWI_SLAVE_INFO_t *twi)

is used by the slave to halt a TWI transaction.
Usually this function must be called from within the TWI slave transaction processing function specified by the **twi_slave_trans** parameter of **twi_slave_init**.

Parameters:

twi represents a pointer to the **TWI_SLAVE_INFO_t** data type variable, that is used to hold all the required information for slave operation of a particular TWI module associated with an I/O port.

TWI master and slave operation example:

```
/*
Sample program to test the XMEGA TWIC master and
TWID slave operation.

If one or several switches SW0..SW7 are pressed
on the STK600 board, their state is transmitted
by the TWIC master to the TWID slave, which
displays the received data on the LED0..LED7.
The slave sends to the master the contents of the
test_data array.

Use a STK600 development board with STK600-TQFP100 and
STK600-RC100X-13 addapters

The STK600 programmer must be set in JTAG programming mode
in the Tools|Programmer menu.

Make sure that the VTARGET and VREF voltages are set to 3.6V
using AVR Studio.
The VTARGET LED on the STK600 board must be lighted.

Make the following connections on the STK600:

PC0 - PD0 SDA pin - 4.7K resistor to VTG
PC1 - PD1 SCL pin - 4.7K resistor to VTG
SW0..SW7 - PE0..PE7 using a ribbon cable with 10 pin connectors
LED0..LED7 - PA0..PA7 using a ribbon cable with 10 pin connectors.
*/

/* TWI functions for XMEGA devices */
#include <twix.h>

/* string functions */
#include <string.h>

/* delay functions */
#include <delay.h>

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000

/* 7 bit TWI slave address */
#define SLAVE_ADDR 0x5A
```

```
/* structure that holds information used by the TWIC master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twi_master;

/* TWIC master interrupt service routine */
interrupt [TWIC_TWIM_vect] void twic_master_isr(void)
{
    twi_master_int_handler(&twi_master);
}

/* TWID slave receive and transmit buffers */
unsigned char twi_slave_rx_buffer[16];
/* data to be transmitted to the master */
unsigned char test_data[]="TWI test";

/* structure that holds information used by the TWID slave
   for performing a TWI bus transaction */
TWI_SLAVE_INFO_t twi_slave;

/* TWID slave interrupt service routine */
interrupt [TWID_TWIS_vect] void twid_slave_isr(void)
{
    twi_slave_int_handler(&twi_slave);
}

/* TWID slave transaction processing function */
void twi_slave_trans(void)
{
    /* read the received data from the buffer and
       output it to the LEDs on PORTA */
    PORTA.OUT=twi_slave.rx_buffer[twi_slave.rx_index];

    /* prepare to transmit the contents of the
       test_data array to the master,
       initialize the number of bytes to transmit
       only once at the beginning of the transmission */
    if (twi_slave.bytes_to_tx==0) twi_slave.bytes_to_tx=sizeof(test_data);

    /* if needed, the function:

       twi_slave_halt(&twi_slave);

       can be called here in order to halt
       the transaction by the slave */
}

void main(void)
{
    unsigned char switches;
    /* received data from the slave */
    unsigned char rx_data[sizeof(test_data)];

    /* initialize PORTA as inverted outputs, used for driving LEDs */
    PORTA.OUT=0x00; /* all LEDs are initially off */
    PORTA.DIR=0xFF;
```

```
PORTA.PIN0CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN1CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN2CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN3CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN4CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN5CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN6CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;
PORTA.PIN7CTRL=PORT_INVEN_bm | PORT_OPC_TOTEM_gc;

/* initialize PORTE as inputs used for reading switches
   pullup resistors are already present on the STK600 board */
PORTE.DIR=0x00;

/* general TWIC initialization
   no external driver interface
   no SDA hold time */
twi_init(&TWIC,false,false);

/* initialize the TWIC master
   use low priority level interrupt */
twi_master_init(&twi_master,&TWIC,TWI_MASTER_INTLVL_LO_gc,
    TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

/* general TWID initialization
   no external driver interface
   no SDA hold time */
twi_init(&TWID,false,false);

/* initialize the TWID slave
   use low priority level interrupt */
twi_slave_init(&twi_slave,&TWID,TWI_SLAVE_INTLVL_LO_gc,
    false,SLAVE_ADDR,0,
    twi_slave_rx_buffer,sizeof(twi_slave_rx_buffer),
    test_data,twi_slave_trans);

/* enable low interrupt level interrupts */
PMIC.CTRL|=PMIC_LOLVLEN_bm;

/* globally enable interrupts */
#asm("sei")

while (1)
{
    /* read the SW0..7 switches
       the switches value is inverted because
       the connection is established to GND
       when a switch is pressed */
    switches= ~PORTE.IN;

    /* check if at least one switch was pressed */
    if (switches)
    {
        /* yes, transmit the switches state to the slave
           and receive the contents of the test_data array
           sent by the slave in rx_data */
        twi_master_trans(&twi_master,SLAVE_ADDR,
            &switches,sizeof(switches),
            rx_data,sizeof(rx_data));
    }
}
```

```
/* check that correct data was received from the slave */
if (strncmp(rx_data,test_data,sizeof(test_data)))
/* if rx_data doesn't match test_data... */
while (1)
{
/* flash all LEDs to signal the mismatch */
PORTA.OUT=0xFF;
delay_ms(200);
PORTA.OUT=0x00;
delay_ms(200);
}
}
}
```

5.18 Software Bit-Banged I²C Bus Functions

The I²C Functions are intended for easy interfacing between C programs and various peripherals using the Philips I²C bus.

These functions treat the microcontroller as a bus master and the peripherals as slaves.

The I²C Functions are implemented in software, using the "bit-banging" method.

The hardware TWI is not used.

Notes:

- For proper operation, the I²C Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V on the SCL and SDA signals.
- The bit-banged I²C Functions do not support the XMEGA chips.

The prototypes for these functions are placed in the file **i2c.h**, located in the **.\INC** subdirectory. This file must be **#include -d** before using the functions.

These functions must be configured, by specifying the I/O port and bits used for communication through the I²C bus and the bit rate of the SCL clock.

This is accomplished in the **Project|Configure|C Compiler|Libraries|I2C** menu:

- the **Enable Bit-Banged I2C Support** option must be activated
- the **I/O Port, SDA** and **SCL** bits must be specified in **Data Connection**
- the Bit Rate of the SCL signal must be set.

Note: For compatibility with projects developed with CodeVisionAVR prior to V2.05.1, the I²C Functions can also be configured as outlined in the example below.

However in this case, the **Enable Bit-Banged I2C Support** option must be disabled in the **Project|Configure|C Compiler|Libraries|I2C** menu.

Example:

```
/* ATmega8515 PORTB bits 0 and 1 are used for the I2C bus
signals SDA and SCL */
#asm
.equ __i2c_port=0x18
.equ __sda_bit=0
.equ __scl_bit=1
#endasm

/* now you can include the I2C Functions */
#include <i2c.h>
```

This method is not recommended for new projects.

The I²C Functions are:

void i2c_init(void)

this function initializes the I²C bus.

This is the first function that must be called prior to using the other I²C Functions.

unsigned char i2c_start(void)

issues a START condition.

Returns 1 if bus is free or 0 if the I²C bus is busy.

void i2c_stop(void)

issues a STOP condition.

unsigned char i2c_read(unsigned char ack)

reads a byte from the bus.

The **ack** parameter specifies if an acknowledgement is to be issued after the byte was read.

Set **ack** to 0 for no acknowledgement or 1 for acknowledgement.

unsigned char i2c_write(unsigned char data)

writes the byte data to the bus.

Returns 1 if the slave acknowledges or 0 if not.

Example how to access an Atmel AT24C08A 8k bytes I²C EEPROM:

```
/* include the I2C bus functions
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <i2c.h>

/* function declaration for delay_ms */
#include <delay.h>

#define I2C_7BIT_DEVICE_ADDRESS 0x50
#define EEPROM_BUS_ADDRESS (I2C_7BIT_DEVICE_ADDRESS << 1)

/* read a byte from the EEPROM */
unsigned char eeprom_read(unsigned int address)
{
    unsigned char data;
    i2c_start();
    i2c_write(EEPROM_BUS_ADDRESS | 0);
    /* send MSB of address */
    i2c_write(address >> 8);
    /* send LSB of address */
    i2c_write((unsigned char) address);
    i2c_start();
    i2c_write(EEPROM_BUS_ADDRESS | 1);
    data=i2c_read(0);
    i2c_stop();
    return data;
}
```

```
/* write a byte to the EEPROM */
void eeprom_write(unsigned int address, unsigned char data)
{
    i2c_start();
    i2c_write(EEPROM_BUS_ADDRESS | 0);
    /* send MSB of address */
    i2c_write(address >> 8);
    /* send LSB of address */
    i2c_write((unsigned char) address);
    i2c_write(data);
    i2c_stop();
    /* 10ms delay to complete the write operation */
    delay_ms(10);
}

void main(void)
{
    unsigned char i;
    /* initialize the I2C bus */
    i2c_init();
    /* write the byte 55h at address AAh */
    eeprom_write(0xaa, 0x55);
    /* read the byte from address AAh */
    i=eeprom_read(0xaa);
    while (1); /* loop forever */
}
```

5.19 SPI Functions

The SPI Functions are intended for easy interfacing between C programs and various peripherals using the SPI bus.

The prototypes for these functions are placed in the file **spi.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

The SPI functions are:

unsigned char spi(unsigned char data)

this function sends the byte data, simultaneously receiving a byte.

Prior to using the **spi** function, you must configure the SPI Control Register SPCR according to the Atmel Data Sheets.

Because the **spi** function uses polling for SPI communication, there is no need to set the SPI Interrupt Enable Bit SPIE.

For the XMEGA chips the **spi** function use by default the **SPIC** controller on I/O port **PORTC**.

If you wish to use another SPI controller, you must define the **_ATXMEGA_SPI_** and **_ATXMEGA_SPI_PORT_** preprocessor macros prior to **#include** the **spi.h** header file, like in the example below:

```
/* use the ATxmega128A1 SPID for the spi function */
#define _ATXMEGA_SPI_SPID
#define _ATXMEGA_SPI_PORT_ PORTD

/* use the SPI functions */
#include <spi.h>
```

The **_ATXMEGA_SPI_** and **_ATXMEGA_SPI_PORT_** macros needs to be defined only once in the whole program, as the compiler will treat them like they are globally defined.

For the XMEGA chips the SPI library also contains the following function:

void spi_init(bool master_mode, bool lsb_first, SPI_MODE_t mode, bool clk2x, SPI_PRESCALER_t clock_div, unsigned char ss_pin)

this function initializes the SPI controller and corresponding I/O port as defined by the **_ATXMEGA_SPI_** and **_ATXMEGA_SPI_PORT_** macros.

If the **master_mode** parameter is true, the SPI controller will function in master mode, otherwise it will function in slave mode.

If the **lsb_first** parameter is true, the data byte sent/received on the bus will start with bit 0, otherwise it will start with bit 7.

The **mode** parameter specifies the SPI clock polarity and phase. The **SPI_MODE_t** data type and SPI modes are defined in the header file **xmbits_a1.h**:

SPI_MODE_0_gc for SPI mode 0
SPI_MODE_1_gc for SPI mode 1
SPI_MODE_2_gc for SPI mode 2
SPI_MODE_3_gc for SPI mode 3.

If the **clk2x** parameter is true, the SPI master will function in double speed mode.

The **clock_div** parameter specifies the SPI clock prescaler division factor. The **SPI_PRESCALER_t** data type and SPI prescaler values are defined in the header file **xmbits_a1.h**:

SPI_PRESCALER_DIV4_gc for System Clock/4
SPI_PRESCALER_DIV16_gc for System Clock/16
SPI_PRESCALER_DIV64_gc for System Clock/64
SPI_PRESCALER_DIV128_gc for System Clock/128.

The **ss_pin** parameter specifies the SPI I/O port pin that is used for SS. Its values are defined in the header file **xmbits_a1.h**.

Example of using the **spi** function for interfacing to an AD7896 ADC:

```
/*
Digital voltmeter using an
Analog Devices AD7896 ADC
connected to an AT90mega8515
using the SPI bus

Chip: AT90mega8515
Memory Model: SMALL
Data Stack Size: 128 bytes
Clock frequency: 4MHz

AD7896 connections to the ATmega8515

[AD7896] [ATmega8515 DIP40]
1 Vin
2 Vref=5V
3 AGND - 20 GND
4 SCLK - 8 SCK
5 SDATA - 7 MISO
6 DGND - 20 GND
7 CONVST- 2 PB1
8 BUSY - 1 PB0

Use an 2x16 alphanumeric LCD connected
to PORTC as follows:

[LCD] [ATmega8515 DIP40]
1 GND- 20 GND
2 +5V- 40 VCC
3 VLC
4 RS - 21 PC0
5 RD - 22 PC1
6 EN - 23 PC2
11 D4 - 25 PC4
12 D5 - 26 PC5
13 D6 - 27 PC6
14 D7 - 28 PC7 */
```



```
/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>
/* SPI driver function */
#include <spi.h>
#include <mega8515.h>
#include <stdio.h>
#include <delay.h>

/* AD7896 reference voltage [mV] */
#define VREF 5000L

/* AD7896 control signals PORTB bit allocation */
#define ADC_BUSY PINB.0
#define NCONVST PORTB.1

/* LCD display buffer */
char lcd_buffer[33];

unsigned read_adc(void)
{
    unsigned result;
    /* start conversion in mode 1, (high sampling performance) */
    NCONVST=0;
    NCONVST=1;
    /* wait for the conversion to complete */
    while (ADC_BUSY);
    /* read the MSB using SPI */
    result=(unsigned) spi(0)<<8;
    /* read the LSB using SPI and combine with MSB */
    result|=spi(0);
    /* calculate the voltage in [mV] */
    result=(unsigned) (((unsigned long) result*VREF)/4096L);
    /* return the measured voltage */
    return result;
}

void main(void)
{
    /* initialize PORTB
       PB.0 input from AD7896 BUSY
       PB.1 output to AD7896 /CONVST
       PB.2 & PB.3 inputs
       PB.4 output (SPI /SS pin)
       PB.5 input
       PB.6 input (SPI MISO)
       PB.7 output to AD7896 SCLK */
    DDRB=0x92;

    /* initialize the SPI in master mode
       no interrupts, MSB first, clock phase negative
       SCK low when idle, clock phase=0
       SCK=fxtal/4 */
    SPCR=0x54;
    SPSR=0x00;
```

```
/* the AD7896 will work in mode 1 (high sampling performance)
   /CONVST=1, SCLK=0 */
PORTB=2;

/* initialize the LCD */
lcd_init(16);

lcd_putsf("AD7896 SPI bus\nVoltmeter");
delay_ms(2000);
lcd_clear();

/* read and display the ADC input voltage */
while (1)
{
    sprintf(lcd_buffer, "Uadc=%4umV", read_adc());
    lcd_clear();
    lcd_puts(lcd_buffer);
    delay_ms(100);
};
}
```

5.20 USB Device Mode Functions

The USB Device Functions are intended for full speed operation in device mode of the USB controller present in the following chips:

- AT90USB646/647/1286/1287
- AT90USB82/162
- ATmega8U2/16U2/32U2
- ATmega16U4/32U4
- ATmega32U6
- ATxmega 64A1U/128A1U
- ATxmega 64A3U/128A3U/192A3U/256A3U
- ATxmega 16A4U/32A4U/64A4U/128A4U
- ATxmega 256A3BU
- ATxmega 64B1/128B1
- ATxmega 64B3/128B3
- ATxmega 32C3/64C3/128C3/256C3/384C3
- ATxmega 16C4/32C4.

The prototypes for these functions are placed in the file **usb_device.h**, located in the .INC subdirectory. This file must be **#include -d** before using the functions.

For non-Xmega chips the USB Device Functions can implement up to two interfaces: 0 and 1, thus allowing the creation of composite USB devices using the same controller, for example: mouse and keyboard.

For Xmega chips up to four interfaces: 0 to 3 are supported.

Five endpoints are supported. Endpoint 0 is always used for control and endpoints 1 to 4 are used for data transfer. The maximum size of an endpoint is 64 bytes.

The following data types are defined in **usb_device.h** and are used by the USB Device Functions:

```
/* USB Device Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 0x12 */
    unsigned char bDescriptorType; /* The constant
                                   USB_DESCRIPTOR_TYPE_DEVICE = 1 */
    unsigned short bcdUSB; /* USB specification release number in
                           BCD format = 0x0200 */
    unsigned char bDeviceClass; /* Class code */
    unsigned char bDeviceSubClass; /* Subclass code, specifies additional
                                   features for a class */
    unsigned char bDeviceProtocol; /* Protocol code for the selected class
                                   and subclass */
    unsigned char bMaxPacketSize0; /* Maximum packet size for endpoint 0 */
    unsigned short idVendor; /* Vendor ID */
    unsigned short idProduct; /* Product ID */
    unsigned short bcdDevice; /* Device release number in BCD format */
    unsigned char iManufacturer; /* Index in the descriptor list of string
                                   descriptor for the manufacturer
                                   Use 0 for no manufacturer descriptor */
    unsigned char iProduct; /* Index in the descriptor list of string
                             descriptor for the product
                             Use 0 for no product descriptor */
    unsigned char iSerialNumber; /* Index in the descriptor list of string
                                  descriptor for the serial number
                                  Use 0 for no serial number */
}
```

```
unsigned char bNumConfigurations; /* Number of possible configurations
                                   supported by the device at the
                                   current operating speed */

} USB_DEVICE_DESCRIPTOR_t;

/* USB Configuration Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_CONFIGURATION = 2 */
    unsigned short wTotalLength; /* The number of bytes in the configuration
                                   descriptor and all of its subordinate
                                   descriptors */
    unsigned char bNumInterfaces; /* The number of interfaces in the
                                    configuration
                                    Must be >= 1 */
    unsigned char bConfigurationValue; /* Identifier for Set Configuration and
                                         Get Configuration requests
                                         Must be >= 1 */
    unsigned char iConfiguration; /* Index of string descriptor for the
                                    configuration
                                    Use 0 for no string descriptor */
    unsigned char bmAttributes; /* Self/bus power and remote wakeup settings
                                   bit 7: =1 for compatibility with USB 1.0
                                   bit 6: =0 the device is bus powered
                                   =1 the device is self powered
                                   bit 5: =1 the device supports remote
                                   wakeup feature
                                   bits 0..4 must be 0 */
    unsigned char bMaxPower; /* Bus power required in multiples of 2 mA */
} USB_CONFIG_DESCRIPTOR_t;

/* USB Other Speed Configuration Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_OTHER_SPEED_CFG=7 */
    unsigned short wTotalLength; /* The number of bytes in the configuration
                                   descriptor and all of its subordinate
                                   descriptors */
    unsigned char bNumInterfaces; /* The number of interfaces in the
                                    configuration
                                    Must be >= 1 */
    unsigned char bConfigurationValue; /* Identifier for Set Configuration and
                                         Get Configuration requests
                                         Must be >= 1 */
    unsigned char iConfiguration; /* Index of string descriptor for the
                                    configuration
                                    Use 0 for no string descriptor */
    unsigned char bmAttributes; /* Self/bus power and remote wakeup settings
                                   bit 7: =1 for compatibility with USB 1.0
                                   bit 6: =0 the device is bus powered
                                   =1 the device is self powered
                                   bit 5: =1 the device supports remote
                                   wakeup feature
                                   bits 0..4 must be 0 */
    unsigned char bMaxPower; /* Bus power required in multiples of 2 mA */
} USB_OTHER_SPEED_CONFIG_DESCRIPTOR_t;
```

```
/* USB Interface Association Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 8 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_INTERFACE_ASSOC =
                                     0x0B */
    unsigned char bFirstInterface; /* Number identifying the first interface
                                     associated with a function */
    unsigned char bInterfaceCount; /* The number of contiguous interfaces
                                     associated with the function */
    unsigned char bFunctionClass; /* Class code */
    unsigned char bFunctionSubClass; /* Subclass code, specifies additional
                                     features for a class */
    unsigned char bFunctionProtocol; /* Protocol code for the selected class
                                     and subclass */
    unsigned char iFunction; /* Index of string descriptor associated
                               with the function
                               Use 0 for no string descriptor */
} USB_INTERFACE_ASSOC_DESCRIPTOR_t;

/* USB Interface Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_INTERFACE = 0x04 */
    unsigned char bInterfaceNumber; /* Number identifying this interface */
    unsigned char bAlternateSetting; /* Number that identifies a descriptor
                                     with alternate settings for this
                                     bInterfaceNumber */
    unsigned char bNumEndpoints; /* Number of supported endpoints, not counting
                                   endpoint 0 */
    unsigned char bInterfaceClass; /* Class code */
    unsigned char bInterfaceSubClass; /* Subclass code, specifies additional
                                     features for a class */
    unsigned char bInterfaceProtocol; /* Protocol code for the selected class
                                     and subclass */
    unsigned char iInterface; /* Index of string descriptor associated
                               with the interface
                               Use 0 for no string descriptor */
} USB_INTERFACE_DESCRIPTOR_t;
```

```
/* USB Endpoint Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 7 */
    unsigned char bDescriptorType; /* The constant
                                   USB_DESCRIPTOR_TYPE_ENDPOINT = 0x05 */
    unsigned char bEndpointAddress; /* Endpoint number and direction
                                     bit 7: =0 OUT, =1 IN
                                     bits 0..3: endpoint number */
    unsigned char bmAttributes; /* Transfer type and additional
                                 information */
    unsigned short wMaxPacketSize; /* Maximum supported packet size */
    unsigned char bInterval; /* Service interval or NAK rate
                              Low-speed interrupt ep: 10..255 [ms]
                              Full-speed interrupt ep: 1..255 [ms]
                              Full-speed isochronous ep: 1..16,
                              interval = 2^(bInterval-1) [ms]
                              High-speed ep: 1..16,
                              interval = 2^(bInterval-1)*125 [us] */
} USB_ENDPOINT_DESCRIPTOR_t;

/* USB Descriptors List */
typedef struct
{
    unsigned char bDescriptorIndex; /* Descriptor index, to specify which
                                     descriptor to return if there are
                                     several descriptors of the same type */
    unsigned char bDescriptorType; /* Descriptor type */
    unsigned short wIndex; /* =0 or Language ID for string descriptors */
    flash void *pDescriptor; /* FLASH storage address of descriptor data */
    unsigned char bLength; /* Descriptor data length */
} USB_DESCRIPTOR_LIST_t;

/* Endpoint configuration */
typedef struct
{
    unsigned char ep:4; /* Endpoint number */
    unsigned char type:2; /* Endpoint type:
                          0 - Control, 1 - Isochronous,
                          2 - Bulk, 3 - Interrupt */
    unsigned char size; /* Endpoint size: 8..64 [bytes],
                        set 0 if endpoint is not used */
} USB_ENDPOINT_t;

/* USB Interface configuration */
typedef struct
{
    unsigned char bInterfaceClass; /* Class code, set 0 if not used */
    unsigned char bInterfaceProtocol; /* Protocol code for the selected class
                                       and subclass */
    void *report_data; /* Pointer to a variable that contains the data to be
                       sent to the host for a report request */
    unsigned char report_size; /* Size of the report to be sent to the host
                               for a report request */
    USB_ENDPOINT_t in; /* IN endpoint configuration */
    USB_ENDPOINT_t out; /* OUT endpoint configuration */
} USB_INTERFACE_t;
```

```
/* USB Communication Timeouts */
typedef struct
{
    unsigned char tx; /* Transmission timeout period [ms],
                       0 value corresponds to 256 ms */
    unsigned char rx; /* Reception timeout period [ms],
                       0 value corresponds to 256 ms */
} USB_TIMEOUT_t;
```

The following global variables are defined by the USB Device Functions library:

unsigned char usb_enumerated

Stores the number of the USB configuration used by the USB device.
It takes the value 0 if the device was not enumerated by the host.

bit usb_current_interface

Stores the number of the currently active Interface which is used by the USB Device Functions.
After device initialization the current interface is 0.

USB_TIMEOUT_t usb_timeout

Stores the USB transmission and reception timeouts.

The USB Device Functions may return one of the following result codes, defined in **usb_device.h**:

```
#define USB_RES_OK 0x00          /* No error */
#define USB_RES_CONFIG_ERROR 0x80 /* Configuration error */
#define USB_RES_DEVICE_NOT_ENUM 0x81 /* Device not enumerated */
#define USB_RES_NO_DATA 0x82      /* No data available */
#define USB_RES_TIMEOUT 0x83      /* Communication timeout */
#define USB_RES_DEVICE_SUSPENDED 0x84 /* The device is in
                                     suspended state */
```

The following functions are implemented by the USB device mode library:

bool usb_init_device(flash USB_CONFIG_t *cfg)

Initializes the USB controller for operation in device mode.
The **cfg** parameter points to a structure of **USB_CONFIG_t** type, located in FLASH memory.
This structure is created by the CodeWizardAVR, based on user requirements.
Details can be found in chapters **6.22 Setting the USB Controller** (for non-Xmega devices) and **7.13 Setting the USB Interface** (for Xmega devices).
The function returns **true** on success or **false** if a configuration error was encountered.

Notes:

- The **usb_current_interface** variable is initialized with the value 0.
- The **usb_timeout** structure is initialized with the transmission and reception timeout values, specified in the **USB_CONFIG_t** structure. Later these values can be modified as needed during program execution.
- For Xmega devices, the system clock must be properly initialized before the **usb_init_device** function is called. The function will read the USB PAD calibration values from the signature row, perform the appropriate calibration and configure the USB registers.
- The USB Device Functions require interrupts to be globally enabled, after the **usb_init_device** function is called.

For non-Xmega devices, the USB Device Configuration used by the **usb_init_device** function is defined as:

```
typedef struct
{
    USB_INTERFACE_t interface[MAX_INTERFACES]; /* Interfaces configuration */
    flash USB_DESCRIPTOR_LIST_t *pdescriptor_list; /* Pointer to the
                                                    USB_DESCRIPTOR_LIST_t
                                                    array */
    unsigned char descriptor_list_items; /* # of elements in the
                                         USB_DESCRIPTOR_LIST_t array */
    USB_TIMEOUT_t timeout; /* Timeout periods */
} USB_CONFIG_t;
```

For Xmega devices, the USB Device Configuration used by the **usb_init_device** function is defined as:

```
typedef struct
{
    USB_INTERFACE_t interface[MAX_INTERFACES]; /* Interfaces configuration */
    flash USB_DESCRIPTOR_LIST_t *pdescriptor_list; /* Pointer to the
                                                    USB_DESCRIPTOR_LIST_t
                                                    array */
    unsigned char descriptor_list_items; /* # of elements in the
                                         USB_DESCRIPTOR_LIST_t array */
    USB_TIMEOUT_t timeout; /* Timeout periods */
    USB_CLOCK_SOURCE_t usb_clock; /* USB controller's clock source:
    USB_CLOCK_RC32M_SOF - 32 MHz RC
    oscillator adjusted
    and calibrated to 48 MHz using
    the DFLL and USB Start Of Frame
    USB_CLOCK_PLL_48M - PLL running
    at 48 MHz
    USB_CLOCK_PLL_96M - PLL running
    at 96 MHz */
    USB_INTLVL_t int_level; /* Interrupt priority for the USB
    controller:
    USB_INTLVL_LO_gc - Low level
    USB_INTLVL_MED_gc - Medium level
    USB_INTLVL_HI_gc - High level */
    void (*usb_suspend_handler) (void); /* Pointer to the power management
    function to be called when the
    device on the USB bus is
    suspended */
    void (*usb_resume_handler) (void); /* Pointer to the power management
    function to be called when the
    device on the USB bus exits the
    suspended state */
} USB_CONFIG_t;
```


Example:

```
/* Delay functions */
#include <delay.h>

/* USB Device functions */
#include <usb_device.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */

};

void main(void)
{
/* Initialization code for other chip peripherals */
/* ... */

/* USB Controller initialization in device mode */
usb_init_device(&usb_config);

/* Globally enable interrupts */
#asm("sei")

/* Wait for the USB device to be enumerated by the host */
while (!usb_enumerated);

/* Wait 1.5 seconds for the operating system to
   load any drivers needed by the USB device */
delay_ms(1500);

/* Now the rest of USB functions may be called */
/* ... */

}
```

unsigned char usb_getconfig(void)

Returns the current configuration or status of the USB interface:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_putchar(char c)

Transmits a byte **c** to the host, using the currently active USB interface.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_putbuf(void *buffer, unsigned short length)

Transmits to the host the contents of a **buffer**, located in RAM, using the currently active USB interface. The **length** parameter specifies the number of bytes to transmit.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_putbuff(flash void *buffer, unsigned short length)

Transmits to the host the contents of a **buffer**, located in FLASH memory, using the currently active USB interface. The **length** parameter specifies the number of bytes to transmit.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_putbufe(eeprom void *buffer, unsigned short length)

Transmits to the host the contents of a **buffer**, located in EEPROM, using the currently active USB interface. The **length** parameter specifies the number of bytes to transmit.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_putstr(char *str)

Transmits to the host the contents of a NULL terminated literal char string, located in RAM, using the currently active USB interface.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_putstrf(flash char *str)

Transmits to the host the contents of a NULL terminated literal char string, located in FLASH memory, using the currently active USB interface.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

Note: The **usb_putchar**, **usb_putbuf**, **usb_putbuff**, **usb_putbufe**, **usb_putstr** and **usb_putstrf** functions effectively transmit the data to the host only when the IN endpoint buffer gets full or the endpoint service interval has elapsed.

If immediate data transmission is required then the **usb_txflush** function, outlined below must be used.

unsigned char usb_txflush(void)

Immediately transmit to the host any buffered output for the currently active USB interface.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_rxclear(void)

Clears the receive buffer for the currently active USB interface.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

short usb_rxbyte(bool wait)

Receives a byte from the OUT endpoint of the currently active USB interface.
If the **wait** parameter is **true**, then the function will wait until data will be available in the OUT endpoint buffer.

If the **wait** parameter is **false**, then the function will not wait for data to be available in the buffer.

Returns:

- in MSB: **USB_RES_OK** (=0) – no error.
The LSB contains the received byte.
- in MSB: **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The LSB value is not defined.
- in MSB: **USB_RES_NO_DATA** – **wait** was set to **false** and there was no data available in the buffer. The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.
The LSB value is not defined.

short usb_getchar(void)

Waits to receive a byte from the OUT endpoint of the currently active USB interface.

Returns:

- in MSB: **USB_RES_OK** (=0) – no error.
The LSB contains the received byte.
- in MSB: **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.
The LSB value is not defined.

short usb_getcharnw(void)

Receives, without waiting, a byte from the OUT endpoint of the currently active USB interface.

Returns:

- in MSB: **USB_RES_OK** (=0) – no error.
The LSB contains the received byte.
- in MSB: **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The LSB value is not defined.
- in MSB: **USB_RES_NO_DATA** – there was no data available in the buffer.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.
The LSB value is not defined.

unsigned char usb_rxavailable(void)

Returns the number of bytes available in the receive buffer of the OUT endpoint for the currently active USB interface.

unsigned char usb_getbuf(void *buffer, unsigned short *length)

Receives data from the host and stores it into a buffer.

The **buffer** pointer, points to the RAM area that will hold the received data.

The **length** pointer, points to an *unsigned short* variable that holds the number of bytes that must be received.

Returns:

- **USB_RES_OK** – no error.
The variable pointed by **length** will hold the number of bytes that were effectively received from the host.
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The value of the variable pointed by **length** will remain unchanged.
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The value of the variable pointed by **length** will remain unchanged.
- **USB_RES_TIMEOUT** – the device didn't receive the required number of bytes, in the time interval specified in **usb_timeout.rx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

The variable pointed by **length** will hold the number of bytes that were effectively received from the host, before the receive timeout occurred.

Example:

```
/* Delay functions */
#include <delay.h>

/* Standard I/O functions */
#include <stdio.h>

/* USB Device functions */
#include <usb_device.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */

};

/* Receive buffer */
unsigned char rx_buffer[32];

void main(void)
{
/* Variable that holds the number of bytes to receive */
unsigned short nbytes;

/* Initialization code for other chip peripherals */
/* ... */

/* USB Controller initialization in device mode */
usb_init_device(&usb_config);

/* Globally enable interrupts */
#asm("sei")

/* Wait for the USB device to be enumerated by the host */
while (!usb_enumerated);
```

```
/* Wait 1.5 seconds for the operating system to
   load any drivers needed by the USB device */
delay_ms(1500);

/* Specify the number of bytes to be received */
nbytes=sizeof(rx_buffer);

/* Receive data from the host and
   display status */
switch (usb_getbuf(rx_buffer, &nbytes))
{
    case USB_RES_OK:
        printf("%u bytes received OK.\r\n",nbytes);
        break;

    case USB_RES_CONFIG_ERROR:
        printf("Error: Device not configured.\r\n");
        break;

    case USB_RES_DEVICE_NOT_ENUM:
        printf("Error: Device not enumerated by the host.\r\n");
        break;

    case USB_RES_TIMEOUT:
        printf("Error: Receive timeout occurred, "
              " only %u bytes received.\r\n",nbytes);
        break;
}

/* Stop here */
while (1);
}
```

5.20.1 USB CDC Virtual Serial Port Functions

The Communication Device Class Virtual Serial Port functions are intended for emulation of a RS-232 serial port, along with its handshaking signals.
The USB controller is operated in device mode.

The prototypes for these functions are placed in the file **usb_cdc.h**, located in the .\INC subdirectory. This file must be **#include -d** before using the functions.
The file **usb_cdc.h** does automatically **#include** the **usb_device.h** header.

For the non-Xmega AVR devices, one CDC Virtual Serial Port is implemented, using the following interfaces:

- Interface 0 implements the Communication Device Control class and uses the IN endpoint 1 for RS-232 handshaking with the host, with *Interrupt* type transfers
- Interface 1 implements the Communication Device Data class and uses the IN endpoint 3 and OUT endpoint 4 for data exchange with the host, with *Bulk* type transfers.

For the Xmega AVR devices, a maximal number of two CDC Virtual Serial Ports are implemented, using the following interfaces:

- Interface 0 implements the Communication Device Control class for Port 0 and uses the IN endpoint 1 for RS-232 handshaking with the host, with *Interrupt* type transfers
- Interface 1 implements the Communication Device Data class for Port 0 and uses the IN and OUT endpoint 2 for data exchange with the host, with *Bulk* type transfers
- Interface 2 implements the Communication Device Control class for Port 1 and uses the IN endpoint 3 for RS-232 handshaking with the host, with *Interrupt* type transfers
- Interface 3 implements the Communication Device Data class for Port 1 and uses the IN and OUT endpoint 4 for data exchange with the host, with *Bulk* type transfers.

Before calling the CDC Virtual Serial Port functions, the USB controller must be properly initialized for operation in device mode, using the **usb_device_init** function.

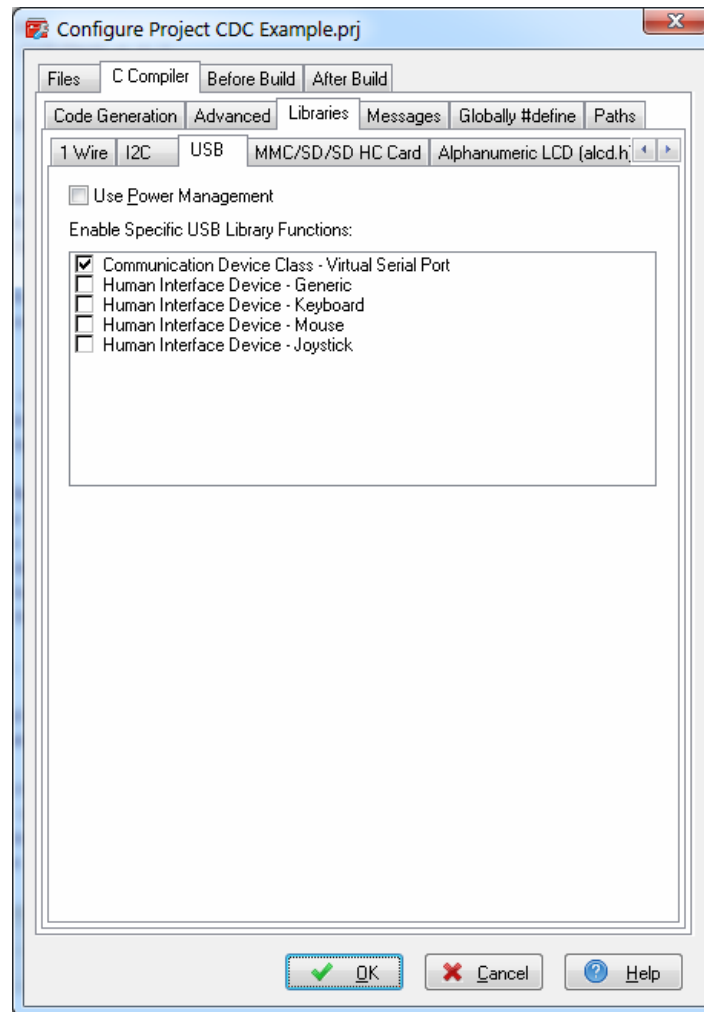
After this function is called, all input/output is directed by default to the Virtual Serial Port 0.

For the Xmega AVR devices this port can be changed during program execution, by calling the **usb_serial_select** function.

All configuration structures required for these functions can be easily created using the CodeWizardAVR.

CodeVisionAVR

Note: In order to use the CDC Virtual Serial Port functions, the corresponding option must be enabled in the **Project|Configure|C Compiler|Libraries|USB** menu:



The following data types are defined in **usb_cdc.h** and are used by the CDC Virtual Serial Port functions:

```
/* CDC Header Functional Descriptor */
typedef struct
{
    unsigned char bFunctionLength; /* Descriptor size in bytes = 5 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_CS_INTERFACE = 0x24
                                     */
    unsigned char bDescriptorSubtype; /* CDC class specific interface
                                       descriptor subtypes */
    unsigned short bcdCDC; /* CDC specification release number in
                           BCD format = 0x0110 */
} USB_CDC_HEADER_FUNC_DESCRIPTOR_t;

/* Call Management Functional Descriptor */
typedef struct
{
    unsigned char bFunctionLength; /* Descriptor size in bytes = 5 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_CS_INTERFACE = 0x24
                                     */
    unsigned char bDescriptorSubtype; /* CDC class specific interface
                                       descriptor subtypes */
    unsigned char bmCapabilities; /* bit 1: =0 - Device sends/receives call
                                   management information only
                                   over the Communication
                                   Class interface
                                   =1 - Device can send/receive
                                   call management
                                   information over a Data
                                   Class interface
                                   bit 0: =0 - Device does not handle call
                                   management itself
                                   =1 - Device handles call
                                   management itself */
    unsigned char bDataInterface; /* Interface number of Data Class
                                   interface, optionally used for call
                                   management (0 based index) */
} USB_CDC_CALL_MAN_FUNC_DESCRIPTOR_t;
```

```
/* Abstract Control Management Functional Descriptor */
typedef struct
{
    unsigned char bFunctionLength; /* Descriptor size in bytes = 4 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_CS_INTERFACE = 0x24
                                     */
    unsigned char bDescriptorSubtype; /* CDC class specific interface
                                       descriptor subtypes */
    unsigned char bmCapabilities; /* bit 3: =1 - Device supports the
                                   notification
                                   Network_Connection
                                   bit 2: =1 - Device supports the request
                                   Send_Break
                                   bit 1: =1 - Device supports the request
                                   combination of
                                   Set_Line_Coding,
                                   Set_Control_Line_State,
                                   Get_Line_Coding and
                                   the notification
                                   Serial_State
                                   bit 0: =1 - Device supports the request
                                   combination of
                                   Set_Comm_Feature,
                                   Clear_Comm_Feature and
                                   Get_Comm_Feature */
} USB_CDC_ACM_FUNC_DESCRIPTOR_t;

/* Union Functional Descriptor */
typedef struct
{
    unsigned char bFunctionLength; /* Descriptor size in bytes = 5 */
    unsigned char bDescriptorType; /* The constant
                                     USB_DESCRIPTOR_TYPE_CS_INTERFACE = 0x24
                                     */
    unsigned char bDescriptorSubtype; /* CDC class specific interface
                                       descriptor subtypes */
    unsigned char bMasterInterface; /* Interface number of the CDC Control
                                     interface */
    unsigned char bSlaveInterface0; /* Interface number of the CDC Data
                                     interface */
} USB_CDC_UNION_FUNC_DESCRIPTOR_t;

/* CDC Virtual Serial Port Line Coding settings */
typedef struct
{
    unsigned long baud_rate; /* Baud rate [bps] */
    unsigned char stop_bits; /* Number of stop bits */
    unsigned char parity; /* Parity bit type */
    unsigned char data_bits; /* Number of data bits */
} USB_CDC_LINE_CODING_t;
```

```
/* CDC Virtual Serial Port communication parameters and control signals */
typedef struct
{
    USB_CDC_LINE_CODING_t parameters; /* Communication parameters */
    union
    {
        struct
        {
            unsigned char dtr:1; /* DTR signal state */
            unsigned char rts:1; /* RTS signal state */
        };
        unsigned char signals;
    } control; /* RS-232 control signals */
} USB_CDC_SERIAL_CONFIG_t;

typedef union
{
    struct
    {
        unsigned char dcd:1; /* DCD signal state */
        unsigned char dsr:1; /* DSR signal state */
        unsigned char break:1; /* Break detected */
        unsigned char ri:1; /* RI signal state */
        unsigned char frame_error:1; /* Frame error detected */
        unsigned char parity_error:1; /* Parity error detected */
        unsigned char overrun_error:1; /* Overrun error detected */
    };
    unsigned char signals;
} USB_CDC_SERIAL_STATUS_t; /* RS-232 signals and error status */
```

The following initialization values are defined:

```
/* bcdCDC value */
#define USB_CDC_SPEC 0x0110 /* CDC 1.10 specification supported */

/* bDescriptorType values */
#define USB_DESCRIPTOR_TYPE_CS_INTERFACE 0x24 /* CS interface */
#define USB_DESCRIPTOR_TYPE_CS_ENDPOINT 0x25 /* CS endpoint */

/* bInterfaceProtocol */
#define USB_PROTOCOL_CDC_AT 0x01 /* AT command protocol */

/* bDescriptorSubType values */
#define CDC_DST_HEADER 0x00 /* Header functional descriptor */
#define CDC_DST_CALL_MANAGEMENT 0x01 /* Call Management functional descriptor */
#define CDC_DST_ACM 0x02 /* Abstract Control Model functional descriptor */
#define CDC_DST_DIRECT_LINE 0x03 /* Direct Line functional descriptor */
#define CDC_DST_TEL_RINGER 0x04 /* Telephone Ringer functional descriptor */
#define CDC_DST_TEL_CALL 0x05 /* Telephone Call functional descriptor */
#define CDC_DST_UNION 0x06 /* Union functional descriptor */
#define CDC_DST_COUNTRY_SEL 0x07 /* Country Selection functional descriptor */
#define CDC_DST_TEL_OP_MODES 0x08 /* Telephone Operation Modes functional descriptor */
```

```
#define CDC_DST_USB_TERMINAL      0x09 /* USB Terminal functional
                                     descriptor */
#define CDC_DST_NETWORK_CH       0x0A /* Network Channel functional
                                     descriptor */
#define CDC_DST_PROTOCOL_UNIT    0x0B /* Protocol Unit functional
                                     descriptor */
#define CDC_DST_EXT_UNIT         0x0C /* Extension Unit functional
                                     descriptor */
#define CDC_DST_MULTI_CH         0x0D /* Multi-Channel Management
                                     functional descriptor */
#define CDC_DST_CAPI             0x0E /* Common ISDN API functional
                                     descriptor */
#define CDC_DST_ETHERNET         0x0F /* Ethernet functional descriptor */
#define CDC_DST_ATM              0x10 /* Asynchronous Transfer Mode
                                     functional descriptor */

/* Call Management Functional Descriptor bmCapabilities flags */
#define CDC_CALL_MAN_COMMUNICATION 0x00 /* Device sends/receives call
                                     management information only
                                     over the Communication Class
                                     interface */
#define CDC_CALL_MAN_DATA 0x02 /* Device sends/receives call
                                     management information only
                                     over a Data Class interface */
#define CDC_CALL_MAN_NOT_ITSELF 0x00 /* Device does not handle call
                                     management itself */
#define CDC_CALL_MAN_ITSELF 0x01 /* Device does handles call
                                     management itself */

/* Abstract Control Management Functional Descriptor
   bmCapabilities flags */
#define CDC_ACM_NET_CONNECTION 0x08 /* Device supports the
                                     notification Network_Connection */
#define CDC_ACM_SEND_BREAK 0x04 /* Device supports the request
                                     Send_Break */
#define CDC_ACM_LC_CLS_SS 0x02 /* Device supports the request
                                     combination of Set_Line_Coding,
                                     Set_Control_Line_State,
                                     Get_Line_Coding and
                                     the notification Serial_State */
#define CDC_ACM_COMM_FEATURE 0x01 /* Device supports the request
                                     combination of Set_Comm_Feature,
                                     Clear_Comm_Feature and
                                     Get_Comm_Feature */

/* Stop_bits values */
#define CDC_SERIAL_STOP_BITS1 0 /* 1 stop bit */
#define CDC_SERIAL_STOP_BITS1_5 1 /* 1.5 stop bits */
#define CDC_SERIAL_STOP_BITS2 2 /* 2 stop bits */

/* Parity values */
#define CDC_SERIAL_PARITY_NONE 0 /* No parity bit */
#define CDC_SERIAL_PARITY_ODD 1 /* Odd parity bit */
#define CDC_SERIAL_PARITY_EVEN 2 /* Even parity bit */
#define CDC_SERIAL_PARITY_MARK 3 /* Mark parity bit */
#define CDC_SERIAL_PARITY_SPACE 4 /* Space parity bit */
```

The following global variable is defined by the CDC Virtual Serial Port library for non-Xmega AVR devices:

USB_CDC_SERIAL_CONFIG_t usb_cdc_serial

Stores the CDC Virtual Serial Port communication parameters and control signals.

As the Xmega AVR devices support two Virtual Serial Ports 0 and 1, the communication parameters and control signals are stored in an array:

USB_CDC_SERIAL_CONFIG_t usb_cdc_serial[2]

The CDC Virtual Serial Port functions may return one of the following result codes, defined in **usb_device.h**:

```
#define USB_RES_OK 0x00          /* No error */
#define USB_RES_CONFIG_ERROR 0x80 /* Configuration error */
#define USB_RES_DEVICE_NOT_ENUM 0x81 /* Device not enumerated */
#define USB_RES_NO_DATA 0x82      /* No data available */
#define USB_RES_TIMEOUT 0x83      /* Communication timeout */
#define USB_RES_DEVICE_SUSPENDED 0x84 /* The device is in
                                     suspended state */
```

The following functions are implemented by the CDC Virtual Serial Port library:

void usb_serial_select(unsigned char port)

Selects, for the Xmega AVR devices, the current Virtual Serial Port 0 or 1 to which all the input/output will be directed.

unsigned char usb_serial_putchar(char c)

Transmits a byte **c** to the host using the currently selected CDC Virtual Serial Port.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_serial_putstr(char *str)

Transmits to the host the contents of a NULL terminated literal char string, located in RAM, using the currently selected CDC Virtual Serial Port.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_serial_putbuf(void *buffer, unsigned short length)

Transmits to the host the contents of a **buffer**, located in RAM, using the currently selected CDC Virtual Serial Port. The **length** parameter specifies the number of bytes to transmit.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_serial_putbuff(flash void *buffer, unsigned short length)

Transmits to the host the contents of a **buffer**, located in FLASH memory, using the currently selected CDC Virtual Serial Port. The **length** parameter specifies the number of bytes to transmit.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_serial_putbufe(eeprom void *buffer, unsigned short length)

Transmits to the host the contents of a **buffer**, located in EEPROM, using the currently selected CDC Virtual Serial Port. The **length** parameter specifies the number of bytes to transmit.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_serial_putstrf(flash char *str)

Transmits to the host the contents of a NULL terminated literal char string, located in FLASH memory, using the currently selected CDC Virtual Serial Port.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

Note: The `usb_serial_putchar`, `usb_serial_putbuf`, `usb_serial_putbuff`, `usb_serial_putbufe`, `usb_serial_putstr` and `usb_serial_putstrf` functions effectively transmit the data to the host only when the IN endpoint buffer gets full or the endpoint service interval has elapsed. If immediate data transmission is required then the `usb_serial_txflush` function, outlined below must be used.

unsigned char usb_serial_txflush(void)

Immediately transmit to the host any buffered output of the currently selected CDC Virtual Serial Port.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in `usb_timeout.tx`
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_serial_rxclear(void)

Clears the receive buffer for the currently selected CDC Virtual Serial Port.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

short usb_serial_getchar(void)

Waits to receive a byte from the currently selected CDC Virtual Serial Port.

Returns:

- in MSB: **USB_RES_OK** (=0) – no error.
The LSB contains the received byte.
- in MSB: **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The LSB value is not defined
- in MSB: **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.
The LSB value is not defined.

short usb_serial_getcharnw(void)

Receives, without waiting, a byte from the CDC Virtual Serial Port.

Returns:

- in MSB: **USB_RES_OK** (=0) – no error.
The LSB contains the received byte.
- in MSB: **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The LSB value is not defined.
- in MSB: **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The LSB value is not defined.

- in MSB: **USB_RES_NO_DATA** – there was no data available in the buffer.
The LSB value is not defined
- in MSB: **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.
The LSB value is not defined.

unsigned char usb_serial_getbuf(void *buffer, unsigned short *length)

Receives data from the from the currently selected CDC Virtual Serial Port and stores it into a buffer.

The **buffer** pointer, points to the RAM area that will hold the received data.

The **length** pointer, points to an *unsigned short* variable that holds the number of bytes that must be received.

Returns:

- **USB_RES_OK** – no error.
The variable pointed by **length** will hold the number of bytes that were effectively received from the host.
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured.
The value of the variable pointed by **length** will remain unchanged.
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host.
The value of the variable pointed by **length** will remain unchanged.
- **USB_RES_TIMEOUT** – the device didn't receive the required number of bytes, in the time interval specified in **usb_timeout.rx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.
The variable pointed by **length** will hold the number of bytes that were effectively received from the host, before the receive timeout occurred.

Example:

```
/* Delay functions */
#include <delay.h>

/* Standard I/O functions */
#include <stdio.h>

/* USB Device functions */
#include <usb_device.h>

/* USB CDC Virtual Serial Port functions */
#include <usb_cdc.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */
};

/* Receive buffer */
unsigned char rx_buffer[32];
```



```
void main(void)
{
/* Variable that holds the number of bytes to receive */
unsigned short nbytes;

/* Initialization code for other chip peripherals */
/* ... */

/* USB Controller initialization in Full Speed, Device mode
   Note: The CDC Virtual Serial Port 0 was set
   as default USB CDC serial input/output */
usb_init_device(&usb_config);

/* Globally enable interrupts */
#asm("sei")

/* Wait for the USB device to be enumerated by the host */
while (!usb_enumerated);

/* Wait 1.5 seconds for the operating system to
   load any drivers needed by the USB device */
delay_ms(1500);

/* Wait for the USB host to be ready to receive serial data by
   setting the CDC Virtual Serial Port 0 RS-232 DTR signal high */
while (usb_cdc_serial[0].control.dtr==0);

/* Specify the number of bytes to be received */
nbytes=sizeof(rx_buffer);

/* Receive data from the host and
   display status */
switch (usb_serial_getbuf(rx_buffer, &nbytes))
{
    case USB_RES_OK:
        printf("%u bytes received OK.\r\n",nbytes);
        break;

    case USB_RES_CONFIG_ERROR:
        printf("Error: Device not configured.\r\n");
        break;

    case USB_RES_DEVICE_NOT_ENUM:
        printf("Error: Device not enumerated by the host.\r\n");
        break;

    case USB_RES_TIMEOUT:
        printf("Error: Receive timeout occurred, "
            " only %u bytes received.\r\n",nbytes);
        break;
}

/* Stop here */
while (1);
}
```

unsigned int usb_serial_available(void)

Returns the number of bytes available in the currently selected CDC Virtual Serial Port's receive buffer.

unsigned char usb_serial_sendstatus(USB_CDC_SERIAL_STATUS_t status)

Sends RS-232 signals and error **status** of the currently selected CDC Virtual Serial Port to the host.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the status, stored in the device's IN endpoint 1, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

Detailed examples on CDC Virtual Serial Port functions usage are available in the **\EXAMPLES\USB\CDC Virtual Serial Port** and **\EXAMPLES ATxmega\USB\CDC Virtual Serial Port** subdirectories of the CodeVisionAVR installation.

The CDC Virtual Serial Port uses the Windows serial driver.
Please follow the installation procedures below:

- **Windows 8 and 8.1**
 - Invoke the **Charms** bar and click on **Settings**
 - Click on **Change PC Settings** (bottom right of the screen)
 - In **PC Settings** click on **Update & recovery** (last option in the left column)
 - In **Update & recovery** select **Recovery**
 - Select in **Advanced startup** the **Restart Now** option
 - In the displayed list of options select **Troubleshoot**
 - In **Troubleshoot** select **Advanced Options**
 - In **Advanced Options** select **Startup Settings**
 - In **Startup Settings** click on the **Restart** button
 - The system will restart
 - When prompted, press the **F7** key, which will disable the driver signature enforcement
 - Wait for the system to boot completely
 - Connect the USB device to the computer's USB port, wait a little
 - Windows tries to install the driver, but doesn't succeed
 - Invoke again the **Charms** bar and click on **Settings**
 - Click on **Change PC Settings** (bottom right of the screen)
 - Click on **Control Panel** (bottom left of the screen)
 - Click on **Hardware and Sound**
 - Under **Device and Printers**, click on **Device Manager**
 - In the **Device Manager** window expand the **Other Devices** node
 - Right click on the **CodeVisionAVR CDC Virtual Serial Port** node of **Other Devices**
 - Select **Update Driver Software...**
 - Select **Browse my computer for driver software**
 - Browse to the directory where the file **CVAVR CDC Virtual Serial Port.inf** is located:
\Examples\USB\CDC Virtual Serial Port
 - Click on the **Next** button
 - Windows starts the driver installation, but displays a warning window with the text: **Windows can't verify the publisher of this driver software**
 - Select **Install this driver software anyway**
 - Windows finally installs the driver

CodeVisionAVR

- The new CDC Virtual Serial Port will be now listed in the Device Manager window under **Ports (COM & LPT)** as **CodeVisionAVR CDC Virtual Serial Port (COMn)**
- Retain the COMn number of the serial port for future use.

- **Windows Vista, Seven**

- After connecting the USB device to the computer's USB port, Windows tries to install the driver, but finally displays: **Device driver software was not successfully installed and No driver found**
- Click on the Windows **Start** button
- Click on **Control Panel**
- Click on **Hardware and Sound**
- Under **Device and Printers**, click on **Device Manager**
- In the **Device Manager** window expand the **Other Devices** node
- Right click on the **CodeVisionAVR CDC Virtual Serial Port** node of **Other Devices**
- Select **Update Driver Software...**
- Select **Browse my computer for driver software**
- Browse to the directory where the file **CVAVR CDC Virtual Serial Port.inf** is located:

\\Examples\\USB\\CDC Virtual Serial Port

- Click on the **Next** button
- Windows starts the driver installation, but displays a warning window with the text: **Windows can't verify the publisher of this driver software**
- Select **Install this driver software anyway**
- Windows finally installs the driver
- The new CDC Virtual Serial Port will be now listed in the **Device Manager** window under **Ports (COM & LPT)** as **CodeVisionAVR CDC Virtual Serial Port (COMn)**
- The new CDC Virtual Serial Port will be now listed in the **Device Manager** window under **Ports (COM & LPT)** as **CodeVisionAVR CDC Virtual Serial Port (COMn)**
- Retain the COMn number of the serial port for future use.

- **Windows XP**

- After connecting the USB device to the computer's USB port, the **Found New Hardware Wizard** window will open
- Select **Install from a List or Specific Location (Advanced)**
- Click on the **Next** button
- Select the **Search for the best driver in these locations** and **Include this location in search options**
- Browse to the directory where the file **CVAVR CDC Virtual Serial Port.inf** is located:

\\Examples\\USB\\CDC Virtual Serial Port

- Click on the **Next** button
- Windows starts the driver installation, but displays a warning window with the message: **CodeVisionAVR CDC Virtual Serial Port has not passed Windows Logo testing to verify its compatibility with Windows XP**
- Click on the **Continue Anyway** button
- Windows finally installs the driver
- The new CDC Virtual Serial Port will be now listed in the **Device Manager** window under **Ports (COM & LPT)** as **CodeVisionAVR CDC Virtual Serial Port (COMn)**
- The new **CDC Virtual Serial Port** will be now listed in the **Device Manager** window under **Ports (COM & LPT)** as **CodeVisionAVR CDC Virtual Serial Port (COMn)**
- Retain the COMn number of the serial port for future use.

5.20.2 Accessing an USB Generic HID

A Generic Human Interface Device class can communicate with the host, using the HID report protocol, the USB controller being operated in device mode.

The required data type and macro definitions are placed in the file **usb_hid.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the functions.

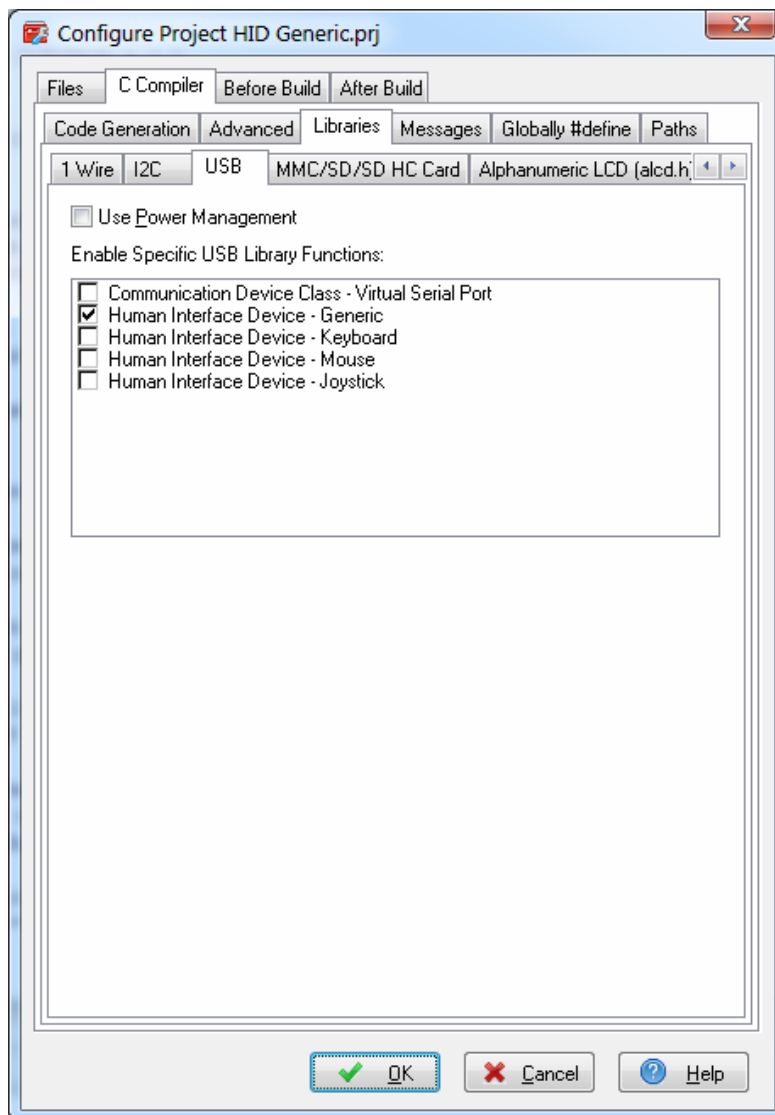
The file **usb_hid.h** does automatically **#include** the **usb_device.h** header.

The Generic HID requires one interface, with the IN and OUT endpoints using *Interrupt* type transfers.

Before accessing a Generic HID, the USB controller must be properly initialized, using the **usb_device_init** function.

All configuration structures required for a Generic HID can be easily created using the CodeWizardAVR.

Note: In order to use a Generic HID, the corresponding option must be enabled in the **Project|Configure|C Compiler|Libraries|USB** menu:



The following data type is defined in **usb_hid.h** and is used by a Generic HID:

```
/* USB HID Interface Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                   USB_DESCRIPTOR_TYPE_HID_INTERFACE = 0x21
                                   */
    unsigned short bcdHID; /* HID specification release number = 0x0111 */
    unsigned char bCountryCode; /* Country code of the localized hardware
                                   See HID spec. 1.11 page 23 */
    unsigned char bNumDescriptors; /* Number of class descriptors, >= 1 */
    unsigned char bReportDescriptorType; /* Constant name identifying the
                                           type of class descriptor */
    unsigned short wDescriptorLength; /* Total size of the Report descriptor */
} USB_HID_INTERFACE_DESCRIPTOR_t;
```

The following initialization values are defined:

```
/* HID specific requests */
#define USB_REQ_HID_GET_REPORT 0x01 /* The host requests an Input or
                                     Feature report from a HID using
                                     a control transfer */
#define USB_REQ_HID_GET_IDLE 0x02 /* The host reads the current Idle
                                     Rate from a HID */
#define USB_REQ_HID_GET_PROTOCOL 0x03 /* The host learns if the boot or
                                     report protocol is currently
                                     active in the HID
                                     Required for HID's that support
                                     a boot protocol */
#define USB_REQ_HID_SET_REPORT 0x09 /* The host sends an Output or
                                     Feature report to a HID */
#define USB_REQ_HID_SET_IDLE 0x0A /* Limits the reporting frequency
                                     of an interrupt IN endpoint
                                     when the data has not changed
                                     since the last report
                                     Required for keyboards that
                                     support a boot protocol */
#define USB_REQ_HID_SET_PROTOCOL 0x0B /* The host specifies whether the
                                     HID should use the boot or
                                     report protocol
                                     Required for HID's that support
                                     a boot protocol */

/* bcdHID value */
#define USB_HID_SPEC 0x0111 /* HID 1.11 specification is supported */
```

After the USB controller is initialized, using the code generated by the CodeWizardAVR, all the **USB Device Mode Functions** (chapter 5.19), can be used for communicating with the host.

Example:

```
/* AT90USB1286/1287 I/O port/register definitions */
#include <io.h>

/* Delay functions */
#include <delay.h>

/* USB Human Interface Device functions */
#include <usb_hid.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */

};

/* Reception buffer */
unsigned char rx_buffer[64];

/* Transmission buffer */
unsigned char tx_buffer[64]={0};

void main(void)
{
    unsigned short nbytes;

    /* Crystal Oscillator division factor: 1 */
    #pragma optsize-
    CLKPR=(1<<CLKPCE);
    CLKPR=(0<<CLKPCE) | (0<<CLKPS3) | (0<<CLKPS2) | (0<<CLKPS1) | (0<<CLKPS0);
    #ifdef _OPTIMIZE_SIZE_
    #pragma optsize+
    #endif

    /* Use PORTD bits 4..7 as outputs to drive the 4 LEDs */
    DDRD=0xF0;

    /* USB Controller initialization in device mode */
    usb_init_device(&usb_config);

    /* Globally enable interrupts */
    #asm("sei")

    /* Wait for the USB device to be enumerated by the host */
    while (!usb_enumerated);

    /* Wait 1.5 seconds for the operating system to
       load any drivers needed by the USB device */
    delay_ms(1500);
}
```

```
/* Configure Timer1 to generate a timer overflow
   interrupt every 1 second
   The AT90USB1286/1287 chip is clocked at 8 MHz */
TCCR1A=(0<<COM1A1) | (0<<COM1A0) | (0<<COM1B1) | (0<<COM1B0) |
        (0<<COM1C1) | (0<<COM1C0) | (0<<WGM11) | (0<<WGM10);
TCCR1B=(0<<ICNC1) | (0<<ICES1) | (0<<WGM13) | (0<<WGM12) |
        (1<<CS12) | (0<<CS11) | (0<<CS10);
TCNT1H=0x85;
TCNT1L=0xEE;

/* Enable Timer1 overflow interrupt */
TIMSK1=(0<<ICIE1) | (0<<OCIE1C) | (0<<OCIE1B) | (0<<OCIE1A) | (1<<TOIE1);

while (1)
{
    /* Check if we have received some data */
    nbytes=sizeof(rx_buffer); /* Number of bytes to receive */
    if (usb_getbuf(rx_buffer,&nbytes)==USB_RES_OK)
    {
        /* Output the received data byte 0 to PORTD bits 4..7 and
           light the corresponding LEDs */
        PORTD=rx_buffer[0]<<4;
    }
}

/* Timer1 overflow interrupt service routine
   occurs every 1 second */
interrupt [TIM1_OVF] void timer1_ovf_isr(void)
{
    static unsigned short counter=0;

    /* Reinitialize Timer1 value */
    TCNT1H=0x85EE >> 8;
    TCNT1L=0x85EE & 0xff;

    /* Write the counter in the first 2 bytes of the transmitted data */
    tx_buffer[0]=counter & 0xFF;
    tx_buffer[1]=counter >> 8;

    /* Write the LEDs current light state into byte #3 */
    tx_buffer[2]=PORTD>>4;

    /* Send buffer's content to the host */
    usb_putbuf(tx_buffer,sizeof(tx_buffer));

    /* Increment the counter */
    ++counter;
}
```

A detailed example on Generic HID usage is available in the **\EXAMPLES\USB\HID Generic** subdirectory of the CodeVisionAVR installation.

The data sent by the example program can be displayed on the host side (PC), using the **Generic HID Test.exe** program located in the above mentioned directory.

The source code for this program is supplied with the commercial versions of CodeVisionAVR.

No special Windows driver is required, the Generic HID will be detected by the operating system when the device is connected to the PC.

5.20.2 USB HID Keyboard Functions

The Human Interface Device Class Keyboard functions are intended for emulation of a PC keyboard. The USB controller is operated in device mode.

The prototypes for these functions are placed in the file **usb_hid.h**, located in the .INC subdirectory. This file must be **#include -d** before using the functions.

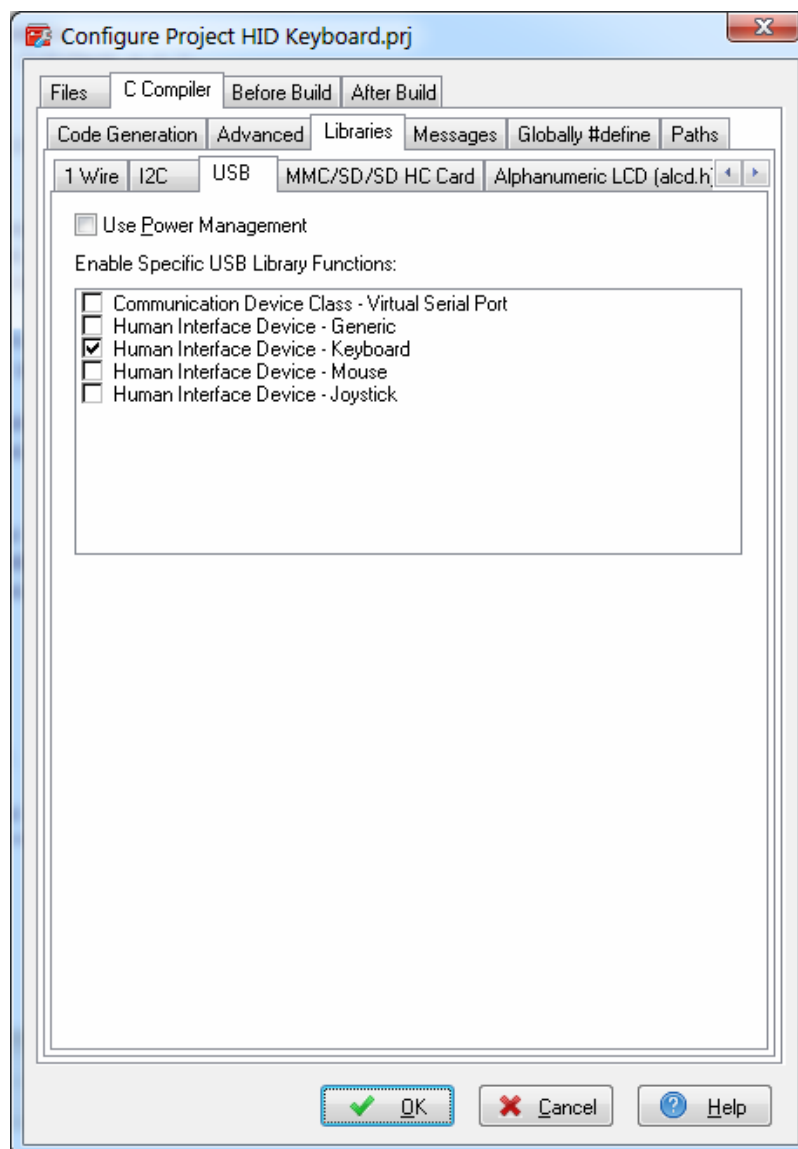
The file **usb_hid.h** does automatically **#include** the **usb_device.h** header.

The HID Keyboard device requires one interface, with one IN endpoint using *Interrupt* type transfers.

Before accessing a HID Keyboard device, the USB controller must be properly initialized, using the **usb_device_init** function.

All configuration structures required for a HID Keyboard can be easily created using the **CodeWizardAVR**.

Note: In order to use the HID Keyboard functions, the corresponding option must be enabled in the **Project|Configure|C Compiler|Libraries|USB** menu:



The following data types are defined in **usb_hid.h** and used by the HID Keyboard functions:

```
/* USB HID Interface Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                   USB_DESCRIPTOR_TYPE_HID_INTERFACE = 0x21
                                   */
    unsigned short bcdHID; /* HID specification release number = 0x0111 */
    unsigned char bCountryCode; /* Country code of the localized hardware
                                See HID spec. 1.11 page 23 */
    unsigned char bNumDescriptors; /* Number of class descriptors, >= 1 */
    unsigned char bReportDescriptorType; /* Constant name identifying the
                                         type of class descriptor */
    unsigned short wDescriptorLength; /* Total size of the Report descriptor */
} USB_HID_INTERFACE_DESCRIPTOR_t;

/* CTRL, SHIFT, ALT, GUI key modifier flags */
typedef unsigned char USB_KEYBOARD_MODIFIER_t;

/* Structure that holds the currently pressed keyboard keys
   and key modifiers */
typedef struct
{
    /* Signal which modifier keys are pressed */
    USB_KEYBOARD_MODIFIER_t modifier_keys;
    unsigned char reserved;
    /* Contains the key scan codes for the currently pressed keys,
       up to 6 keys at the same time */
    unsigned char keys[6];
} USB_KEYBOARD_t;

/* Keyboard LEDs state */
typedef unsigned char USB_KEYBOARD_LEDS_t;
```

The following initialization values are defined:

```
/* HID specific requests */
#define USB_REQ_HID_GET_REPORT 0x01 /* The host requests an Input or
                                     Feature report from a HID using
                                     a control transfer */
#define USB_REQ_HID_GET_IDLE 0x02 /* The host reads the current Idle
                                   Rate from a HID */
#define USB_REQ_HID_GET_PROTOCOL 0x03 /* The host learns if the boot or
                                        report protocol is currently
                                        active in the HID
                                        Required for HID's that support
                                        a boot protocol */
#define USB_REQ_HID_SET_REPORT 0x09 /* The host sends an Output or
                                     Feature report to a HID */
#define USB_REQ_HID_SET_IDLE 0x0A /* Limits the reporting frequency
                                   of an interrupt IN endpoint
                                   when the data has not changed
                                   since the last report
                                   Required for keyboards that
                                   support a boot protocol */
```

```
#define USB_REQ_HID_SET_PROTOCOL 0x0B /* The host specifies whether the
                                        HID should use the boot or
                                        report protocol
                                        Required for HID's that support
                                        a boot protocol */

/* bcdHID value */
#define USB_HID_SPEC 0x0111 /* HID 1.11 specification is supported */

/* Key modifier bit masks */
#define KM_LEFT_CTRL 0x01 /* Signal that the Left Ctrl key is pressed */
#define KM_LEFT_SHIFT 0x02 /* Signal that the Left Shift key is pressed */
#define KM_LEFT_ALT 0x04 /* Signal that the Left Alt key is pressed */
#define KM_LEFT_GUI 0x08 /* Signal that the Left GUI key is pressed */
#define KM_RIGHT_CTRL 0x10 /* Signal that the Right Ctrl key is pressed */
#define KM_RIGHT_SHIFT 0x20 /* Signal that the Right Shift key is pressed
*/
#define KM_RIGHT_ALT 0x40 /* Signal that the Right Alt key is pressed */
#define KM_RIGHT_GUI 0x80 /* Signal that the Right GUI key is pressed */

/* Keyboard HID report key scan codes */
#define KS_ERROR_ROLLOVER 0x01
#define KS_POST_FAILED 0x02
#define KS_ERROR_UNDEFINED 0x03
#define KS_A 0x04
#define KS_B 0x05
#define KS_C 0x06
#define KS_D 0x07
#define KS_E 0x08
#define KS_F 0x09
#define KS_G 0x0A
#define KS_H 0x0B
#define KS_I 0x0C
#define KS_J 0x0D
#define KS_K 0x0E
#define KS_L 0x0F
#define KS_M 0x10
#define KS_N 0x11
#define KS_O 0x12
#define KS_P 0x13
#define KS_Q 0x14
#define KS_R 0x15
#define KS_S 0x16
#define KS_T 0x17
#define KS_U 0x18
#define KS_V 0x19
#define KS_W 0x1A
#define KS_X 0x1B
#define KS_Y 0x1C
#define KS_Z 0x1D
#define KS_1_EXCLAMATION 0x1E
#define KS_2_AT 0x1F
#define KS_3_HASHMARK 0x20
#define KS_4_DOLLAR 0x21
#define KS_5_PERCENTAGE 0x22
#define KS_6_CARET 0x23
#define KS_7_AMPERSAND 0x24
#define KS_8_ASTERISK 0x25
#define KS_9_OPENING_PARENS 0x26
#define KS_0_CLOSING_PARENS 0x27
```

```
#define KS_ENTER 0x28
#define KS_ESC 0x29
#define KS_BACKSPACE 0x2A
#define KS_TAB 0x2B
#define KS_SPACE 0x2C
#define KS_MINUS_UNDERSCORE 0x2D
#define KS_EQUAL_PLUS 0x2E
#define KS_OPENING_BRACKET_BRACE 0x2F
#define KS_CLOSING_BRACKET_BRACE 0x30
#define KS_BACKSLASH_PIPE 0x31
#define KS_NON_US_HASHMARK_TILDE 0x32
#define KS_SEMICOLON_COLON 0x33
#define KS_APOSTROPHE_QUOTE 0x34
#define KS_GRAVE_ACCENT_TILDE 0x35
#define KS_COMMA_LESS_THAN 0x36
#define KS_DOT_GREATER_THAN 0x37
#define KS_SLASH_QUESTION_MARK 0x38
#define KS_CAPS_LOCK 0x39
#define KS_F1 0x3A
#define KS_F2 0x3B
#define KS_F3 0x3C
#define KS_F4 0x3D
#define KS_F5 0x3E
#define KS_F6 0x3F
#define KS_F7 0x40
#define KS_F8 0x41
#define KS_F9 0x42
#define KS_F10 0x43
#define KS_F11 0x44
#define KS_F12 0x45
#define KS_PRINT_SCREEN 0x46
#define KS_SCROLL_LOCK 0x47
#define KS_PAUSE 0x48
#define KS_INSERT 0x49
#define KS_HOME 0x4A
#define KS_PAGE_UP 0x4B
#define KS_DELETE 0x4C
#define KS_END 0x4D
#define KS_PAGE_DOWN 0x4E
#define KS_RIGHT_ARROW 0x4F
#define KS_LEFT_ARROW 0x50
#define KS_DOWN_ARROW 0x51
#define KS_UP_ARROW 0x52
#define KS_NUM_LOCK 0x53
#define KS_KEYPAD_SLASH 0x54
#define KS_KEYPAD_ASTERISK 0x55
#define KS_KEYPAD_MINUS 0x56
#define KS_KEYPAD_PLUS 0x57
#define KS_KEYPAD_ENTER 0x58
#define KS_KEYPAD_1_END 0x59
#define KS_KEYPAD_2_DOWN_ARROW 0x5A
#define KS_KEYPAD_3_PAGE_DOWN 0x5B
#define KS_KEYPAD_4_LEFT_ARROW 0x5C
#define KS_KEYPAD_5 0x5D
#define KS_KEYPAD_6_RIGHT_ARROW 0x5E
#define KS_KEYPAD_7_HOME 0x5F
#define KS_KEYPAD_8_UP_ARROW 0x60
#define KS_KEYPAD_9_PAGE_UP 0x61
#define KS_KEYPAD_0_INSERT 0x62
#define KS_KEYPAD_DOT_DELETE 0x63
```

```
#define KS_NON_US_BACKSLASH_PIPE 0x64
#define KS_APPLICATION 0x65
#define KS_POWER 0x66
#define KS_KEYPAD_EQUAL 0x67
#define KS_F13 0x68
#define KS_F14 0x69
#define KS_F15 0x6A
#define KS_F16 0x6B
#define KS_F17 0x6C
#define KS_F18 0x6D
#define KS_F19 0x6E
#define KS_F20 0x6F
#define KS_F21 0x70
#define KS_F22 0x71
#define KS_F23 0x72
#define KS_F24 0x73
#define KS_EXECUTE 0x74
#define KS_HELP 0x75
#define KS_MANU 0x76
#define KS_SELECT 0x77
#define KS_STOP 0x78
#define KS_AGAIN 0x79
#define KS_UNDO 0x7A
#define KS_CUT 0x7B
#define KS_COPY 0x7C
#define KS_PASTE 0x7D
#define KS_FIND 0x7E
#define KS_MUTE 0x7F
#define KS_VOLUME_UP 0x80
#define KS_VOLUME_DOWN 0x81
#define KS_LOCKING_CAPS_LOCK 0x82
#define KS_LOCKING_NUM_LOCK 0x83
#define KS_LOCKING_SCROLL_LOCK 0x84
#define KS_KEYPAD_COMMA 0x85
#define KS_KEYPAD_EQUAL_AS400 0x86
#define KS_INTERNATIONAL1 0x87
#define KS_INTERNATIONAL2 0x88
#define KS_INTERNATIONAL3 0x89
#define KS_INTERNATIONAL4 0x8A
#define KS_INTERNATIONAL5 0x8B
#define KS_INTERNATIONAL6 0x8C
#define KS_INTERNATIONAL7 0x8D
#define KS_INTERNATIONAL8 0x8E
#define KS_INTERNATIONAL9 0x8F
#define KS_LANG1 0x90
#define KS_LANG2 0x91
#define KS_LANG3 0x92
#define KS_LANG4 0x93
#define KS_LANG5 0x94
#define KS_LANG6 0x95
#define KS_LANG7 0x96
#define KS_LANG8 0x97
#define KS_LANG9 0x98
#define KS_ALTERNATE_ERASE 0x99
#define KS_SISREQ 0x9A
#define KS_CANCEL 0x9B
#define KS_CLEAR 0x9C
#define KS_PRIOR 0x9D
#define KS_RETURN 0x9E
#define KS_SEPARATOR 0x9F
```

```
#define KS_OUT 0xA0
#define KS_OPER 0xA1
#define KS_CLEAR_AGAIN 0xA2
#define KS_CRSEL_ANDPROPS 0xA3
#define KS_EXSEL 0xA4
#define KS_KEYPAD_00 0xB0
#define KS_KEYPAD_000 0xB1
#define KS_THOUSANDS_SEP 0xB2
#define KS_DECIMAL_SEP 0xB3
#define KS_CURRENCY_UNIT 0xB4
#define KS_CURRENCY_SUB_UNIT 0xB5
#define KS_KEYPAD_OPENING_PARENS 0xB6
#define KS_KEYPAD_CLOSING_PARENS 0xB7
#define KS_KEYPAD_OPENING_BRACE 0xB8
#define KS_KEYPAD_CLOSING_BRACE 0xB9
#define KS_KEYPAD_TAB 0xBA
#define KS_KEYPAD_BACKSPACE 0xBB
#define KS_KEYPAD_A 0xBC
#define KS_KEYPAD_B 0xBD
#define KS_KEYPAD_C 0xBE
#define KS_KEYPAD_D 0xBF
#define KS_KEYPAD_E 0xC0
#define KS_KEYPAD_F 0xC1
#define KS_KEYPAD_XOR 0xC2
#define KS_KEYPAD_CARET 0xC3
#define KS_KEYPAD_PERCENTAGE 0xC4
#define KS_KEYPAD_LESS_THAN 0xC5
#define KS_KEYPAD_GREATER_THAN 0xC6
#define KS_KEYPAD_AMP 0xC7
#define KS_KEYPAD_AMP_AMP 0xC8
#define KS_KEYPAD_PIPE 0xC9
#define KS_KEYPAD_PIPE_PIPE 0xCA
#define KS_KEYPAD_COLON 0xCB
#define KS_KEYPAD_HASHMARK 0xCC
#define KS_KEYPAD_SPACE 0xCD
#define KS_KEYPAD_AT 0xCE
#define KS_KEYPAD_EXCLAMATION 0xCF
#define KS_KEYPAD_MEMORY_STORE 0xD0
#define KS_KEYPAD_MEMORY_RECALL 0xD1
#define KS_KEYPAD_MEMORY_CLEAR 0xD2
#define KS_KEYPAD_MEMORY_ADD 0xD3
#define KS_KEYPAD_MEMORY_SUB 0xD4
#define KS_KEYPAD_MEMORY_MULT 0xD5
#define KS_KEYPAD_MEMORY_DIV 0xD6
#define KS_KEYPAD_PLUS_MINUS 0xD7
#define KS_KEYPAD_CLEAR 0xD8
#define KS_KEYPAD_CLEAR_ENTRY 0xD9
#define KS_KEYPAD_BINARY 0xDA
#define KS_KEYPAD_OCTAL 0xDB
#define KS_KEYPAD_DECIMAL 0xDC
#define KS_KEYPAD_HEX 0xDD
#define KS_LEFT_CTRL 0xE0
#define KS_LEFT_SHIFT 0xE1
#define KS_LEFT_ALT 0xE2
#define KS_LEFT_GUI 0xE3
#define KS_RIGHT_CTRL 0xE4
#define KS_RIGHT_SHIFT 0xE5
#define KS_RIGHT_ALT 0xE6
#define KS_RIGHT_GUI 0xE7
```

```
/* LEDs bit masks */
#define USB_KEYBOARD_LED_NUM_LOCK (1<<0) /* Signal that Num Lock mode
                                             is currently set */
#define USB_KEYBOARD_LED_CAPS_LOCK (1<<1) /* Signal that Caps Lock mode
                                             is currently set */
#define USB_KEYBOARD_LED_SCROLL_LOCK (1<<2) /* Signal that Scroll Lock
                                              mode is currently set */
#define USB_KEYBOARD_LED_COMPOSE (1<<3) /* Signal that Compose mode
                                           is currently set */
#define USB_KEYBOARD_LED_KANA (1<<4) /* Signal that KANA mode
                                       is currently set */
```

The following global variables are defined by the HID Keyboard library:

USB_KEYBOARD_t usb_keyboard

Stores the pressed keys & key modifier buffer.

USB_KEYBOARD_LEDS_t usb_keyboard_leds

Stores the keyboard's LEDs state (updated by the host).

The HID Keyboard functions may return one of the following result codes, defined in **usb_device.h**:

```
#define USB_RES_OK 0x00 /* No error */
#define USB_RES_CONFIG_ERROR 0x80 /* Configuration error */
#define USB_RES_DEVICE_NOT_ENUM 0x81 /* Device not enumerated */
#define USB_RES_NO_DATA 0x82 /* No data available */
#define USB_RES_TIMEOUT 0x83 /* Communication timeout */
#define USB_RES_DEVICE_SUSPENDED 0x84 /* The device is in
                                         suspended state */
```

The following HID Keyboard functions are implemented:

unsigned char usb_keyboard_sendkeys(void)

Sends the state of the currently pressed keys from **usb_keyboard** variable to the host, using the currently active interface.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

**unsigned char usb_keyboard_keypress(unsigned char key_scan,
USB_KEYBOARD_MODIFIER_t modifier)**

Sends a single keypress to the host, using the currently active interface.

key_scan contains the key scan code and **modifier** the key modifier values (both defined in `usb_hid.h`).

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in `usb_timeout.tx`
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

Example:

```
/* Delay functions */
#include <delay.h>

/* USB HID functions */
#include <usb_hid.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */
};

void main(void)
{
/* Initialization code for other chip peripherals */
/* ... */

/* USB Controller initialization in device mode */
usb_init_device(&usb_config);

/* Globally enable interrupts */
#asm("sei")

/* Wait for the USB device to be enumerated by the host */
while (!usb_enumerated);

/* Wait 1.5 seconds for the operating system to
   load any drivers needed by the USB device */
delay_ms(1500);

/* Sends a Left Ctrl+C key press to the host */
usb_keyboard_keypress(KS_C, KM_LEFT_CTRL);

/* Stop here */
while (1);
}
```

A detailed example on HID Keyboard usage is available in the **\\EXAMPLES\\USB\\HID Keyboard** subdirectory of the CodeVisionAVR installation.

No special Windows driver is required, the HID Keyboard will be detected by the operating system when the device is connected to the PC.

5.20.3 USB HID Mouse Functions

The Human Interface Device Class Mouse functions are intended for emulation of a three button mouse equipped with a wheel.

The USB controller is operated in device mode.

The prototypes for these functions are placed in the file **usb_hid.h**, located in the **.\INC** subdirectory. This file must be **#include -d** before using the functions.

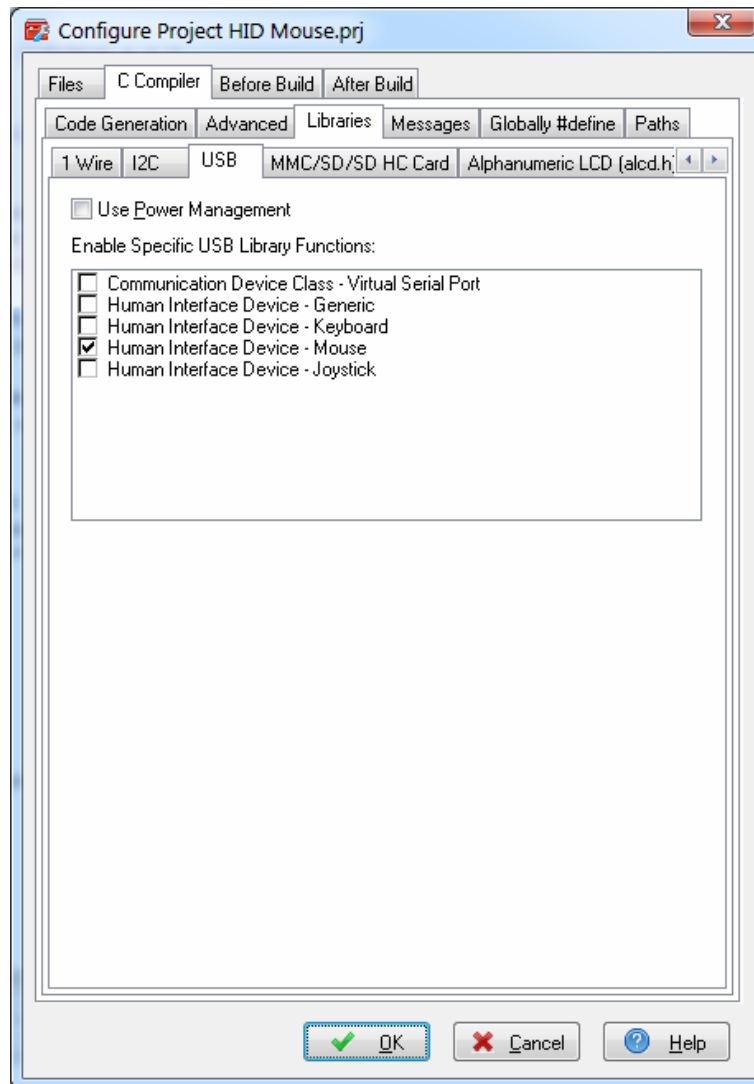
The file **usb_hid.h** does automatically **#include** the **usb_device.h** header.

The HID Mouse requires one interface, with one IN endpoint using *Interrupt* type transfers.

Before accessing a HID Mouse, the USB controller must be properly initialized, using the **usb_device_init** function.

All configuration structures required for a HID Mouse can be easily created using the CodeWizardAVR.

Note: In order to use the HID Mouse functions, the corresponding option must be enabled in the **Project|Configure|C Compiler|Libraries|USB** menu:



The following data types are defined in **usb_hid.h** and used by the HID Mouse functions:

```
/* USB HID Interface Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                   USB_DESCRIPTOR_TYPE_HID_INTERFACE = 0x21
                                   */
    unsigned short bcdHID; /* HID specification release number = 0x0111 */
    unsigned char bCountryCode; /* Country code of the localized hardware
                                   See HID spec. 1.11 page 23 */
    unsigned char bNumDescriptors; /* Number of class descriptors, >= 1 */
    unsigned char bReportDescriptorType; /* Constant name identifying the
                                           type of class descriptor */
    unsigned short wDescriptorLength; /* Total size of the Report descriptor */
} USB_HID_INTERFACE_DESCRIPTOR_t;

/* Mouse buttons state */
typedef unsigned char USB_MOUSE_BUTTONS_t;

/* Structure that contains the mouse state */
typedef struct
{
    USB_MOUSE_BUTTONS_t buttons; /* Which buttons are currently pressed */
    signed char x;
    signed char y;
    signed char wheel;
} USB_MOUSE_t;
```

The following initialization values are defined:

```
/* HID specific requests */
#define USB_REQ_HID_GET_REPORT 0x01 /* The host requests an Input or
                                     Feature report from a HID using
                                     a control transfer */
#define USB_REQ_HID_GET_IDLE 0x02 /* The host reads the current Idle
                                     Rate from a HID */
#define USB_REQ_HID_GET_PROTOCOL 0x03 /* The host learns if the boot or
                                     report protocol is currently
                                     active in the HID
                                     Required for HID's that support
                                     a boot protocol */
#define USB_REQ_HID_SET_REPORT 0x09 /* The host sends an Output or
                                     Feature report to a HID */
#define USB_REQ_HID_SET_IDLE 0x0A /* Limits the reporting frequency
                                     of an interrupt IN endpoint
                                     when the data has not changed
                                     since the last report
                                     Required for keyboards that
                                     support a boot protocol */
#define USB_REQ_HID_SET_PROTOCOL 0x0B /* The host specifies whether the
                                     HID should use the boot or
                                     report protocol
                                     Required for HID's that support
                                     a boot protocol */
```

CodeVisionAVR

```
/* bcdHID value */
#define USB_HID_SPEC 0x0111 /* HID 1.11 specification is supported */

/* Mouse button state flags */
#define USB_MOUSE_BTN_LEFT (1<<0) /* Left mouse button is pressed */
#define USB_MOUSE_BTN_RIGHT (1<<1) /* Right mouse button is pressed */
#define USB_MOUSE_BTN_MIDDLE (1<<2) /* Middle mouse button is pressed */
```

The following global variable is defined by the HID Mouse library:

USB_MOUSE_t usb_mouse

Stores the current mouse state.

The HID Mouse functions may return one of the following result codes, defined in **usb_device.h**:

```
#define USB_RES_OK 0x00 /* No error */
#define USB_RES_CONFIG_ERROR 0x80 /* Configuration error */
#define USB_RES_DEVICE_NOT_ENUM 0x81 /* Device not enumerated */
#define USB_RES_NO_DATA 0x82 /* No data available */
#define USB_RES_TIMEOUT 0x83 /* Communication timeout */
#define USB_RES_DEVICE_SUSPENDED 0x84 /* The device is in
suspended state */
```

The following HID Mouse functions are implemented:

unsigned char usb_mouse_move(signed char x, signed char y, signed char wheel)

Sends mouse movement information to the host, using the currently active interface.
x, **y** and **wheel** range is -127 to 127. A value of 0 specifies no movement.

Note: The values of the **x**, **y** and **wheel** members of the **usb_mouse** global structure are updated accordingly.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_mouse_buttons(USB_MOUSE_BUTTONS_t buttons)

Sends the mouse buttons state to the host, using the currently active interface.

Note: The value of the **buttons** member in the **usb_mouse** global structure is updated with the new state of the buttons.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

unsigned char usb_mouse_click(USB_MOUSE_BUTTONS_t buttons)

Sends a mouse click to the host, using the currently active interface.

Note: The value of the **buttons** member in the **usb_mouse** global structure will be 0 after function execution.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

Example:

```
/* Delay functions */
#include <delay.h>

/* USB HID functions */
#include <usb_hid.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */

};

void main(void)
{
/* Initialization code for other chip peripherals */
/* ... */

/* USB Controller initialization in device mode */
usb_init_device(&usb_config);

/* Globally enable interrupts */
#asm("sei")

/* Wait for the USB device to be enumerated by the host */
while (!usb_enumerated);

/* Wait 1.5 seconds for the operating system to
   load any drivers needed by the USB device */
delay_ms(1500);

/* Move the mouse cursor diagonally by 30 pixels */
usb_mouse_move(30,30,0);

/* Send a left mouse button click to the host */
usb_mouse_click(USB_MOUSE_BTN_LEFT);

/* Stop here */
while (1);
}
```

A detailed example on HID Mouse usage is available in the **\EXAMPLES\USB\HID Mouse** subdirectory of the CodeVisionAVR installation.

No special Windows driver is required, the HID Mouse will be detected by the operating system when the device is connected to the PC.

5.20.4 USB HID Joystick Functions

The Human Interface Device Class Joystick functions are intended for emulation of a joystick controller with two buttons and movements on the X, Y and Z axis.
The USB controller is operated in device mode.

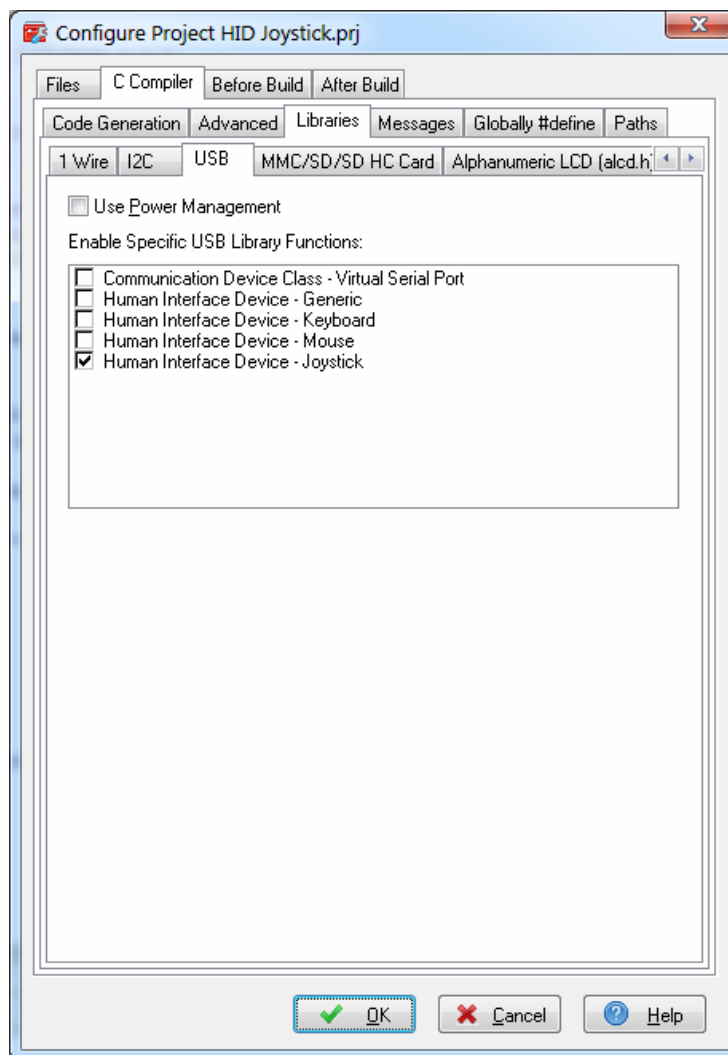
The prototypes for these functions are placed in the file **usb_hid.h**, located in the .\INC subdirectory. This file must be **#include -d** before using the functions.
The file **usb_hid.h** does automatically **#include** the **usb_device.h** header.

The HID Joystick requires one interface, with one IN endpoint using *Interrupt* type transfers.

Before accessing a HID Joystick, the USB controller must be properly initialized, using the **usb_device_init** function.

All configuration structures required for a HID Joystick can be easily created using the CodeWizardAVR.

Note: In order to use the HID Joystick functions, the corresponding option must be enabled in the **Project|Configure|C Compiler|Libraries|USB** menu:



The following data types are defined in **usb_hid.h** and used by the HID Joystick functions:

```
/* USB HID Interface Descriptor */
typedef struct
{
    unsigned char bLength; /* Descriptor size in bytes = 9 */
    unsigned char bDescriptorType; /* The constant
                                   USB_DESCRIPTOR_TYPE_HID_INTERFACE = 0x21
                                   */
    unsigned short bcdHID; /* HID specification release number = 0x0111 */
    unsigned char bCountryCode; /* Country code of the localized hardware
                                   See HID spec. 1.11 page 23 */
    unsigned char bNumDescriptors; /* Number of class descriptors, >= 1 */
    unsigned char bReportDescriptorType; /* Constant name identifying the
                                           type of class descriptor */
    unsigned short wDescriptorLength; /* Total size of the Report descriptor */
} USB_HID_INTERFACE_DESCRIPTOR_t;

/* Joystick buttons state */
typedef unsigned char USB_JOYSTICK_BUTTONS_t;

/* Structure that contains the joystick state */
typedef struct
{
    signed char x; /* Current joystick absolute X position [-100,100] */
    signed char y; /* Current joystick absolute Y position [-100,100] */
    signed char z; /* Current joystick absolute Z position [-100,100] */
    USB_JOYSTICK_BUTTONS_t buttons; /* Which buttons are currently pressed */
} USB_JOYSTICK_t;
```

The following initialization values are defined:

```
/* HID specific requests */
#define USB_REQ_HID_GET_REPORT 0x01 /* The host requests an Input or
                                     Feature report from a HID using
                                     a control transfer */
#define USB_REQ_HID_GET_IDLE 0x02 /* The host reads the current Idle
                                     Rate from a HID */
#define USB_REQ_HID_GET_PROTOCOL 0x03 /* The host learns if the boot or
                                     report protocol is currently
                                     active in the HID
                                     Required for HID's that support
                                     a boot protocol */
#define USB_REQ_HID_SET_REPORT 0x09 /* The host sends an Output or
                                     Feature report to a HID */
#define USB_REQ_HID_SET_IDLE 0x0A /* Limits the reporting frequency
                                     of an interrupt IN endpoint
                                     when the data has not changed
                                     since the last report
                                     Required for keyboards that
                                     support a boot protocol */
#define USB_REQ_HID_SET_PROTOCOL 0x0B /* The host specifies whether the
                                     HID should use the boot or
                                     report protocol
                                     Required for HID's that support
                                     a boot protocol */

/* bcdHID value */
#define USB_HID_SPEC 0x0111 /* HID 1.11 specification is supported */
```

```
/* Joystick button state flags */
#define USB_JOYSTICK_BTN1 (1<<0) /* Button 1 is pressed */
#define USB_JOYSTICK_BTN2 (1<<1) /* Button 2 is pressed */
```

The following global variable is defined by the HID Joystick library:

USB_JOYSTICK_t usb_joystick

Stores the current joystick state.

The HID Joystick functions may return one of the following result codes, defined in **usb_device.h**:

```
#define USB_RES_OK 0x00          /* No error */
#define USB_RES_CONFIG_ERROR 0x80 /* Configuration error */
#define USB_RES_DEVICE_NOT_ENUM 0x81 /* Device not enumerated */
#define USB_RES_NO_DATA 0x82      /* No data available */
#define USB_RES_TIMEOUT 0x83     /* Communication timeout */
#define USB_RES_DEVICE_SUSPENDED 0x84 /* The device is in
                                     suspended state */
```

The following HID Joystick function is implemented:

unsigned char usb_joystick_move(USB_JOYSTICK_t *joystick_state)

Sends joystick movement and button state to the host, using the currently active interface. The **joystick_state** parameter points to an **USB_JOYSTICK_t** structure that holds the movement values for the X, Y, Z axis and the state of the two buttons.

Note: The **usb_joystick** global structure is updated with the new values, after the function is executed.

Returns:

- **USB_RES_OK** – no error
- **USB_RES_CONFIG_ERROR** – the USB controller was not (correctly) configured
- **USB_RES_DEVICE_NOT_ENUM** – the device was not yet enumerated by the host
- **USB_RES_TIMEOUT** – the host didn't get the data, stored in the device's IN endpoint, in the time interval specified in **usb_timeout.tx**
- **USB_RES_DEVICE_SUSPENDED** – the device is currently in suspended state.

Example:

```
/* Delay functions */
#include <delay.h>

/* memcmp function */
#include <string.h>

/* USB HID functions */
#include <usb_hid.h>

/* USB device configuration */
flash USB_CONFIG_t usb_config=
{
/* Initialization data created by the CodeWizardAVR */
/* ... */
};
```

```
/* Function that reads joystick movement data */
void read_joystick(USB_JOYSTICK_t *joystick_state)
{
    /* The code below must be replaced with one that
       actually reads data from the joystick hardware */

    /* Move the joystick diagonally by 50 units
       and press button 1 */
    joystick_state->x=50;
    joystick_state->y=50;
    joystick_state->z=0;
    joystick_state->buttons=USB_JOYSTICK_BTN1;
}

void main(void)
{
    /* New new_joystick movement and button state */
    USB_JOYSTICK_t new_joystick;

    /* Initialization code for other chip peripherals */
    /* ... */

    /* USB Controller initialization in device mode */
    usb_init_device(&usb_config);

    /* Globally enable interrupts */
    #asm("sei")

    /* Wait for the USB device to be enumerated by the host */
    while (!usb_enumerated);

    /* Wait 1.5 seconds for the operating system to
       load any drivers needed by the USB device */
    delay_ms(1500);

    /* Initially there's no joystick movement
       and no buttons are pressed */
    usb_joystick.x=0;
    usb_joystick.y=0;
    usb_joystick.z=0;
    usb_joystick.buttons=0;

    while (1)
    {
        /* Read new joystick movement data */
        read_joystick(&new_joystick);

        /* Send the new_joystick movement data to the host
           only if the joystick state changed */
        if (memcmp(&usb_joystick,&new_joystick,sizeof(USB_JOYSTICK_t)))
            /* This function also updates the usb_joystick global
               structure with the new values */
            usb_joystick_move(&new_joystick);
    }
}
```

A detailed example on HID Joystick usage is available in the **\\EXAMPLES\\USB\\HID Joystick** subdirectory of the CodeVisionAVR installation.
The data sent by the joystick example can be displayed on the host side (PC), using the **Joystick Test.exe** program located in the above mentioned directory.

No special Windows driver is required, the HID Joystick will be detected by the operating system when the device is connected to the PC.

5.21 Power Management Functions

The Power Management Functions are intended for putting the AVR chip in one of its low power consumption modes.

The prototypes for these functions are placed in the file **sleep.h**, located in the **.\INC** subdirectory. This file must be **#include -d** before using the functions.

The Power Management Functions are:

void sleep_enable(void)

this function enables entering the low power consumption modes.

void sleep_disable(void)

this function disables entering the low power consumption modes.

It is used to disable accidental entering the low power consumption modes.

void idle(void)

this function puts the AVR chip in the idle mode.

Prior to using this function, the **sleep_enable** function must be invoked to allow entering the low power consumption modes.

In this mode the CPU is stopped, but the Timers/Counters, Watchdog and interrupt system continue operating.

The CPU can wake up from external triggered interrupts as well as internal ones.

void powerdown(void)

this function puts the AVR chip in the powerdown mode.

Prior to using this function, the **sleep_enable** function must be invoked to allow entering the low power consumption modes.

In this mode the external oscillator is stopped.

The AVR can wake up only from an external reset, Watchdog time-out or external level triggered interrupt.

void powersave(void)

this function puts the AVR chip in the powersave mode.

Prior to using this function, the **sleep_enable** function must be invoked to allow entering the low power consumption modes.

This mode is similar to the powerdown mode with some differences, please consult the Atmel Data Sheet for the particular chip that you use.

void standby(void)

this function puts the AVR chip in the standby mode.

Prior to using this function, the **sleep_enable** function must be invoked to allow entering the low power consumption modes.

This mode is similar to the powerdown mode with the exception that the external clock oscillator keeps on running.

Consult the Atmel Data Sheet for the particular chip that you use, in order to see if the standby mode is available for it.

void extended_standby(void)

this function puts the AVR chip in the extended standby mode.
Prior to using this function, the **sleep_enable** function must be invoked to allow entering the low power consumption modes.
This mode is similar to the powersave mode with the exception that the external clock oscillator keeps on running.
Consult the Atmel Data Sheet for the particular chip that you use, in order to see if the standby mode is available for it.

Note: There are specific situations where the power management functions can't be used because of the timing limitations.
For example the ATmega168P chip has a feature which is not available in ATmega168: Brown-Out Detection disable during sleep.
If we wish to use this feature, we need to enter in sleep mode in maximum 4 clocks after the **BODS** bit is set in the **MCUCR** register.
But calling and executing the **powersave** function requires a longer time than this, so this example code will not function correctly:

```
unsigned char tmp;

sleep_enable();
/* Disable brown out detection in sleep */
tmp = MCUCR | (1<<BODS) | (1<<BODSE);
MCUCR = tmp;
MCUCR = tmp & ~(1<<BODSE);
powersave(); /* Takes too long until the sleep instruction is executed */
```

This is the correct code:

```
unsigned char tmp;

/* Prepare the sleep in power save mode*/
SMCR |= (1<<SE) | (1<<SM1) | (1<<SM0);
/* Disable brown out detection in sleep */
tmp = MCUCR | (1<<BODS) | (1<<BODSE);
MCUCR = tmp;
MCUCR = tmp & ~(1<<BODSE);
/* Enter sleep mode */
asm("sleep");
```

5.22 Delay Functions

These functions are intended for generating delays in C programs.

The prototypes for these functions are placed in the file **delay.h**, located in the **.\INC** subdirectory. This file must be **#include -d** before using the functions.

Before calling the functions the interrupts must be disabled, otherwise the delays will be much longer than expected.

Also it is very important to specify the correct AVR chip clock frequency in the **Project|Configure|C Compiler|Code Generation** menu.

The functions are:

void delay_us(unsigned int n)

generates a delay of n μ seconds. n must be a constant expression.

void delay_ms(unsigned int n)

generates a delay of n milliseconds.

This function automatically resets the watchdog timer every 1ms by generating the **wdr** instruction.

Example:

```
void main(void) {
/* disable interrupts */
#asm("cli")

/* 100 $\mu$ s delay */
delay_us(100);

/* ..... */

/* 10ms delay */
delay_ms(10);

/* enable interrupts */
#asm("sei")

/* ..... */
}
```

5.23 MMC/SD/SD HC FLASH Memory Card Driver Functions

The MMC/SD/SD HC FLASH Memory Card Driver Functions are intended for interfacing between C programs and MMC, SD, SD HC cards using the SPI bus interface.

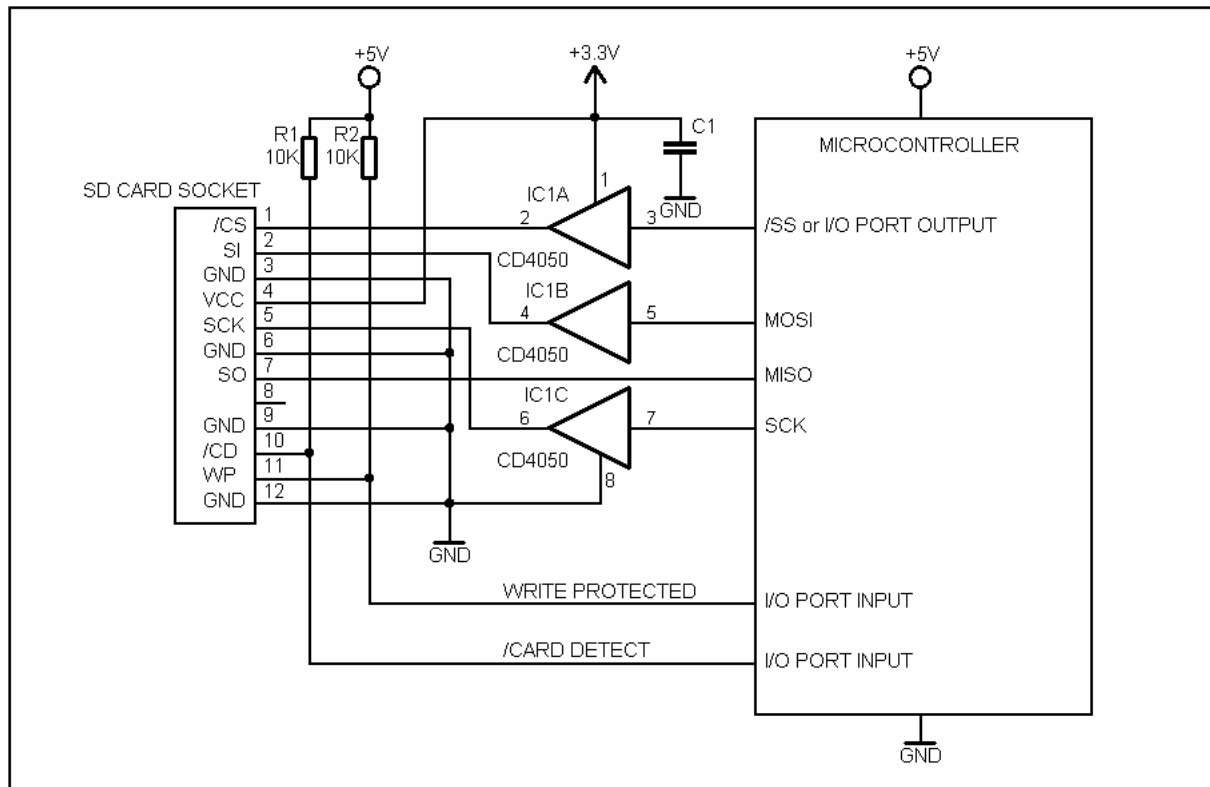
These low level functions are referenced by the high level **FAT Access Functions**.

The unctons are based on the open source drivers provided by Mr. ChaN from Electronic Lives Mfg.
<http://elm-chan.org>

Before using the card driver functions, the I/O port signals employed for communication with the MMC/SD/SD HC card must be configured in the **Project|Configure|C Compiler|Libraries|MMC/SD/SD HC Card** menu.

Note: The MMC/SD/SD HC card driver functions are not re-entrant. They must not be called from interrupt service routines.

The MMC/SD/SD HC card must be connected to the AVR microcontroller using a CD4050 CMOS buffer that will translate the 5V logic signals to 3.3V as needed by the card. The connection schematic is provided below:



Note: The drivers can be also used with hardware designs which set the **WP** signal to logic 0 when the MMC/SD/SD HC Card is write protected. In this case the **WP Active Low** option must be enabled in the **Project|Configure|C Compiler|Libraries|MMC/SD/SD HC Card** menu.

The MMC/SD/SD HC card driver function prototypes, helper type definitions and macros are placed in the header file **sdcard.h**, located in the **.INC** subdirectory. This file must be **#include -d** before using the functions.

The MMC/SD/SD HC card driver functions are:

void disk_timerproc (void)

is a low level timing function that must be called every 10ms by a Timer interrupt.

Note: It is mandatory to ensure that this function is called every 10ms in your program. Otherwise the MMC/SD/SD HC card driver functions will lock in an endless loop when testing for disk operations timeout.

Example:

```
/* ATmega128 I/O register definitions */
#include <mega128.h>
/* MMC/SD/SD HC card support */
#include <sdcard.h>

/* Timer1 overflow interrupt frequency [Hz] */
#define T1_OVF_FREQ 100
/* Timer1 clock prescaler value */
#define T1_PRESC 1024L
/* Timer1 initialization value after overflow */
#define T1_INIT (0x1000L-(_MCU_CLOCK_FREQUENCY_/ (T1_PRESC*T1_OVF_FREQ)))

/* 100Hz timer interrupt generated by ATmega128 Timer1 overflow */
interrupt [TIM1_OVF] void timer_comp_isr(void)
{
    /* re-initialize Timer1 */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* card access low level timing function */
    disk_timerproc();

    /* the rest of the interrupt service routine */
    /* .... */

}

void main(void)
{
    /* initialize Timer1 overflow interrupts in Mode 0 (Normal) */
    TCCR1A=0x00;
    /* clkio/1024 */
    TCCR1B=(1<<CS12)|(1<<CS10);
    /* timer overflow interrupts will occur with 100Hz frequency */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* enable Timer1 overflow interrupt */
    TIMSK=1<<TOIE1;
    /* globally enable interrupts */
    #asm("sei")

    /* the rest of the program */
    /* .... */

    while(1)
    {
        /* .... */
    }
}
```

unsigned char disk_initialize(unsigned char drv)

performs the initialization, including the SPI bus interface and I/O ports, of a physical drive located on a MMC, SD or SD HC card.

Parameters:

drv represents the drive number. Drive numbering starts with 0.

Return value:

The function returns 1 byte containing the disk status flags, specified by the following macros defined in **sdcard.h**:

- STA_NOINIT (=0x01, bit 0 of function result) Disk drive not initialized. This flag is set after microcontroller reset, card removal or when the **disk_initialize** function has failed.
- STA_NODISK (=0x02, bit 1 of function result) This flag is set if no card is inserted in the socket. **Note:** the STA_NOINIT flag is also set in this situation.
- STA_PROTECT (=0x04, bit 2 of function result) Card is write protected. If the STA_NODISK flag is also set, the STA_PROTECT flag is not valid.

On success, the function returns 0, which means all status flags are reset.

Note:

- For the MMC/SD/SD HC card driver using the SPI interface, the **drv** parameter must be always 0, otherwise the function will return with the STA_NOINIT flag set.
- The **disk_initialize** function will always configure the I/O port pin, where the SPI /SS signal is present, as an output. This is required for the correct operation of the SPI in master mode. The /SS signal can be used as a general purpose output, without affecting the MMC/SD/SD HC card driver operation.

Example:

```
/* ATmega128 I/O register definitions */
#include <mega128.h>
/* MMC/SD/SD HC card support */
#include <sdcard.h>
/* delay functions */
#include <delay.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* Timer1 overflow interrupt frequency [Hz] */
#define T1_OVF_FREQ 100
/* Timer1 clock prescaler value */
#define T1_PRESC 1024L
/* Timer1 initialization value after overflow */
#define T1_INIT (0x10000L-(_MCU_CLOCK_FREQUENCY_/ (T1_PRESC*T1_OVF_FREQ)))
```

```
/* 100Hz timer interrupt generated by ATmega128 Timer1 overflow */
interrupt [TIM1_OVF] void timer_comp_isr(void)
{
    /* re-initialize Timer1 */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* card access low level timing function */
    disk_timerproc();

    /* the rest of the interrupt service routine */
    /* .... */

}

void main(void)
{
    unsigned char status;

    /* initialize Timer1 overflow interrupts in Mode 0 (Normal) */
    TCCR1A=0x00;
    /* clkio/1024 */
    TCCR1B=(1<<CS12)|(1<<CS10);
    /* timer overflow interrupts will occur with 100Hz frequency */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* enable Timer1 overflow interrupt */
    TIMSK=1<<TOIE1;
    /* initialize the LCD, 16 characters/line */
    lcd_init(16);
    /* globally enable interrupts */
    #asm("sei")
    /* initialize SPI interface and card driver */
    status=disk_initialize(0);
    /* clear the LCD */
    lcd_clear();
    /* display disk initialization result on the LCD */
    if (status & STA_NODISK) lcd_puts("Card not present");
    else
    if (status & STA_NOINIT) lcd_puts("Disk init failed");
    else
    if (status & STA_PROTECT) lcd_puts("Card write\nprotected");
    /* all status flags are 0, disk initialization OK */
    else lcd_puts("Init OK");
    /* wait 2 seconds */
    delay_ms(2000);

    /* the rest of the program */
    /* .... */

    while(1)
    {
        /* .... */

    }
}
```

bool sdcard_present(void)

is used for detecting the presence of a FLASH memory card inserted in the socket. It returns **true** in this case.

Notes:

- This function must be called before performing memory card accesses, in the situation when the usage of the /CD (card detect) signal is disabled in the in the **Project|Configure|C Compiler|Libraries|MMC/SD/SD HC Card** menu.
- If the function is called before **disk_initialize**, it will automatically first perform the initialization, including the SPI bus interface and I/O ports, of the physical drive.

unsigned char disk_status(unsigned char drv)

returns the current disk status of a physical drive located on a MMC, SD or SD HC card.

Parameters:

drv represents the drive number. Drive numbering starts with 0.

Return value:

The function returns 1 byte containing the disk status flags, specified by the following macros defined in **sdcard.h**:

- STA_NOINIT (=0x01, bit 0 of function result) Disk drive not initialized. This flag is set after microcontroller reset, card removal or when the **disk_initialize** function has failed.
- STA_NODISK (=0x02, bit 1 of function result) This flag is set if no card is inserted in the socket. **Note:** the STA_NOINIT flag is also set in this situation.
- STA_PROTECT (=0x04, bit 2 of function result) Card is write protected. If the STA_NODISK flag is also set, the STA_PROTECT flag is not valid.

On success, the function returns 0, which means all status flags are reset.

Note: For the MMC/SD/SD HC card driver using the SPI interface, the **drv** parameter must be always 0, otherwise the function will return with the STA_NOINIT flag set.

The **DRESULT** enumeration data type is defined in **sdcard.h**:

```
typedef enum
{
    RES_OK=0,           /* 0: Successful */
    RES_ERROR,          /* 1: R/W Error */
    RES_WRPRT,          /* 2: Write Protected */
    RES_NOTRDY,         /* 3: Not Ready */
    RES_PARERR          /* 4: Invalid Parameter */
} DRESULT;
```

It is used for returning the result of the following driver functions:

DRESULT disk_read (unsigned char drv, unsigned char* buff, unsigned long sector, unsigned char count)

reads sectors from a physical drive.

Parameters:

drv represents the drive number. Drive numbering starts with 0.

buff points to the char array where read data will be stored.

sector represents the Logical Block Address number of the first sector to be read.

count represents the number of sectors to be read (1..255).

Return value:

RES_OK - success

RES_ERROR - a write error occurred

RES_WRPRT - the MMC/SD/SD HC card is write protected

RES_NOTRDY - the disk drive has not been initialized

RES_PARERR - invalid parameters were passed to the function.

Note: For the MMC/SD/SD HC card driver using the SPI interface, the **drv** parameter must be always 0, otherwise the function will return with the STA_NOINIT flag set.

DRESULT disk_write (unsigned char drv, unsigned char* buff, unsigned long sector, unsigned char count)

writes sectors to a physical drive.

Parameters:

drv represents the drive number. Drive numbering starts with 0.

buff points to the char array where the data to be written is stored.

sector represents the Logical Block Address number of the first sector to be written.

count represents the number of sectors to be written (1..255).

Return value:

RES_OK - success

RES_ERROR - a write error occurred

RES_WRPRT - the SD/SD HC card is write protected

RES_NOTRDY - disk drive has not been initialized

RES_PARERR - invalid parameters were passed to the function.

Note: For the MMC/SD/SD HC card driver using the SPI interface, the **drv** parameter must be always 0, otherwise the function will return with the STA_NOINIT flag set.

DRESULT disk_ioctl (unsigned char drv, unsigned char ctrl, void* buff)

this function is used for controlling MMC/SD/SD HC card specific features and other disk functions.

Parameters

drv represents the drive number. Drive numbering starts with 0.

ctrl specifies the command code.

buff points to the buffer that will hold function results depending on the command code.

When not used, a NULL pointer must be passed as parameter.

Return value:

RES_OK - success

RES_ERROR - an error occurred

RES_NOTRDY - the disk drive has not been initialized

RES_PARERR - invalid parameters were passed to the function.

Note: For the MMC/SD/SD HC card driver using the SPI interface, the **drv** parameter must be always 0, otherwise the function will return with the STA_NOINIT flag set.

The following **ctrl** command codes, specified by the macros defined in the **sdcard.h** header file, can be issued to the **disk_ioctl** function:

- CTRL_SYNC - wait until the disk drive has finished the write process. The **buff** pointer must be NULL.
- GET_SECTOR_SIZE - returns the size of the drive's sector. The **buff** pointer must point to a 16bit **unsigned int** variable, that will contain the sector size. For MMC/SD/SD HC cards the returned sector size will be 512 bytes.
- GET_SECTOR_COUNT - returns the total number of sectors on the drive. The **buff** pointer must point to a 32bit **unsigned long int** variable, that will contain the sector count.
- GET_BLOCK_SIZE - returns the erase block size of the drive's memory array in sectors count. The **buff** pointer must point to a 32bit **unsigned long int** variable, that will contain the block size. If the erase block size is not known, the returned value will be 1.

Example:

```
/* ATmega128 I/O register definitions */
#include <mega128.h>
/* MMC/SD/SD HC card support */
#include <sdcard.h>
/* delay functions */
#include <delay.h>
/* sprintf */
#include <stdio.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* Timer1 overflow interrupt frequency [Hz] */
#define T1_OVF_FREQ 100
/* Timer1 clock prescaler value */
#define T1_PRESC 1024L
/* Timer1 initialization value after overflow */
#define T1_INIT (0x1000L-(_MCU_CLOCK_FREQUENCY_/(T1_PRESC*T1_OVF_FREQ)))
```

```
/* 100Hz timer interrupt generated by ATmega128 Timer1 overflow */
interrupt [TIM1_OVF] void timer_comp_isr(void)
{
/* re-initialize Timer1 */
TCNT1H=T1_INIT>>8;
TCNT1L=T1_INIT&0xFF;
/* card access low level timing function */
disk_timerproc();

/* the rest of the interrupt service routine */
/* .... */

}

void main(void)
{
char display_buffer[64]; /* buffer used by sprintf */
unsigned char status;
unsigned int sector_size;
unsigned long int sector_count;

/* initialize Timer1 overflow interrupts in Mode 0 (Normal) */
TCCR1A=0x00;
/* clkio/1024 */
TCCR1B=(1<<CS12)|(1<<CS10);
/* timer overflow interrupts will occur with 100Hz frequency */
TCNT1H=T1_INIT>>8;
TCNT1L=T1_INIT&0xFF;
/* enable Timer1 overflow interrupt */
TIMSK=1<<TOIE1;
/* initialize the LCD */
lcd_init(16);
/* globally enable interrupts */
#asm("sei")
/* initialize SPI interface and card driver */
status=disk_initialize(0);
/* clear the LCD */
lcd_clear();
/* display disk initialization result on the LCD */
if (status & STA_NOINIT) lcd_puts("Disk init failed");
else
if (status & STA_NODISK) lcd_puts("Card not present");
else
if (status & STA_PROTECT) lcd_puts("Card write\nprotected");
/* all status flags are 0, disk initialization OK */
else
{
lcd_puts("Init OK");
/* wait 2 seconds */
delay_ms(2000);
/* clear the LCD */
lcd_clear();
}
```

```
/* get the sector size */
if (disk_ioctl(0,GET_SECTOR_SIZE,&sector_size)==RES_OK)
{
    /* sector size read OK, display it */
    sprintf(display_buffer,"Sector size=%u",sector_size);
    lcd_puts(display_buffer);
    /* wait 2 seconds */
    delay_ms(2000);
    /* clear the LCD */
    lcd_clear();
    /* get the sector count */
    if (disk_ioctl(0,GET_SECTOR_COUNT,&sector_count)==RES_OK)
    {
        /* sector count read OK, display it */
        sprintf(display_buffer,"Sector count=%lu",sector_count);
        lcd_puts(display_buffer);
    }
    else lcd_puts("Error reading\nsector count");
}
else lcd_puts("Error reading\nsector size");
}

/* wait 2 seconds */
delay_ms(2000);

/* the rest of the program */
/* .... */

while(1)
{
    /* .... */

}
```

Note: When compiling the above example, make sure that the **(s)printf Features** option in the **Project|Configure|C Compiler|Code Generation** menu will be set to: **long, width**. This will ensure that the unsigned long int **sector_count** variable will be displayed correctly by the **sprintf** function.

5.24 FAT Access Functions

These functions are intended for high level data access to MMC/SD/SD HC FLASH memory cards formatted using the FAT12, FAT16 or FAT32 standards.

The FAT access functions are based on FATFS open source library by Mr. ChaN from Electronic Lives Mfg. <http://elm-chan.org>

The FAT access function prototypes, helper type definitions and macros are placed in the header file **ff.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

The FAT access functions call the low level **MMC/SD/SD HC Card Driver** functions, so the I/O port signals employed for communication with the MMC/SD/SD HC card must be configured in the **Project|Configure|C Compiler|Libraries|MMC/SD/SD HC Card** menu.

Notes:

- The FAT access functions are not re-entrant. They must not be called from interrupt service routines.
- Currently the FAT access functions support only the DOS short 8.3 file name format. Long file names are not supported.
- The file/directory names are encoded using 8bit ASCII, unicode characters are not supported.
- Before being accessed using the FAT functions, the MMC/SD/SD HC card must be partitioned and formatted to FAT12, FAT16 or FAT32 system on a PC.

The following helper data types are defined in **ff.h**:

- The **FRESULT** type is used for returning the result of the FAT access functions:

```
typedef enum
{
    FR_OK = 0,                /* (0) Succeeded */
    FR_DISK_ERR,             /* (1) A hard error occurred in the low level
                             disk I/O layer */
    FR_INT_ERR,              /* (2) Assertion failed */
    FR_NOT_READY,            /* (3) The physical drive doesn't work */
    FR_NO_FILE,              /* (4) Could not find the file */
    FR_NO_PATH,              /* (5) Could not find the path */
    FR_INVALID_NAME,         /* (6) The path name format is invalid */
    FR_DENIED,               /* (7) Acces denied due to prohibited access or
                             directory full */
    FR_EXIST,                /* (8) Acces denied due to prohibited access */
    FR_INVALID_OBJECT,       /* (9) The file/directory object is invalid */
    FR_WRITE_PROTECTED,      /* (10) The physical drive is write protected */
    FR_INVALID_DRIVE,        /* (11) The logical drive number is invalid */
    FR_NOT_ENABLED,          /* (12) The volume has no work area */
    FR_NO_FILESYSTEM,        /* (13) There is no valid FAT volume */
    FR_MKFS_ABORTED,         /* (14) f_mkfs() aborted due to a parameter
                             error */
    FR_TIMEOUT,              /* (15) Could not access the volume within
                             the defined period */
    FR_INVALID_PARAMETER=19 /* (19) Given parameter is invalid */
} FRESULT;
```

- The **FATFS** type structure is used for holding the work area associated with each logical drive volume:

```
typedef struct _FATFS_  
{  
    unsigned char    fs_type;    /* FAT sub type */  
    unsigned char    drive;      /* Physical drive number */  
    unsigned char    csize;      /* Number of sectors per cluster */  
    unsigned char    n_fats;     /* Number of FAT copies */  
    unsigned char    wflag;      /* win[] dirty flag (1:must be written  
                                back) */  
  
    unsigned short   id;         /* File system mount ID */  
    unsigned short   n_rootdir;  /* Number of root directory entries  
                                (0 on FAT32) */  
    unsigned char    fsi_flag;   /* fsinfo dirty flag  
                                (1:must be written back) */  
    unsigned long    last_clust; /* Last allocated cluster */  
    unsigned long    free_clust; /* Number of free clusters */  
    unsigned long    fsi_sector; /* fsinfo sector */  
    unsigned long    cdir;       /* Current directory (0:root)*/  
    unsigned long    sects_fat;   /* Sectors per fat */  
    unsigned long    max_clust;   /* Maximum cluster# + 1.  
                                Number of clusters is max_clust-2 */  
    unsigned long    fatbase;     /* FAT start sector */  
    unsigned long    dirbase;     /* Root directory start sector  
                                (Cluster# on FAT32) */  
    unsigned long    database;    /* Data start sector */  
    unsigned long    winsect;     /* Current sector appearing in the  
                                win[] */  
    unsigned char    win[512];    /* Disk access window for Directory/FAT  
                                */  
}  
FATFS;
```

A **FATFS** type object is allocated by the **f_mount** function for each logical drive.

- The **FIL** type structure is used to hold the state of an open file:

```
typedef struct _FIL_  
{  
    FATFS*    fs;                /* Pointer to the owner file system  
                                object */  
    unsigned short   id;         /* Owner file system mount ID */  
    unsigned char    flag;       /* File status flags */  
    unsigned char    csect;      /* Sector address in the cluster */  
    unsigned long    fptr;       /* File R/W pointer */  
    unsigned long    fsize;      /* File size */  
    unsigned long    org_clust;  /* File start cluster */  
    unsigned long    curr_clust; /* Current cluster */  
    unsigned long    dsect;      /* Current data sector */  
    unsigned long    dir_sect;   /* Sector containing the directory  
                                entry */  
    unsigned char*    dir_ptr;    /* Pointer to the directory entry in  
                                the window */  
    unsigned char    buf[512];   /* File R/W buffer */  
}  
FIL;
```

This structure is initialized by the **f_open** and discarded by the **f_close** functions.

- The **FILINFO** type structure is used to hold the information returned by the **f_stat** and **f_readdir** functions:

```
typedef struct _FILINFO_  
{  
    unsigned long    fsize;        /* File size */  
    unsigned short   fdate;        /* Last modified date */  
    unsigned short   ftime;        /* Last modified time */  
    unsigned char     fattrib;     /* Attribute */  
    char  fname[13]; /* Short file name (DOS 8.3 format) */  
} FILINFO;
```

The **fdate** structure member indicates the date when the file was modified or the directory was created.

It has the following format:

bits 0:4 - Day: 1...31
bits 5:8 - Month: 1...12
bits 9:15 - Year starting with 1980: 0...127

The **ftime** structure member indicates the time when the file was modified or the directory was created.

It has the following format:

bits 0:4 - Second/2: 0...29
bits 5:10 - Minute: 0...59
bits 11:15 - Hour: 0...23

The **fattrib** structure member indicates the file or directory attributes combination defined by the following macros:

AM_RDO - Read Only attribute
AM_HID - Hidden attribute
AM_SYS - System attribute
AM_VOL - Volume attribute
AM_DIR - Directory attribute
AM_ARC - Archive attribute
AM_MASK - Mask of all defined attributes.

- The **DIR** type structure is used for holding directory information returned by the **f_opendir** and **f_readdir** functions:

```
typedef struct _DIR_  
{  
    FATFS*      fs;        /* Pointer to the owner file system object */  
    unsigned short  id;     /* Owner file system mount ID */  
    unsigned short  index;  /* Current read/write index number */  
    unsigned long   sclust; /* Table start cluster (0:Static table) */  
    unsigned long   clust;  /* Current cluster */  
    unsigned long   sect;   /* Current sector */  
    unsigned char*  dir;    /* Pointer to the current SFN entry in the win[] */  
    unsigned char*  fn;     /* Pointer to the SFN (in/out) {file[8],ext[3],status[1]} */  
} DIR;
```

The FAT access functions require the presence of a Real Time Clock in the system, in order to be able to set the time stamp of files or directories.

The following pointers to functions, that allow reading the time and date from the Real Time Clock, are declared in the **ff.h** header file:

void (*prtc_get_time) (unsigned char *hour, unsigned char *min, unsigned char *sec)

pointer to a Real Time Clock function used for reading time.

void (*prtc_get_date) (unsigned char *date, unsigned char *month, unsigned int *year)

pointer to a Real Time Clock function used for reading date.

On program startup these pointers need to be initialized to point to the appropriate RTC functions, like in the following example:

```
/* FAT on MMC/SD/SD HC card support */
#include <ff.h>

/* include the PCF8563 functions
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <PCF8563.h>

void main(void)
{
    /* init the PCF8563 RTC */
    rtc_init(0,RTC_CLKOUT_OFF,RTC_TIMER_OFF);

    /* init the pointer to the RTC function used for reading time */
    prtc_get_time=
        (void (*)(unsigned char *,unsigned char *,unsigned char *))
        rtc_get_time;

    /* init the pointer to the RTC function used for reading time */
    prtc_get_date=
        (void (*)(unsigned char *,unsigned char *,unsigned int *))
        rtc_get_date;

    /* follows the rest of the program */
    /* ... */
}
```

Notes:

- If the return type of the RTC functions is different from **void**, like required by the **prtc_get_time** and **prtc_get_date** pointer declarations, then casting to the appropriate type must be performed, like in the above example.
- If the system doesn't have a Real Time Clock, then these pointers must not be initialized at program startup. In this situation, they will be automatically initialized to NULL in the FAT access library and all files or directories created or modified by the FAT access functions will have the time stamp: January 1, 2009 00:00:00.

The FAT access functions are:

FRESULT f_mount(unsigned char vol, FATFS *fs)

allocates/deallocates a work area of memory for a logical drive volume.
This function must be called first before any other FAT access function.
In order to deallocate a work area associated with a logical drive, a NULL pointer must be passed as **fs**.

Note: This function only initializes the work area, no physical disk access is performed at this stage. The effective volume mount is performed on first file access after the function was called or after a media change.

Parameters:

vol specifies the logical drive number (0...9).
fs is a pointer to the FATFS type data structure associated with the logical drive that must be allocated/deallocated.

Return Values:

FR_OK - success
FR_INVALID_DRIVE - the drive number is invalid.

FRESULT f_open(FIL* fp, const char* path, unsigned char mode)

creates a file object **FIL** structure which will be used for accessing the file. The file read/write pointer is set to the start of the file.

Parameters:

fp points to the **FIL** type structure to be created. After the **f_open** function succeeds, this structure can be used by the other functions to access the file.
path points to a RAM based NULL terminated char string that represents the path name for the file to be created or opened.
The path name has the following format:

[logical_drive_number:][/][directory_name/]file_name

Examples:

file.txt - a file located in the current directory (specified previously by the **f_chdir** function) on the current drive (specified previously by the **f_chdrive** function).

/file.txt - a file located in the root directory of the current drive.

0:file.txt - a file located in the current directory (specified previously by the **f_chdir** function) on the logical drive 0.

0:/ - the root directory of logical drive 0.

0:/file.txt - a file located in the root directory of logical drive 0.

. - current directory.

.. - parent directory of the current directory.

The file_name must have the DOS 8.3 short file name format.

mode is the file access type and open method, represented by a combination of the flags specified by the following macros:

FA_READ - Read access to the object. Data can be read from the file. For read-write access it must be combined with **FA_WRITE**.

FA_WRITE - Write access to the object. Data can be written to the file. For read-write access it must be combined with **FA_READ**.

FA_OPEN_EXISTING - Opens the file. If the file doesn't exist, the function will fail.

FA_OPEN_ALWAYS - If the file exists, it will be opened. If the file doesn't exist, it will be first created and then opened.

FA_CREATE_NEW - Creates a new file. If the file already exists, the function will fail.

FA_CREATE_ALWAYS - Creates a new file. If the file already exists, it will be overwritten and its size set to 0.

Return values:

FR_OK - success.

FR_NO_FILE - couldn't find the file.

FR_NO_PATH - couldn't find the path.

FR_INVALID_NAME - the file name is invalid.

FR_INVALID_DRIVE - the drive number is invalid.

FR_EXIST - the file already exists.

FR_DENIED - file access was denied because one of the following reasons:

- trying to open a read-only file in write mode

- file couldn't be created because a file with the same name or read-only attribute already exists

- file couldn't be created because the directory table or disk are full.

FR_NOT_READY - no disk access was possible due to missing media or other reason.

FR_WRITE_PROTECTED - opening in write mode or creating a file was not possible because the media is write protected.

FR_DISK_ERR - the function failed because of a physical disk access function failure.

FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.

FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.

FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_read(FIL* fp, void* buff, unsigned int btr, unsigned int* br)

reads data from a file previously opened with **f_open**.

After the function is executed, the file read/write pointer advances with the number of bytes read from the file.

Parameters:

fp points to the **FIL** type structure that contains the file parameters. This structure must have been previously initialized by calling the **f_open** function.

buff points to a byte buffer array, located in RAM, that will hold the data read from the file. The size of the buffer must be large enough so that the data will fit in.

btr specifies the number of bytes to be read from the file.

br points to an unsigned int variable that will hold the number of bytes of data effectively read from the file. On function success, if the number of effectively read bytes is smaller than the **btr** value, then the file read/write pointer reached the end of the file.

Return values:

FR_OK - success.
FR_DENIED - file access was denied because it was opened in write-only mode.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_INVALID_OBJECT - the file was not opened with **f_open**.

FRESULT f_write(FIL* fp, const void* buff, unsigned int btw, unsigned int* bw)

writes data to a file previously opened with **f_open**.

After the function is executed, the file read/write pointer advances with the number of bytes written to the file.

Parameters:

fp points to the **FIL** type structure that contains the file parameters. This structure must have been previously initialized by calling the **f_open** function.

buff points to a byte buffer array, located in RAM, that holds the data to be written to the file.

btw specifies the number of bytes to be written to the file.

bw points to an unsigned int variable that will hold the number of bytes of data effectively written to the file.

Return values:

FR_OK - success.
FR_DENIED - file access was denied because it was opened in read-only mode.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_INVALID_OBJECT - the file was not opened with **f_open**.

FRESULT f_lseek(FIL* fp, unsigned long ofs)

moves the file read/write pointer of a file previously opened with **f_open**.

In write-mode, this function can be also used to extend the file size, by moving the file read/write pointer past the end of the file. On success the value of the **fptr** member of the **FIL** structure, pointed by **fp**, must be checked to see if the file read/write pointer effectively advanced to the correct position and the drive didn't get full.

In read-mode, trying to advance the file read/write pointer past the end, will limit its position to the end of the file. In this case the **fptr** member of the **FIL** structure, pointed by **fp**, will hold the size of the file.

Parameters:

fp points to the **FIL** type structure that contains the file parameters. This structure must have been previously initialized by calling the **f_open** function.

ofs represents the byte position where the file read/write pointer must be placed starting with the beginning of the file.

Return values:

FR_OK - success.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_INVALID_OBJECT - the file was not opened with **f_open**.

FRESULT f_truncate(FIL* fp)

truncates the file's size to the current position of the file read/write pointer.
If the read/write pointer is already at the end of the file, the function will have no effect.

Parameter:

fp points to the **FIL** type structure that contains the file parameters. This structure must have been previously initialized by calling the **f_open** function.

Return values:

FR_OK - success.
FR_DENIED - file access was denied because it was opened in read-only mode.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_INVALID_OBJECT - the file was not opened with **f_open**.

FRESULT f_close(FIL* fp)

closes a file previously opened using **f_open**.
If any data was written to the file, the cached information is written to the disk.
After the function succeeded, the **FIL** type structure pointed by **fp**, is not valid anymore and the RAM memory allocated for it can be released.
If the file was opened in read-only mode, the memory allocated for the **FIL** type structure, pointed by **fp**, can be released without the need for previously calling the **f_close** function.

Parameter:

fp points to the **FIL** type structure that contains the file parameters. This structure must have been previously initialized by calling the **f_open** function.

Return values:

FR_OK - success.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_INVALID_OBJECT - the file was not opened with **f_open**.

FRESULT f_sync(FIL* fp)

flushes the cached data when writing a file.
This function is useful for applications when a file is opened for a long time in write mode.
Calling **f_sync** periodically or right after **f_write** minimizes the risk of data loss due to power failure or media removal from the drive.

Note: There is no need to call **f_sync** before **f_close**, as the later also performs a write cache flush.

Parameter:

fp points to the **FIL** type structure that contains the file parameters. This structure must have been previously initialized by calling the **f_open** function.

Return values:

FR_OK - success.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_INVALID_OBJECT - the file was not opened with **f_open**.

FRESULT f_opendir(DIR* dj, const char* path)

opens an existing directory and initializes the **DIR** type structure that holds directory information, which may be used by other FAT access functions.
The memory allocated for the **DIR** type structure may be de-allocated at any time.

Parameters:

dj points to the **DIR** type structure that must be initialized.
path points to a RAM based NULL terminated char string that represents the path name for the directory to be opened.

Return values:

FR_OK - success.
FR_NO_PATH - couldn't find the path.
FR_INVALID_NAME - the directory name is invalid.
FR_INVALID_DRIVE - the drive number is invalid.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_readdir(DIR* dj, FILINFO* fno)

sequentially reads directory entries.
In order to read all the items in a directory this function must be called repeatedly.
When all items were read, the function will return a empty NULL char string in the **fname** member of the **FILINFO** structure, without any error.

Note: The "." and ".." directory entries are not filtered and will appear in the read entries.

Parameters:

dj points to the **DIR** type structure that holds directory information previously initialized by calling the **f_opendir** function.

fno points to the **FILINFO** type structure that will hold the file information for a read directory entry. If a NULL pointer is passed as **fno**, the directory entry read process will start from the beginning.

Return values:

FR_OK - success.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

Example:

```
/* ATmega128 I/O register definitions */
#include <mega128.h>
/* FAT on MMC/SD/SD HC card support */
#include <ff.h>
/* printf */
#include <stdio.h>
/* string functions */
#include <string.h>

/* Timer1 overflow interrupt frequency [Hz] */
#define T1_OVF_FREQ 100
/* Timer1 clock prescaler value */
#define T1_PRESC 1024L
/* Timer1 initialization value after overflow */
#define T1_INIT (0x10000L-(MCU_CLOCK_FREQUENCY/(T1_PRESC*T1_OVF_FREQ)))

/* USART Baud rate */
#define BAUD_RATE 19200
#define BAUD_INIT (MCU_CLOCK_FREQUENCY/(BAUD_RATE*16L)-1)

/* 100Hz timer interrupt generated by ATmega128 Timer1 overflow */
interrupt [TIM1_OVF] void timer_comp_isr(void)
{
    /* re-initialize Timer1 */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* MMC/SD/SD HC card access low level timing function */
    disk_timerproc();
}
```

```
/* error message list */
flash char * flash_error_msg[]=
{
    "", /* not used */
    "FR_DISK_ERR",
    "FR_INT_ERR",
    "FR_INT_ERR",
    "FR_NOT_READY",
    "FR_NO_FILE",
    "FR_NO_PATH",
    "FR_INVALID_NAME",
    "FR_DENIED",
    "FR_EXIST",
    "FR_INVALID_OBJECT",
    "FR_WRITE_PROTECTED",
    "FR_INVALID_DRIVE",
    "FR_NOT_ENABLED",
    "FR_NO_FILESYSTEM",
    "FR_MKFS_ABORTED",
    "FR_TIMEOUT"
};

/* display error message and stop */
void error(FRESULT res)
{
    if ((res>=FR_DISK_ERR) && (res<=FR_TIMEOUT))
        printf("ERROR: %p\r\n",error_msg[res]);
    /* stop here */
    while(1);
}

/* will hold file/directory information returned by f_readdir */
FILINFO file_info;

/* recursively scan directory entries and display them */
FRESULT directory_scan(char *path)
{
    /* will hold the directory information */
    DIR directory;
    /* FAT function result */
    FRESULT res;
    int i;
```

```
if ((res=f_opendir(&directory,path))==FR_OK)
{
    while (((res=f_readdir(&directory,&file_info))==FR_OK) &&
        file_info.fname[0])
    {
        /* display file/directory name and associated information */
        printf("%c%c%c%c%c %02u/%02u/%u %02u:%02u:%02u %9lu"
            " %s/%s\r\n",
            (file_info.fattrib & AM_DIR) ? 'D' : '-',
            (file_info.fattrib & AM_RDO) ? 'R' : '-',
            (file_info.fattrib & AM_HID) ? 'H' : '-',
            (file_info.fattrib & AM_SYS) ? 'S' : '-',
            (file_info.fattrib & AM_ARC) ? 'A' : '-',
            file_info.fdate & 0x1F, (file_info.fdate >> 5) & 0xF,
            (file_info.fdate >> 9)+1980,
            file_info.ftime >> 11, (file_info.ftime >> 5) & 0x3F,
            (file_info.ftime & 0x1F) << 1,
            file_info.fsize,path,file_info.fname);
        if (file_info.fattrib & AM_DIR)
        {
            /* it's a subdirectory */
            /* make sure to skip past "." and ".." when recursing */
            if (file_info.fname[0]!='.')
            {
                i=strlen(path);
                /* append the subdirectory name to the path */
                if (path[i-1]!='/') strcatf(path,"/");
                strcat(path,file_info.fname);
                /* scan subdirectory */
                res=directory_scan(path);
                /* restore the old path name */
                path[i]=0;
                /* remove any eventual '/' from the end of the path */
                --i;
                if (path[i]=='/') path[i]=0;
                /* stop if an error occurred */
                if (res!=FR_OK) break;
            }
        }
    }
}
return res;
}

void main(void)
{
    /* FAT function result */
    FRESULT res;
    /* will hold the information for logical drive 0: */
    FATFS drive;
    /* root directory path */
    char path[256]="0:/";
```

```
/* initialize Timer1 overflow interrupts in Mode 0 (Normal) */
TCCR1A=0x00;
/* clkio/1024 */
TCCR1B=(1<<CS12)|(1<<CS10);
/* timer overflow interrupts will occur with 100Hz frequency */
TCNT1H=T1_INIT>>8;
TCNT1L=T1_INIT&0xFF;
/* enable Timer1 overflow interrupt */
TIMSK=1<<TOIE1;

/* initialize the USART0 TX, 8N1, Baud rate: 19200 */
UCSR0A=0;
UCSR0B=1<<TXEN0;
UCSR0C=(1<<UCSZ01)|(1<<UCSZ00);
UBRR0H=BAUD_INIT>>8;
UBRR0L=BAUD_INIT&0xFF;

/* globally enable interrupts */
#asm("sei")

printf("Directory listing for root of logical drive 0:\r\n");

/* mount logical drive 0: */
if ((res=f_mount(0,&drive))==FR_OK)
    printf("Logical drive 0: mounted OK\r\n");
else
    /* an error occurred, display it and stop */
    error(res);

/* repeatedly read directory entries and display them */
if ((res=directory_scan(path))!=FR_OK)
    /* if an error occurred, display it and stop */
    error(res);

/* stop here */
while(1);
}
```

Note: When compiling the above example, make sure that the **(s)printf Features** option in the **Project|Configure|C Compiler|Code Generation** menu will be set to: **long, width**. This will ensure that the unsigned long int file sizes will be displayed correctly by the **printf** function.

FRESULT f_stat(const char* path, FILINFO* fno)

gets the file or directory status in a **FILINFO** type structure.

Parameters:

path points to a RAM based NULL terminated char string that represents the path name for the file or directory.

fno points to the **FILINFO** type structure that will hold the status information.

Return values:

FR_OK - success.
FR_NO_FILE - couldn't find the file.
FR_NO_PATH - couldn't find the path.
FR_INVALID_NAME - the file name is invalid.
FR_INVALID_DRIVE - the drive number is invalid.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_WRITE_PROTECTED - opening in write mode or creating a file was not possible because the media is write protected.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_getfree(const char* path, unsigned long* nclst, FATFS fatfs)**

gets the number of free clusters on the drive.

Parameters:

path points to a RAM based NULL terminated char string that represents the path name of the root directory of the logical drive.

nclst points to an unsigned long int variable that will hold the number of free clusters.

fatfs points to a pointer to the FATFS type structure associated with the logical drive.

Return values:

FR_OK - success.
FR_INVALID_DRIVE - the drive number is invalid.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_WRITE_PROTECTED - opening in write mode or creating a file was not possible because the media is write protected.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

The **csize** member of the FATFS structure represents the number of sectors/cluster, so the free size in bytes can be calculated using the example below:

```
/* ATmega128 I/O register definitions */
#include <mega128.h>
/* FAT on MMC/SD/SD HC card support */
#include <ff.h>
/* printf */
#include <stdio.h>

/* Timer1 overflow interrupt frequency [Hz] */
#define T1_OVF_FREQ 100
/* Timer1 clock prescaler value */
#define T1_PRESC 1024L
/* Timer1 initialization value after overflow */
#define T1_INIT (0x1000L-(_MCU_CLOCK_FREQUENCY_/ (T1_PRESC*T1_OVF_FREQ)))

/* USART Baud rate */
#define BAUD_RATE 19200
#define BAUD_INIT (_MCU_CLOCK_FREQUENCY_/ (BAUD_RATE*16L)-1)

/* 100Hz timer interrupt generated by ATmega128 Timer1 overflow */
interrupt [TIM1_OVF] void timer_comp_isr(void)
{
    /* re-initialize Timer1 */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* card access low level timing function */
    disk_timerproc();
}

/* error message list */
flash char * flash_error_msg[]=
{
    "", /* not used */
    "FR_DISK_ERR",
    "FR_INT_ERR",
    "FR_INT_ERR",
    "FR_NOT_READY",
    "FR_NO_FILE",
    "FR_NO_PATH",
    "FR_INVALID_NAME",
    "FR_DENIED",
    "FR_EXIST",
    "FR_INVALID_OBJECT",
    "FR_WRITE_PROTECTED",
    "FR_INVALID_DRIVE",
    "FR_NOT_ENABLED",
    "FR_NO_FILESYSTEM",
    "FR_MKFS_ABORTED",
    "FR_TIMEOUT"
};
```

```
/* display error message and stop */
void error(FRESULT res)
{
    if ((res>=FR_DISK_ERR) && (res<=FR_TIMEOUT))
        printf("ERROR: %p\r\n",error_msg[res]);
    /* stop here */
    while(1);
}

void main(void)
{
    /* FAT function result */
    FRESULT res;
    /* will hold the information for logical drive 0: */
    FATFS fat;
    /* pointer to the FATFS type structure */
    FATFS *pfat;
    /* number of free clusters on logical drive 0:*/
    unsigned long free_clusters;
    /* number of free kbytes on logical drive 0: */
    unsigned long free_kbytes;
    /* root directory path for logical drive 0: */
    char root_path[]="0:/";

    /* initialize Timer1 overflow interrupts in Mode 0 (Normal) */
    TCCR1A=0x00;
    /* clkio/1024 */
    TCCR1B=(1<<CS12)|(1<<CS10);
    /* timer overflow interrupts will occur with 100Hz frequency */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* enable Timer1 overflow interrupt */
    TIMSK=1<<TOIE1;

    /* initialize the USART0 TX, 8N1, Baud rate: 19200 */
    UCSR0A=0;
    UCSR0B=1<<TXEN0;
    UCSR0C=(1<<UCSZ01)|(1<<UCSZ00);
    UBRR0H=BAUD_INIT>>8;
    UBRR0L=BAUD_INIT&0xFF;

    /* globally enable interrupts */
    #asm("sei")

    /* point to the FATFS structure that holds
    information for the logical drive 0: */
    pfat=&fat;

    /* mount logical drive 0: */
    if ((res=f_mount(0,pfat))==FR_OK)
        printf("Logical drive 0: mounted OK\r\n");
    else
        /* an error occurred, display it and stop */
        error(res);
}
```

```
/* get the number of free clusters */
if ((res=f_getfree(root_path,&free_clusters,&pfat))==FR_OK)
{
    /* calculate the number of free bytes */
    free_kbytes=free_clusters *
        /* cluster size in sectors */
        pfat->csize
        /* divide by 2 to obtain the sector size in kbytes
        512 (sector size in bytes)/1024 = 1/2 kbytes
        we need to do the division by 2 directly,
        in order to prevent unsigned long multiplication
        overflow for 8GB+ SD HC cards */
        /2;
    /* display the number of free kbytes */
    printf("Free space on logical drive 0: %lu kbytes\r\n",free_kbytes);
}
else
    /* an error occurred, display it and stop */
    error(res);

/* stop here */
while(1);
}
```

Note: When compiling the above example, make sure that the **(s)printf Features** option in the **Project[Configure]C Compiler[Code Generation]** menu will be set to: **long, width**. This will ensure that the unsigned long int file sizes will be displayed correctly by the **printf** function.

FRESULT f_mkdir (const char* path)

creates a new directory.

Parameter:

path points to a RAM based NULL terminated char string that represents the path name for the directory to be created.

Return values:

FR_OK - success.
FR_NO_PATH - couldn't find the path.
FR_INVALID_NAME - the directory name is invalid.
FR_INVALID_DRIVE - the drive number is invalid.
FR_EXIST - the directory already exists.
FR_DENIED - the directory couldn't be created because the directory table or disk are full.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_WRITE_PROTECTED - creating the directory was not possible because the media is write protected.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_unlink(const char* path)

deletes an existing file or directory.

Parameter:

path points to a RAM based NULL terminated char string that represents the path name for the file or directory to be deleted.

Return values:

FR_OK - success.
FR_NO_FILE - couldn't find the file or directory.
FR_NO_PATH - couldn't find the path.
FR_INVALID_NAME - the file or directory name is invalid.
FR_INVALID_DRIVE - the drive number is invalid.
FR_DENIED - access was denied because one of the following reasons:
 - file or directory read-only attribute is set
 - the directory is not empty.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_WRITE_PROTECTED - the media in the drive is write protected.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_chmod (const char* path, unsigned char value, unsigned char mask)

changes the attribute of a file or directory.

Parameters:

path points to a RAM based NULL terminated char string that represents the path name for the file or directory.

value specifies the new combination of attribute flags to be set.

mask specifies the combination of which attribute flags must be changed.

The attribute is obtained by combining the following predefined macros:

AM_RDO - Read Only attribute flag
AM_HID - Hidden attribute flag
AM_SYS - System attribute flag
AM_ARC - Archive attribute flag

using the | binary OR operator.

Return values:

FR_OK - success.
FR_NO_FILE - couldn't find the file or directory.
FR_NO_PATH - couldn't find the path.
FR_INVALID_NAME - the file or directory name is invalid.
FR_INVALID_DRIVE - the drive number is invalid.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_WRITE_PROTECTED - the media in the drive is write protected.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_utime (const char* path, const FILINFO* fno)

changes the time stamp of a file or directory.

Parameters:

path points to a RAM based NULL terminated char string that represents the path name for the file or directory.

fno points to the **FILINFO** type structure that holds the file information and has the time stamp to be set contained in the **fdate** and **ftime** members.

Return values:

FR_OK - success.
FR_NO_FILE - couldn't find the file or directory.
FR_NO_PATH - couldn't find the path.
FR_INVALID_NAME - the file or directory name is invalid.
FR_INVALID_DRIVE - the drive number is invalid.
FR_NOT_READY - no disk access was possible due to missing media or other reason.
FR_WRITE_PROTECTED - the media in the drive is write protected.
FR_DISK_ERR - the function failed because of a physical disk access function failure.
FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.
FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.
FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

Example:

```
/* ATmega128 I/O register definitions */
#include <mega128.h>

/* FAT on MMC/SD/SD HC card support */
#include <ff.h>

/* printf */
#include <stdio.h>

/* include the PCF8563 functions
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <PCF8563.h>

/* Timer1 overflow interrupt frequency [Hz] */
#define T1_OVF_FREQ 100
/* Timer1 clock prescaler value */
#define T1_PRESC 1024L
/* Timer1 initialization value after overflow */
#define T1_INIT (0x10000L-(_MCU_CLOCK_FREQUENCY_/(T1_PRESC*T1_OVF_FREQ)))

/* USART Baud rate */
#define BAUD_RATE 19200
#define BAUD_INIT (_MCU_CLOCK_FREQUENCY_/(BAUD_RATE*16L)-1)

/* FAT function result */
FRESULT res;
/* number of bytes written/read to the file */
unsigned int nbytes;
/* will hold the information for logical drive 0: */
FATFS fat;
/* will hold the file information */
FIL file;
/* will hold file attributes, time stamp information */
FILINFO finfo;
/* file path */
char path[]="0:/file.txt";
/* text to be written to the file */
char text[]="I like CodeVisionAVR!";
/* file read buffer */
char buffer[256];

/* 100Hz timer interrupt generated by ATmega128 Timer1 overflow */
interrupt [TIM1_OVF] void timer_comp_isr(void)
{
    /* re-initialize Timer1 */
    TCNT1H=T1_INIT>>8;
    TCNT1L=T1_INIT&0xFF;
    /* card access low level timing function */
    disk_timerproc();
}
```

```
/* error message list */
flash char * flash_error_msg[]=
{
    "", /* not used */
    "FR_DISK_ERR",
    "FR_INT_ERR",
    "FR_INT_ERR",
    "FR_NOT_READY",
    "FR_NO_FILE",
    "FR_NO_PATH",
    "FR_INVALID_NAME",
    "FR_DENIED",
    "FR_EXIST",
    "FR_INVALID_OBJECT",
    "FR_WRITE_PROTECTED",
    "FR_INVALID_DRIVE",
    "FR_NOT_ENABLED",
    "FR_NO_FILESYSTEM",
    "FR_MKFS_ABORTED",
    "FR_TIMEOUT"
};

/* display error message and stop */
void error(FRESULT res)
{
    if ((res>=FR_DISK_ERR) && (res<=FR_TIMEOUT))
        printf("ERROR: %p\r\n",error_msg[res]);
    /* stop here */
    while(1);
}

/* display file's attribute, size and time stamp */
void display_status(char *file_name)
{
    if ((res=f_stat(file_name,&finfo))==FR_OK)
        printf("File: %s, Attributes: %c%c%c%c%c\r\n"
            "Date: %02u/%02u/%u, Time: %02u:%02u:%02u\r\n"
            "Size: %lu bytes\r\n",
            finfo.fname,
            (finfo.fattrib & AM_DIR) ? 'D' : '-',
            (finfo.fattrib & AM_RDO) ? 'R' : '-',
            (finfo.fattrib & AM_HID) ? 'H' : '-',
            (finfo.fattrib & AM_SYS) ? 'S' : '-',
            (finfo.fattrib & AM_ARC) ? 'A' : '-',
            finfo.fdate & 0x1F, (finfo.fdate >> 5) & 0xF,
            (finfo.fdate >> 9) + 1980,
            (finfo.ftime >> 11), (finfo.ftime >> 5) & 0x3F,
            (finfo.ftime & 0x1F) << 1,
            finfo.fsize);
    else
        /* an error occurred, display it and stop */
        error(res);
}
```



```
void main(void)
{
/* initialize Timer1 overflow interrupts in Mode 0 (Normal) */
TCCR1A=0x00;
/* clkio/1024 */
TCCR1B=(1<<CS12)|(1<<CS10);
/* timer overflow interrupts will occur with 100Hz frequency */
TCNT1H=T1_INIT>>8;
TCNT1L=T1_INIT&0xFF;
/* enable Timer1 overflow interrupt */
TIMSK=1<<TOIE1;

/* initialize the USART0 TX, 8N1, Baud rate: 19200 */
UCSR0A=0;
UCSR0B=1<<TXEN0;
UCSR0C=(1<<UCSZ01)|(1<<UCSZ00);
UBRR0H=BAUD_INIT>>8;
UBRR0L=BAUD_INIT&0xFF;

/* init the PCF8563 RTC */
rtc_init(0,RTC_CLKOUT_OFF,RTC_TIMER_OFF);

/* init the pointer to the RTC function used for reading time */
prtc_get_time=
    (void (*)(unsigned char *,unsigned char *,unsigned char *))
    rtc_get_time;

/* init the pointer to the RTC function used for reading date */
prtc_get_date=
    (void (*)(unsigned char *,unsigned char *,unsigned int *))
    rtc_get_date;

/* globally enable interrupts */
asm("sei")

/* mount logical drive 0: */
if ((res=f_mount(0,&fat))==FR_OK)
    printf("Logical drive 0: mounted OK\r\n");
else
    /* an error occurred, display it and stop */
    error(res);

printf("%s \r\n",path);

/* create a new file in the root of drive 0:
and set write access mode */
if ((res=f_open(&file,path,FA_CREATE_ALWAYS | FA_WRITE))==FR_OK)
    printf("File %s created OK\r\n",path);
else
    /* an error occurred, display it and stop */
    error(res);

/* write some text to the file,
without the NULL string terminator sizeof(data)-1 */
if ((res=f_write(&file,text,sizeof(text)-1,&nbytes))==FR_OK)
    printf("%u bytes written of %u\r\n",nbytes,sizeof(text)-1);
else
    /* an error occurred, display it and stop */
    error(res);
```

```
/* close the file */
if ((res=f_close(&file))==FR_OK)
    printf("File %s closed OK\r\n",path);
else
    /* an error occurred, display it and stop */
    error(res);

/* open the file in read mode */
if ((res=f_open(&file,path,FA_READ))==FR_OK)
    printf("File %s opened OK\r\n",path);
else
    /* an error occurred, display it and stop */
    error(res);

/* read and display the file's content.
   make sure to leave space for a NULL terminator
   in the buffer, so maximum sizeof(buffer)-1 bytes can be read */
if ((res=f_read(&file,buffer,sizeof(buffer)-1,&nbytes))==FR_OK)
{
    printf("%u bytes read\r\n",nbytes);
    /* NULL terminate the char string in the buffer */
    buffer[nbytes+1]=NULL;
    /* display the buffer contents */
    printf("Read text: \"%s\"\r\n",buffer);
}
else
    /* an error occurred, display it and stop */
    error(res);

/* close the file */
if ((res=f_close(&file))==FR_OK)
    printf("File %s closed OK\r\n",path);
else
    /* an error occurred, display it and stop */
    error(res);

/* display file's attribute, size and time stamp */
display_status(path);

/* change file's attributes, set the file to be Read-Only */
if ((res=f_chmod(path,AM_RDO,AM_RDO))==FR_OK)
    printf("Read-Only attribute set OK\r\n",path);
else
    /* an error occurred, display it and stop */
    error(res);
```

```
/* change file's time stamp */
#define DAY (6)
#define MONTH (3)
#define YEAR (2000)
#define SECOND (0)
#define MINUTE (40)
#define HOUR (14)

finfo.fdate=DAY | (MONTH<<5) | ((YEAR-1980)<<9);
finfo.ftime=(SECOND>>1) | (MINUTE<<5) | (HOUR<<11);
if ((res=f_utime(path,&finfo))==FR_OK)
    printf("New time stamp %02u/%02u/%u %02u:%02u:%02u set OK\r\n",
        DAY,MONTH,YEAR,HOUR,MINUTE,SECOND);
else
    /* an error occurred, display it and stop */
    error(res);

/* display file's new attribute and time stamp */
display_status(path);

/* change file's attributes, clear the Read-Only attribute */
if ((res=f_chmod(path,0,AM_RDO))==FR_OK)
    printf("Read-Only attribute cleared OK\r\n",path);
else
    /* an error occurred, display it and stop */
    error(res);

/* display file's new attribute and time stamp */
display_status(path);

/* stop here */
while(1);
}
```

Note: When compiling the above example, make sure that the **(s)printf Features** option in the **Project|Configure|C Compiler|Code Generation** menu will be set to: **int, width**.

FRESULT f_rename(const char* path_old, const char* path_new)

renames a file or directory.

If the new path contains a different directory than the old path, the file will be also moved to this directory.

The logical drive is determined by the old path, it must not be specified in the new path.

Parameters:

path_old points to a RAM based NULL terminated char string that represents the path name for the file or directory to be renamed.

path_new points to a RAM based NULL terminated char string that represents the new path name for the file or directory.

Return values:

FR_OK - success.

FR_NO_FILE - couldn't find the file or directory.

FR_NO_PATH - couldn't find the path.

FR_INVALID_NAME - the file or directory name is invalid.

FR_INVALID_DRIVE - the drive number is invalid.

FR_NOT_READY - no disk access was possible due to missing media or other reason.

FR_EXIST - the file or directory already exists.

FR_DENIED - the file or directory couldn't be created or moved from any reason..

FR_WRITE_PROTECTED - the media in the drive is write protected.

FR_DISK_ERR - the function failed because of a physical disk access function failure.

FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.

FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.

FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_chdir(const char* path)

changes the current directory of the current logical drive.

When the drive is mounted, the current directory is the root directory.

Note: After **f_chdir** is called, all subsequent file access function operations will be performed by default in the new current directory, if no other directory is specified when calling these functions.

Parameter:

path points to a RAM based NULL terminated char string that represents the path name for the directory to go.

Return values:

FR_OK - success.

FR_NO_PATH - couldn't find the path.

FR_INVALID_NAME - the file or directory name is invalid.

FR_INVALID_DRIVE - the drive number is invalid.

FR_NOT_READY - no disk access was possible due to missing media or other reason.

FR_DISK_ERR - the function failed because of a physical disk access function failure.

FR_INT_ERR - the function failed due to a wrong FAT structure or an internal error.

FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.

FR_NO_FILESYSTEM - there is no valid FAT partition on the disk.

FRESULT f_chdrive(unsigned char drv)

changes the current logical drive. The initial logical drive is 0.

Note: After **f_chdrive** is called, all subsequent file/directory access function operations will be performed by default on the new logical drive, if no other drive is specified when calling these functions.

Parameter:

drv specifies the logical drive number (0...9) to be set as current drive.

Return values:

FR_OK - success.

FR_INVALID_DRIVE - the drive number is invalid.

FRESULT f_mkfs(unsigned char drv, unsigned char number_fats, unsigned short bytes_cluster)

creates a single primary partition on the drive and formats it.

Parameter:

drv specifies the logical drive number (0...9) to be formatted.

number_fats specifies the number of FATs to be created on the drive during formatting. This parameter may take the values 1 or 2.

bytes_cluster specifies the number of bytes allocated for one cluster.

Return values:

FR_OK - success.

FR_INVALID_DRIVE - the drive number is invalid.

FR_INVALID_PARAMETER – the **number_fats** or **bytes_cluster** parameters are not valid

FR_NOT_READY - no disk access was possible due to missing media or other reason.

FR_DISK_ERR - the function failed because of a physical disk access function failure.

FR_NOT_ENABLED - the logical drive was not mounted with **f_mount**.

FR_WRITE_PROTECTED - the media in the drive is write protected.

FR_MKFS_ABORTED – the formatted disk size is too small or the **bytes_cluster** parameter is not correct for the disk size.

5.25 Peripheral Chips Functions

The CodeVisionAVR C Compiler has a rich set of library functions for accessing a large variety of peripheral chips using the I²C (TWI), 1 Wire and SPI buses.

5.25.1 Philips PCF8563 Real Time Clock Functions

These functions are intended for easy interfacing between C programs and the PCF8563 I²C bus real time clock (RTC), using both the hardware TWI and software bit-banged I²C bus functions. One of the following header files, located in the .INC subdirectory must be **#include** -d before using these functions:

- **pcf8563_twi.h** for hardware TWI
- **pcf8563.h** for software bit-banged I²C bus.

The appropriate header files for hardware TWI (**twi.h** or **twix.h**) or software bit-banged I²C bus (**i2c.h**) functions prototypes are automatically **#include** -d with the **pcf8563_twi.h** or **pcf8563.h**.

The **Project|Configure|C Compiler|Libraries|I2C** menu must be used for specifying the I/O port allocation of the **SCL** and **SDA** signals, along the **bit rate** of the **SCL** clock, for bit-banged I²C bus (not the hardware TWI) communication.

Note: For proper operation, the PCF8563 Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V (+3.3V for XMEGA devices) on the SCL and SDA signals.

The PCF8563 Functions are:

void rtc_init(unsigned char ctrl2, unsigned char clkout, unsigned char timer_ctrl)

this function initializes the PCF8563 chip.

Before calling this function, the TWI hardware, respectively I²C bus, must be initialized by calling the **twi_master_init** (**twi_init**, **twi_master_init** and **pcf8563_twi_init** for XMEGA devices), respectively **i2c_init** functions.

This is the first function that must be called prior to using the other PCF8563 Functions. Only one PCF8563 chip can be connected to the I²C bus.

The **ctrl2** parameter specifies the initialization value for the PCF8563 **Control/Status 2** register. The **pcf8563.h** header file defines the following macros which allow the easy setting of the **ctrl2** parameter:

- **RTC_TIE_ON** sets the **Control/Status 2** register bit **TIE** to 1
- **RTC_AIE_ON** sets the **Control/Status 2** register bit **AIE** to 1
- **RTC_TP_ON** sets the **Control/Status 2** register bit **TI/TP** to 1

These macros can be combined using the **|** operator in order to set more bits to 1.

The **clkout** parameter specifies the initialization value for the PCF8563 **CLKOUT Frequency** register. The **pcf8563.h** header file defines the following macros which allow the easy setting of the **clkout** parameter:

- **RTC_CLKOUT_OFF** disables the generation of pulses on the PCF8563 CLKOUT output
- **RTC_CLKOUT_1** generates 1Hz pulses on the PCF8563 CLKOUT output
- **RTC_CLKOUT_32** generates 32Hz pulses on the PCF8563 CLKOUT output
- **RTC_CLKOUT_1024** generates 1024Hz pulses on the PCF8563 CLKOUT output
- **RTC_CLKOUT_32768** generates 32768Hz pulses on the PCF8563 CLKOUT output.

The **timer_ctrl** parameter specifies the initialization value for the PCF8563 **Timer Control** register. The **pcf8563.h** header file defines the following macros which allow the easy setting of the **timer_ctrl** parameter:

- **RTC_TIMER_OFF** disables the PCF8563 Timer countdown
- **RTC_TIMER_CLK_1_60** sets the PCF8563 Timer countdown clock frequency to 1/60Hz
- **RTC_TIMER_CLK_1** sets the PCF8563 Timer countdown clock frequency to 1Hz
- **RTC_TIMER_CLK_64** sets the PCF8563 Timer countdown clock frequency to 64Hz
- **RTC_TIMER_CLK_4096** sets the PCF8563 Timer countdown clock frequency to 4096Hz.

Refer to the PCF8563 data sheet for more information.

void pcf8563_twi_init(TWI_MASTER_INFO_t *ptwim)

this function is used to initialize the PCF8563 library's internal variables when using the **TWI Functions for Master Mode Operation for XMEGA Devices**. It is not used for non-XMEGA devices.

The **ptwim** parameter must point to a **TWI_MASTER_INFO_t** structure variable, that is used to hold the information required by the TWI module when operating in master mode.

The **pcf8563_twi_init** function must be called before **rtc_init**.

Refer to the supplied example at the end of this chapter for more details.

unsigned char rtc_read(unsigned char address)

this function reads the byte stored in a PCF8563 register at **address**.

void rtc_write(unsigned char address, unsigned char data)

this function stores the byte **data** in the PCF8563 register at **address**.

unsigned char rtc_get_time(unsigned char *hour, unsigned char *min, unsigned char *sec)

this function returns the current time measured by the RTC .

The ***hour**, ***min** and ***sec** pointers must point to the variables that must receive the values of hour, minutes and seconds.

The function return the value 1 if the read values are correct.

If the function returns 0 then the chip supply voltage has dropped below the Vlow value and the time values are incorrect.

void rtc_set_time(unsigned char hour, unsigned char min, unsigned char sec)

this function sets the current time of the RTC .

The **hour**, **min** and **sec** parameters represent the values of hour, minutes and seconds.

void rtc_get_date(unsigned char *day, unsigned char *month, unsigned *year)

this function returns the current date measured by the RTC .

The ***day**, ***month** and ***year** pointers must point to the variables that must receive the values of day, month and year.

void rtc_set_date(unsigned char day, unsigned char month, unsigned year)

this function sets the current date of the RTC .

void rtc_alarm_off(void)

this function disables the RTC alarm function.

void rtc_alarm_on(void)

this function enables the RTC alarm function.

void rtc_get_alarm(unsigned char *day, unsigned char *hour, unsigned char *min)

this function returns the alarm time and date of the RTC.

The ***day**, ***hour** and ***min** pointers must point to the variables that must receive the values of day, hour and minutes.

void rtc_set_alarm(unsigned char day, unsigned char hour, unsigned char min)

this function sets the alarm time and date of the RTC.

The **day**, **hour** and **min** parameters represent the values of day, hours and minutes.

If **day** is set to 0, then this parameter will be ignored.

After calling this function the alarm will be turned off. It must be enabled using the **rtc_alarm_on** function.

void rtc_set_timer(unsigned char val)

this function sets the countdown value of the PCF8563 Timer.

PCF8563 example using the hardware TWI Functions for Master Mode Operation for non-XMEGA Devices:

```
/* include the PCF8563 functions for TWI */
#include <pcf8563_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,day,month;
    unsigned int year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the TWI in master mode with 100 kHz bit rate */
    twi_master_init(100);

    /* enable interrupts so that TWI can be used */
    #asm("sei")
}
```



```
/* initialize the RTC,
   Timer interrupt enabled,
   Alarm interrupt enabled,
   CLKOUT frequency=1Hz
   Timer clock frequency=1Hz */
rtc_init(RTC_TIE_ON | RTC_AIE_ON,RTC_CLKOUT_1,RTC_TIMER_CLK_1);

rtc_set_time(12,0,0); /* set time 12:00:00 */

rtc_set_date(1,2,2011); /* set date 1/02/2011 */

/* display the time and date continuously */
while (1)
{
    /* read the time from the RTC */
    rtc_get_time(&hour,&min,&sec);

    /* read the date from the RTC */
    rtc_get_date(&day,&month,&year);

    /* display the time on the LCD */
    sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
    lcd_clear();
    lcd_puts(display_buffer);

    /* display the date on the LCD */
    sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,year);
    lcd_puts(display_buffer);

    delay_ms(500); /* 0.5 second delay */
}
}
```

PCF8563 example using the hardware **TWI Functions for Master Mode Operation for XMEGA Devices.**

The chip is connected to the TWI of PORTD (TWID) of an ATxmega128A1.

```
/* include the PCF8563 functions for TWI */
#include <pcf8563_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;
```

```
/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000

void main(void)
{
    unsigned char hour,min,sec,day,month;
    unsigned int year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* general TWID initialization: no external driver interface,
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* enable and initialize the TWID master interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* enable the Low interrupt level */
    PMIC.CTRL|=PMIC_LOLVLEN_bm;

    /* set the PCF8563 functions to use TWID */
    pcf8563_twi_init(&twid_master);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the RTC,
       Timer interrupt enabled,
       Alarm interrupt enabled,
       CLKOUT frequency=1Hz
       Timer clock frequency=1Hz */
    rtc_init(RTC_TIE_ON | RTC_AIE_ON,RTC_CLKOUT_1,RTC_TIMER_CLK_1);

    rtc_set_time(12,0,0); /* set time 12:00:00 */

    rtc_set_date(1,2,2011); /* set date 1/02/2011 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);
    }
}
```

```
/* display the date on the LCD */
sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,year);
lcd_puts(display_buffer);

delay_ms(500); /* 0.5 second delay */
}
}
```

PCF8563 example using the **Software Bit-Banged I2C Bus Functions**:

```
/* include the PCF8563 functions for bit-banged I2C
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <pcf8563.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,day,month;
    unsigned int year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the bit-banged I2C functions */
    i2c_init();

    /* initialize the RTC: Timer interrupt enabled, Alarm interrupt enabled,
       CLKOUT frequency=1Hz, Timer clock frequency=1Hz */
    rtc_init(RTC_TIE_ON | RTC_AIE_ON,RTC_CLKOUT_1,RTC_TIMER_CLK_1);

    rtc_set_time(12,0,0); /* set time 12:00:00 */

    rtc_set_date(1,2,2011); /* set date 1/02/2011 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&day,&month,&year);
    }
}
```

```
/* display the time on the LCD */
sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
lcd_clear();
lcd_puts(display_buffer);

/* display the date on the LCD */
sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,year);
lcd_puts(display_buffer);

delay_ms(500); /* 0.5 second delay */
}
```

5.25.2 Philips PCF8583 Real Time Clock Functions

These functions are intended for easy interfacing between C programs and the PCF8583 I²C bus real time clock (RTC), using both the hardware TWI and software bit-banged I²C bus functions.

One of the following header files, located in the .INC subdirectory must be **#include** -d before using these functions:

- **pcf8583_twi.h** for hardware TWI
- **pcf8583.h** for software bit-banged I²C bus.

The appropriate header files for hardware TWI (**twi.h** or **twix.h**) or software bit-banged I²C bus (**i2c.h**) functions prototypes are automatically **#include** -d with the **pcf8583_twi.h** or **pcf8583.h**.

The **Project|Configure|C Compiler|Libraries|I2C** menu must be used for specifying the I/O port allocation of the **SCL** and **SDA** signals, along the **bit rate** of the **SCL** clock, for bit-banged I²C bus (not the hardware TWI) communication.

Note: For proper operation, the PCF8583 Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V (+3.3V for XMEGA devices) on the SCL and SDA signals.

The PCF8583 Functions are:

void rtc_init(unsigned char chip, unsigned char dated_alarm)

this function initializes the PCF8583 chip.

Before calling this function, the TWI hardware, respectively I²C bus, must be initialized by calling the **twi_master_init** (**twi_init**, **twi_master_init** and **pcf8583_twi_init** for XMEGA devices), respectively **i2c_init** functions.

This is the first function that must be called prior to using the other PCF8583 Functions.

If more then one chip is connected to the I²C bus, then the function must be called for each one, specifying accordingly the function parameter **chip**.

Maximum 2 PCF8583 chips can be connected to the I²C bus, their chip address can be 0 or 1.

The **dated_alarm** parameter specifies if the RTC alarm takes in account both the time and date (**dated_alarm=1**), or only the time (**dated_alarm=0**).

Refer to the PCF8583 data sheet for more information.

After calling this function the RTC alarm is disabled.

void pcf8583_twi_init(TWI_MASTER_INFO_t *ptwim)

this function is used to initialize the PCF8583 library's internal variable swhen using the **TWI Functions for Master Mode Operation for XMEGA Devices**.

It is not used for non-XMEGA devices.

The **ptwim** parameter must point to a **TWI_MASTER_INFO_t** structure variable, that is used to hold the information required by the TWI module when operating in master mode.

The **pcf8583_twi_init** function must be called before **rtc_init**.

Refer to the supplied example at the end of this chapter for more details.

unsigned char rtc_read(unsigned char chip, unsigned char address)

this function reads the byte stored in the PCF8583 SRAM.

void rtc_write(unsigned char chip, unsigned char address, unsigned char data)

this function stores the byte **data** in the PCF8583 SRAM.

When writing to the SRAM the user must take in account that locations at addresses 10h and 11h are used for storing the current year value.

unsigned char rtc_get_status(unsigned char chip)

this function returns the value of the PCF8583 control/status register.
By calling this function the global variables **rtc_status** and **rtc_alarm** are automatically updated.
The **rtc_status** variable holds the value of the PCF8583 control/status register.
The **rtc_alarm** variable takes the value 1 if an RTC alarm occurred.

void rtc_get_time(unsigned char chip, unsigned char *hour, unsigned char *min, unsigned char *sec, unsigned char *hsec)

this function returns the current time measured by the RTC.
The ***hour**, ***min**, ***sec** and ***hsec** pointers must point to the variables that must receive the values of hour, minutes, seconds and hundreds of a second.

void rtc_set_time(unsigned char chip, unsigned char hour, unsigned char min, unsigned char sec, unsigned char hsec)

this function sets the current time of the RTC.
The **hour**, **min**, **sec** and **hsec** parameters represent the values of hour, minutes, seconds and hundreds of a second.

void rtc_get_date(unsigned char chip, unsigned char *day, unsigned char *month, unsigned char *year)

this function returns the current date measured by the RTC.
The ***day**, ***month** and ***year** pointers must point to the variables that must receive the values of day, month and year.

void rtc_set_date(unsigned char chip, unsigned char day, unsigned char month, unsigned char year)

this function sets the current date of the RTC.

void rtc_alarm_off(unsigned char chip)

this function disables the RTC alarm function.

void rtc_alarm_on(unsigned char chip)

this function enables the RTC alarm function.

void rtc_get_alarm_time(unsigned char chip, unsigned char *hour, unsigned char *min, unsigned char *sec, unsigned char *hsec)

this function returns the alarm time of the RTC.
The ***hour**, ***min**, ***sec** and ***hsec** pointers must point to the variables that must receive the values of hours, minutes, seconds and hundreds of a second.

void rtc_set_alarm_time(unsigned char chip, unsigned char hour, unsigned char min, unsigned char sec, unsigned char hsec)

this function sets the alarm time of the RTC.
The **hour**, **min**, **sec** and **hsec** parameters represent the values of hours, minutes, seconds and hundreds of a second.

void rtc_get_alarm_date(unsigned char chip, unsigned char *day, unsigned char *month)

this function returns the alarm date of the RTC.
The ***day** and ***month** pointers must point to the variables that must receive the values of date and month.

void rtc_set_alarm_date(unsigned char chip, unsigned char day, unsigned char month)

this function sets the alarm date of the RTC.

PCF8583 example using the hardware **TWI Functions for Master Mode Operation for non-XMEGA Devices**:

```
/* include the PCF8583 functions for TWI */
#include <pcf8583_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,hsec,day,month;
    unsigned int year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the TWI in master mode with 100 kHz bit rate */
    twi_master_init(100);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the RTC 0, no dated alarm */
    rtc_init(0,0);

    rtc_set_time(0,12,0,0,0); /* set time 12:00:00.00 on RTC 0*/

    rtc_set_date(0,1,2,2011); /* set date 1/02/2011 on RTC 0 */
```

```
/* display the time and date continuously */
while (1)
{
    /* read the time from the RTC 0 */
    rtc_get_time(0,&hour,&min,&sec,&hsec);

    /* read the date from the RTC 0 */
    rtc_get_date(0,&day,&month,&year);

    /* display the time on the LCD */
    sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
    lcd_clear();
    lcd_puts(display_buffer);

    /* display the date on the LCD */
    sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,year);
    lcd_puts(display_buffer);

    delay_ms(500); /* 0.5 second delay */
}
}
```

PCF8583 example using the hardware TWI Functions for Master Mode Operation XMEGA Devices.

The chip is connected to the TWI of PORTD (TWID) of an ATxmega128A1.

```
/* include the PCF8583 functions for TWI */
#include <pcf8583_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000
```



```
void main(void)
{
    unsigned char hour,min,sec,hsec,day,month;
    unsigned int year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* general TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
    TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* enable the Low interrupt level */
    PMIC_CTRL|=PMIC_LOLVLEN_bm;

    /* set the PCF8583 functions to use TWID */
    pcf8583_twi_init(&twid_master);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the RTC 0, no dated alarm */
    rtc_init(0,0);

    rtc_set_time(0,12,0,0,0); /* set time 12:00:00.00 on RTC 0*/

    rtc_set_date(0,1,2,2011); /* set date 1/02/2011 on RTC 0 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC 0 */
        rtc_get_time(0,&hour,&min,&sec,&hsec);

        /* read the date from the RTC 0 */
        rtc_get_date(0,&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);

        /* display the date on the LCD */
        sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,year);
        lcd_puts(display_buffer);

        delay_ms(500); /* 0.5 second delay */
    }
}
```

PCF8583 example using the **Software Bit-Banged I2C Bus Functions**:

```
/* include the PCF8583 functions for bit-banged I2C
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <pcf8583.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,hsec,day,month;
    unsigned int year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the bit-banged I2C functions */
    i2c_init();

    /* initialize the RTC 0, no dated alarm */
    rtc_init(0,0);

    rtc_set_time(0,12,0,0,0); /* set time 12:00:00.00 on RTC 0*/

    rtc_set_date(0,1,2,2011); /* set date 1/02/2011 on RTC 0 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC 0 */
        rtc_get_time(0,&hour,&min,&sec,&hsec);

        /* read the date from the RTC 0 */
        rtc_get_date(0,&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);

        /* display the date on the LCD */
        sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,year);
        lcd_puts(display_buffer);

        delay_ms(500); /* 0.5 second delay */
    }
}
```

5.25.3 Maxim DS1302 Real Time Clock Functions

These functions are intended for easy interfacing between C programs and the DS1302 real time clock (RTC).

The prototypes for these functions are placed in the file **ds1302.h**, located in the .\INC subdirectory. This file must be **#include -d** before using the functions.

The DS1302 RTC Functions functions do not yet support the XMEGA chips.

Prior to **#include** -ing the **ds1302.h** file, you must declare which microcontroller port and port bits are used for communication with the DS1302.

Example:

```
/* the DS1302 is connected to ATmega8515 PORTB
   the IO signal is bit 3
   the SCLK signal is bit 4
   the RST signal is bit 5 */
#asm
    .equ __ds1302_port=0x18
    .equ __ds1302_io=3
    .equ __ds1302_sclk=4
    .equ __ds1302_rst=5
#endasm

/* now you can include the DS1302 Functions */
#include <ds1302.h>
```

Note: For XMEGA chips a virtual port must be mapped to the I/O port used for connecting to the DS1302 chip, and the address of the virtual port **VPORT n _OUT** register must be specified.

The DS1302 Functions are:

void rtc_init(unsigned char tc_on, unsigned char diodes, unsigned char res)

this function initializes the DS1302 chip.

This is the first function that must be called prior to using the other DS1302 Functions.

If the **tc_on** parameter is set to 1 then the DS1302's trickle charge function is enabled.

The **diodes** parameter specifies the number of diodes used when the trickle charge function is enabled. This parameter can take the value 1 or 2.

The **res** parameter specifies the value of the trickle charge resistor:

- 0 for no resistor
- 1 for a 2k Ω resistor
- 2 for a 4k Ω resistor
- 3 for a 8k Ω resistor.

Refer to the DS1302 data sheet for more information.

unsigned char ds1302_read(unsigned char addr)

this function reads a byte stored at address **addr** in the DS1302 registers or SRAM.

void ds1302_write(unsigned char addr, unsigned char data)

this function stores the byte **data** at address **addr** in the DS1302 registers or SRAM.

void rtc_get_time(unsigned char *hour, unsigned char *min, unsigned char *sec)

this function returns the current time measured by the RTC.
The ***hour**, ***min** and ***sec** pointers must point to the variables that must receive the values of hours, minutes and seconds.

void rtc_set_time(unsigned char hour, unsigned char min, unsigned char sec)

this function sets the current time of the RTC.
The **hour**, **min** and **sec** parameters represent the values of hour, minutes and seconds.

void rtc_get_date(unsigned char *day, unsigned char *month, unsigned char *year)

this function returns the current date measured by the RTC.
The ***day**, ***month** and ***year** pointers must point to the variables that must receive the values of day, month and year.

void rtc_set_date(unsigned char day, unsigned char month, unsigned char year)

this function sets the current date of the RTC.

Example program for a DS1302 connected to an ATmega8515 chip:

```
/* the DS1302 is connected to ATmega8515 PORTB
   the IO signal is bit 3
   the SCLK signal is bit 4
   the RST signal is bit 5 */
#asm
    .equ __ds1302_port=0x18 ; Address of the PORTB register
    .equ __ds1302_io=3
    .equ __ds1302_sclk=4
    .equ __ds1302_rst=5
#endasm

/* include the DS1302 */
#include <ds1302.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);
```

```
/* initialize the DS1302 RTC:
   use trickle charge,
   with 1 diode and 8K resistor */
rtc_init(1,1,3);

rtc_set_time(12,0,0); /* set time 12:00:00 */

rtc_set_date(1,2,11); /* set date 1/02/2011 */

/* display the time and date continuously */
while (1)
{
    /* read the time from the RTC */
    rtc_get_time(&hour,&min,&sec);

    /* read the date from the RTC */
    rtc_get_date(&day,&month,&year);

    /* display the time on the LCD */
    sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
    lcd_clear();
    lcd_puts(display_buffer);

    /* display the date on the LCD */
    sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,2000+year);
    lcd_puts(display_buffer);

    delay_ms(500); /* 0.5 second delay */
}
}
```

Example program for a DS1302 connected to an ATxmega128A1 chip on PORTA pins 0, 1 and 2. The PORTA is mapped to the virtual port VPORT0.

```
/* the DS1302 is connected to ATxmega 128A1 VPORT0
   the IO signal is bit 0
   the SCLK signal is bit 1
   the RST signal is bit 2 */
#asm
    .equ __ds1302_port=0x11 ; Address of the VPORT0_OUT register
    .equ __ds1302_io=0
    .equ __ds1302_sclk=1
    .equ __ds1302_rst=2
#endasm

/* include the DS1302 */
#include <ds1302.h>

/* include the ATxmega128A1 I/O register definitions */
#include <io.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>
```

```
/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,day,month,year;

    /* PORTA is mapped to VPORT0
       PORTB is mapped to VPORT1 */
    PORTCFG.VPCTRLA=PORTCFG_VP1MAP_PORTB_gc | PORTCFG_VP0MAP_PORTA_gc;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the DS1302 RTC:
       use trickle charge,
       with 1 diode and 8K resistor */
    rtc_init(1,1,3);

    rtc_set_time(12,0,0); /* set time 12:00:00 */

    rtc_set_date(1,2,2011); /* set date 1/02/2011 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);

        /* display the date on the LCD */
        sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,2000+year);
        lcd_puts(display_buffer);

        delay_ms(500); /* 0.5 second delay */
    }
}
```

5.25.4 Maxim DS1307 Real Time Clock Functions

These functions are intended for easy interfacing between C programs and the DS1307 I²C bus real time clock (RTC), using both the hardware TWI and software bit-banged I²C bus functions.

One of the following header files, located in the .INC subdirectory must be **#include** -d before using these functions:

- **ds1307_twi.h** for hardware TWI
- **ds1307.h** for software bit-banged I²C bus.

The appropriate header files for hardware TWI (**twi.h** or **twix.h**) or software bit-banged I²C bus (**i2c.h**) functions prototypes are automatically **#include** -d with the **ds1307_twi.h** or **ds1307.h**.

The **Project|Configure|C Compiler|Libraries|I2C** menu must be used for specifying the I/O port allocation of the **SCL** and **SDA** signals, along the **bit rate** of the **SCL** clock, for bit-banged I²C bus (not the hardware TWI) communication.

Note: For proper operation, the DS1307 Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V (+3.3V for XMEGA devices) on the SCL and SDA signals.

The DS1307 Functions are:

void rtc_init(unsigned char rs, unsigned char sqwe, unsigned char out)

this function initializes the DS1307 chip.

Before calling this function, the TWI hardware, respectively I²C bus, must be initialized by calling the **twi_master_init** (**twi_init**, **twi_master_init** and **ds1307_twi_init** for XMEGA devices), respectively **i2c_init** functions.

This is the first function that must be called prior to using the other DS1307 Functions.

The **rs** parameter specifies the value of the square wave output frequency on the SQW/OUT pin:

- 0 for 1 Hz
- 1 for 4096 Hz
- 2 for 8192 Hz
- 3 for 32768 Hz.

If the **sqwe** parameter is set to 1 then the square wave output on the SQW/OUT pin is enabled.

The **out** parameter specifies the logic level on the SQW/OUT pin when the square wave output is disabled (sqwe=0).

Refer to the DS1307 data sheet for more information.

void ds1307_twi_init(TWI_MASTER_INFO_t *ptwim)

this function is used to initialize the DS1307 library's internal variables when using the **TWI Functions for Master Mode Operation for XMEGA Devices**.

It is not used for non-XMEGA devices.

The **ptwim** parameter must point to a **TWI_MASTER_INFO_t** structure variable, that is used to hold the information required by the TWI module when operating in master mode.

The **ds1307_twi_init** function must be called before **rtc_init**.

Refer to the supplied example at the end of this chapter for more details.

void rtc_get_time(unsigned char *hour, unsigned char *min, unsigned char *sec)

this function returns the current time measured by the RTC.

The ***hour**, ***min** and ***sec** pointers must point to the variables that must receive the values of hours, minutes and seconds.

void rtc_set_time(unsigned char hour, unsigned char min, unsigned char sec)

this function sets the current time of the RTC.
The **hour**, **min** and **sec** parameters represent the values of hour, minutes and seconds.

void rtc_get_date(unsigned char *week_day, unsigned char *day, unsigned char *month, unsigned char *year)

this function returns the current date measured by the RTC.
The ***week_day**, ***day**, ***month** and ***year** pointers must point to the variables that must receive the values of day of week, day, month and year.

void rtc_set_date(unsigned char week_day, unsigned char day, unsigned char month, unsigned char year)

this function sets the current date of the RTC.

DS1307 example using the hardware TWI Functions for Master Mode Operation for non-XMEGA Devices:

```
/* include the DS1307 functions for TWI */
#include <ds1307_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,week_day,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the TWI in master mode with 100 kHz bit rate */
    twi_master_init(100);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the RTC
       square wave output is disabled
       SQW/OUT has logic state 0 */
    rtc_init(0,0,0);

    rtc_set_time(12,0,0); /* set time 12:00:00 */

    rtc_set_date(2,1,2,11); /* set date Tuesday 1/02/2011 */
}
```



```
/* display the time and date continuously */
while (1)
{
    /* read the time from the RTC */
    rtc_get_time(&hour,&min,&sec);

    /* read the date from the RTC */
    rtc_get_date(&week_day,&day,&month,&year);

    /* display the time on the LCD */
    sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
    lcd_clear();
    lcd_puts(display_buffer);

    /* display the date on the LCD */
    sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,2000+year);
    lcd_puts(display_buffer);

    delay_ms(500); /* 0.5 second delay */
}
}
```

DS1307 example using the hardware TWI Functions for Master Mode Operation for XMEGA Devices.

The chip is connected to the TWI of PORTD (TWID) of an ATxmega128A1.

```
/* include the DS1307 functions for TWI */
#include <ds1307_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000
```

```
void main(void)
{
    unsigned char hour,min,sec,week_day,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* general TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
    TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* enable the Low interrupt level */
    PMIC.CTRL|=PMIC_LOLVLEN_bm;

    /* set the DS1307 functions to use TWID */
    ds1307_twi_init(&twid_master);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the RTC
       square wave output is disabled
       SQW/OUT has logic state 0 */
    rtc_init(0,0,0);

    rtc_set_time(12,0,0); /* set time 12:00:00 */

    rtc_set_date(2,1,2,11); /* set date Tuesday 1/02/2011 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&week_day,&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);

        /* display the date on the LCD */
        sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,2000+year);
        lcd_puts(display_buffer);

        delay_ms(500); /* 0.5 second delay */
    }
}
```

DS1307 example using the **Software Bit-Banged I2C Bus Functions**:

```
/* include the DS1307 functions for bit-banged I2C
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <ds1307.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,week_day,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the bit-banged I2C functions */
    i2c_init();

    /* initialize the RTC
       square wave output is disabled
       SQW/OUT has logic state 0 */
    rtc_init(0,0,0);

    rtc_set_time(12,0,0); /* set time 12:00:00 */

    rtc_set_date(2,1,2,11); /* set date Tuesday 1/02/2011 */

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&week_day,&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);

        /* display the date on the LCD */
        sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,2000+year);
        lcd_puts(display_buffer);

        delay_ms(500); /* 0.5 second delay */
    }
}
```

5.25.5 Maxim DS3231 Real Time Clock Functions

These functions are intended for easy interfacing between C programs and the DS3231 I²C bus real time clock (RTC), using both the hardware TWI and software bit-banged I²C bus functions.

One of the following header files, located in the .INC subdirectory must be **#include** -d before using these functions:

- **ds3231_twi.h** for hardware TWI
- **ds3231.h** for software bit-banged I²C bus.

The appropriate header files for hardware TWI (**twi.h** or **twix.h**) or software bit-banged I²C bus (**i2c.h**) functions prototypes are automatically **#include** -d with the **ds3231_twi.h** or **ds3231.h**.

The **Project|Configure|C Compiler|Libraries|I2C** menu must be used for specifying the I/O port allocation of the **SCL** and **SDA** signals, along the **bit rate** of the **SCL** clock, for bit-banged I²C bus (not the hardware TWI) communication.

Note: For proper operation, the DS3231 Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V (+3.3V for XMEGA devices) on the SCL and SDA signals.

The DS3231 Functions are:

unsigned char ds3231_read(unsigned char address)

returns the data byte read from the specified **address** of a DS3231 register.

void ds3231_write(unsigned char address,unsigned char data)

writes a **data** byte to the specified **address** of a DS3231 register.

The address values for the DS3231 registers are defined in the **ds3231_twi.h** and **ds3231.h** header files:

```
#define DS3231_SEC_REG 0x00      /* Seconds register */
#define DS3231_MIN_REG 0x01      /* Minutes register */
#define DS3231_HOUR_REG 0x02     /* Hours register */
#define DS3231_WEEK_DAY_REG 0x03 /* Week day register */
#define DS3231_DATE_REG 0x04     /* Date register */
#define DS3231_MONTH_REG 0x05    /* Month register */
#define DS3231_YEAR_REG 0x06     /* Year register */
#define DS3231_AL1SEC_REG 0x07   /* Alarm 1 seconds register */
#define DS3231_AL1MIN_REG 0x08   /* Alarm 1 minutes register */
#define DS3231_AL1HOUR_REG 0x09  /* Alarm 1 hours register */
#define DS3231_AL1DATE_REG 0x0A  /* Alarm 1 date register */
#define DS3231_AL2MIN_REG 0x0B   /* Alarm 2 minutes register */
#define DS3231_AL2HOUR_REG 0x0C  /* Alarm 2 hours register */
#define DS3231_AL2DATE_REG 0x0D  /* Alarm 2 date register */
#define DS3231_CTRL_REG 0x0E     /* Control register */
#define DS3231_STS_REG 0x0F      /* Status register */
#define DS3231_AGGING_OFFSETS 0x10 /* Agging offset register */
#define DS3231_AGGING_TEMP_MSB 0x11 /* Temperature MSB */
#define DS3231_AGGING_TEMP_LSB 0x12 /* Temperature LSB */
```

The DS3231 control register bits definitions are:

```
#define DS3231_CTRL_A1IE 0 /* Alarm 1 interrupt enable */
#define DS3231_CTRL_A2IE 1 /* Alarm 2 interrupt enable */
#define DS3231_CTRL_INTCN 2 /* Interrupt control */
#define DS3231_CTRL_RS1 3 /* Rate select bit 1 */
#define DS3231_CTRL_RS2 4 /* Rate select bit 2 */
#define DS3231_CTRL_CONV 5 /* Start temperature conversion */
#define DS3231_CTRL_BBSQW 6 /* Battery-Backed Square-Wave enable */
#define DS3231_CTRL_NEOSC 7 /* Enable the oscillator when set to logic 0 */
```

unsigned char ds3231_status_read(void)

returns the data byte read from the DS3231 status register.

The DS3231 status register bits definitions are:

```
#define DS3231_STS_A1F 0 /* Alarm 1 flag */
#define DS3231_STS_A2F 1 /* Alarm 2 flag */
#define DS3231_STS_BSY 2 /* Device is busy executing TXCO functions */
#define DS3231_STS_EN32KHZ 3 /* Enable the 32kHz output */
#define DS3231_STS_OSF 7 /* A logic 1 in this bit indicates that
                           the oscillator either is stopped or
                           was stopped for some period */
```

void rtc_init(unsigned char int_sqw_mode, bool en32khz)

this function initializes the DS3231 chip.

Before calling this function, the TWI hardware, respectively I²C bus, must be initialized by calling the **twi_master_init** (**twi_init**, **twi_master_init** and **ds3231_twi_init** for XMEGA devices), respectively **i2c_init** functions.

This is the first function that must be called prior to using the other DS3231 Functions.

Parameters:

int_sqw_mode - specifies the operating modes of the **~INT/SQW** output, as defined in the **ds3231_twi.h** and **ds3231.h** header files:

```
#define DS3231_INT_SQW_OFF 0 /* The ~INT/SQW output is disabled */
#define DS3231_INT_ON 1 /* A match between the timekeeping
                        registers and either of the alarm
                        registers activates the ~INT/SQW
                        output (if the alarm is also enabled) */
#define DS3231_SQW_1HZ 2 /* SQW outputs a 1Hz square wave */
#define DS3231_SQW_1024HZ 3 /* SQW outputs a 1024Hz square wave */
#define DS3231_SQW_4096HZ 4 /* SQW outputs a 4096Hz square wave */
#define DS3231_SQW_8192HZ 5 /* SQW outputs a 8192Hz square wave */
```

en32khz - enables/disables the output of a square wave on the DS3231 **32kHz** pin.

Refer to the DS3231 data sheet for more information.

void ds3231_twi_init(TWI_MASTER_INFO_t *ptwim)

this function is used to initialize the DS3231 library's internal variables when using the **TWI Functions for Master Mode Operation for XMEGA Devices**.
It is not used for non-XMEGA devices.

The **ptwim** parameter must point to a **TWI_MASTER_INFO_t** structure variable, that is used to hold the information required by the TWI module when operating in master mode.
The **ds3231_twi_init** function must be called before **rtc_init**.
Refer to the supplied example at the end of this topic for more details.

float ds3231_get_temp(void)

reads the DS3231 temperature in [°C] with 0.25°C resolution.

void rtc_get_time(unsigned char *hour, unsigned char *min, unsigned char *sec)

this function returns the current time measured by the RTC.
The ***hour**, ***min** and ***sec** pointers must point to the variables that must receive the values of hours, minutes and seconds.

void rtc_set_time(unsigned char hour, unsigned char min, unsigned char sec)

this function sets the current time of the RTC.
The **hour**, **min** and **sec** parameters represent the values of hour, minutes and seconds.

void rtc_get_date(unsigned char *week_day, unsigned char *day, unsigned char *month, unsigned char *year)

this function returns the current date measured by the RTC.
The ***week_day**, ***day**, ***month** and ***year** pointers must point to the variables that must receive the values of day of week, day, month and year.

void rtc_set_date(unsigned char week_day, unsigned char day, unsigned char month, unsigned char year)

this function sets the current date of the RTC.

void rtc_set_alarm1(DS3231_ALARM_t *alarm)

this function sets the configuration for the DS3231 RTC alarm 1.
The **alarm** parameter points to a structure, defined in the **ds3231_twi.h** and **ds3231.h** headers, that holds the settings:

```
typedef struct {
    unsigned char sec;          /* Alarm seconds value [0..59] */
    unsigned char min;          /* Alarm minutes value [0..59] */
    unsigned char hour;          /* Alarm hour value [0..23] */
    unsigned char day;           /* Date day value [1..31] */
    unsigned char use_sec:1;     /* Trigger alarm when seconds match */
    unsigned char use_min:1;     /* Trigger alarm when minutes match */
    unsigned char use_hour:1;    /* Trigger alarm when hour match */
    unsigned char use_day:1;     /* Trigger alarm when date day match */
    unsigned char enabled:1;     /* Alarm interrupt is enabled */
} DS3231_ALARM_t;
```

void rtc_get_alarm1(DS3231_ALARM_t *alarm)

this function reads the configuration for the DS3231 RTC alarm 1 into the **DS3231_ALARM_t** type structure pointed by the **alarm** pointer.

void rtc_enable_alarm1(bool alarm_on)

enables or disables DS3231 alarm 1 interrupt.

Note: In order to sense the alarm triggering, the **~INT/SQW** output must be enabled:

```
rtc_init(DS3231_INT_ON, false);
```

and connected to a hardware interrupt pin of the AVR chip.

Alternatively, the status of the **DS3231_STS_A1F** alarm 1 interrupt flag bit, defined in the **ds3231_twi.h** and **ds3231.h** headers, can be tested periodically:

```
if (ds3231_read_status() & (1<<DS3231_STS_A1F))
{
    /* Alarm 1 was triggered */
}
```

void rtc_set_alarm2(DS3231_ALARM_t *alarm)

this function sets the configuration for the DS3231 RTC alarm 2.

The **alarm** parameter points to a **DS3231_ALARM_t** type structure, defined in the **ds3231_twi.h** and **ds3231.h** headers, that holds the settings.

Note: For the DS3231 alarm 2, the seconds trigger value is not implemented, therefore the **sec** and **use_sec** members of the **DS3231_ALARM_t** structure must be set to 0.

void rtc_get_alarm2(DS3231_ALARM_t *alarm)

this function reads the configuration for the DS3231 RTC alarm 2 into the **DS3231_ALARM_t** type structure pointed by the **alarm** pointer.

void rtc_enable_alarm2(bool alarm_on)

enables or disables DS3231 alarm 2 interrupt.

Note: In order to sense the alarm triggering, the **~INT/SQW** output must be enabled:

```
rtc_init(DS3231_INT_ON, false);
```

and connected to a hardware interrupt pin of the AVR chip.

Alternatively, the status of the **DS3231_STS_A2F** alarm 2 interrupt flag bit, defined in the **ds3231_twi.h** and **ds3231.h** headers, can be tested periodically:

```
if (ds3231_read_status() & (1<<DS3231_STS_A2F))
{
    /* Alarm 2 was triggered */
}
```

DS3231 example using the hardware **TWI Functions for Master Mode Operation for non-XMEGA Devices**:

```
/* include the DS3231 functions for TWI */
#include <ds3231_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,week_day,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the TWI in master mode with 100 kHz bit rate */
    twi_master_init(100);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the DS3231 RTC:
       - use the ~INT/SQW pin to output a 1024Hz
         square wave signal
       - the 32kHz output is disabled
       - alarms are disabled */
    rtc_init(DS3231_SQW_1024HZ,false);

    /* set time 12:00:00 */
    rtc_set_time(12,0,0);

    /* set date Monday 24/08/2016 */
    rtc_set_date(1,24,8,15);

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&week_day,&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);
    }
}
```



```
/* display the date on the LCD */
sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,
        2000+year);
lcd_puts(display_buffer);

delay_ms(500); /* 0.5 second delay */
}
}
```

DS3231 example using the hardware TWI Functions for Master Mode Operation for XMEGA Devices.

The chip is connected to the TWI of PORTD (TWID) of an ATxmega128A1.

```
/* include the DS3231 functions for TWI */
#include <ds3231_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000

void main(void)
{
    unsigned char hour,min,sec,week_day,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* general TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));
}
```

```
/* enable the Low interrupt level */
PMIC.CTRL|=PMIC_LOLVLEN_bm;

/* set the DS3231 functions to use TWID */
ds3231_twi_init(&twid_master);

/* enable interrupts so that TWI can be used */
#asm("sei")

/* initialize the DS3231 RTC:
   - use the ~INT/SQW pin to output a 1024Hz
     square wave signal
   - the 32kHz output is disabled
   - alarms are disabled */
rtc_init(DS3231_SQW_1024HZ,false);

/* set time 12:00:00 */
rtc_set_time(12,0,0);

/* set date Monday 24/08/2016 */
rtc_set_date(1,24,8,15);

/* display the time and date continuously */
while (1)
{
    /* read the time from the RTC */
    rtc_get_time(&hour,&min,&sec);

    /* read the date from the RTC */
    rtc_get_date(&week_day,&day,&month,&year);

    /* display the time on the LCD */
    sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
    lcd_clear();
    lcd_puts(display_buffer);

    /* display the date on the LCD */
    sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,
        2000+year);
    lcd_puts(display_buffer);

    delay_ms(500); /* 0.5 second delay */
}
}
```

DS3231 example using the **Software Bit-Banged I2C Bus Functions**:

```
/* include the DS3231 functions for bit-banged I2C
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <ds3231.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>
```

```
/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[17]; /* LCD display buffer for 1 line */

void main(void)
{
    unsigned char hour,min,sec,week_day,day,month,year;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the bit-banged I2C functions */
    i2c_init();

    /* initialize the DS3231 RTC:
       - use the ~INT/SQW pin to output a 1024Hz
         square wave signal
       - the 32kHz output is disabled
       - alarms are disabled */
    rtc_init(DS3231_SQW_1024HZ,false);

    /* set time 12:00:00 */
    rtc_set_time(12,0,0);

    /* set date Monday 24/08/2016 */
    rtc_set_date(1,24,8,15);

    /* display the time and date continuously */
    while (1)
    {
        /* read the time from the RTC */
        rtc_get_time(&hour,&min,&sec);

        /* read the date from the RTC */
        rtc_get_date(&week_day,&day,&month,&year);

        /* display the time on the LCD */
        sprintf(display_buffer,"Time: %2d:%02d:%02d\n",hour,min,sec);
        lcd_clear();
        lcd_puts(display_buffer);

        /* display the date on the LCD */
        sprintf(display_buffer,"Date: %2d/%02d/%d",day,month,
            2000+year);
        lcd_puts(display_buffer);

        delay_ms(500); /* 0.5 second delay */
    }
}
```

Additional examples with alarm triggering can be found in the **\Examples\AVR\DS3231 RTC\TWI** and **\Examples\AVR\DS3231 RTC\Bit Banged I2C** subdirectories of the CodeVisionAVR installation.

5.25.6 Maxim DS1621 Thermometer/ Thermostat Functions

These functions are intended for easy interfacing between C programs and the DS1621 I²C bus thermometer/thermostat, using both the hardware TWI and software bit-banged I²C bus functions. One of the following header files, located in the .INC subdirectory must be **#include** -d before using these functions:

- **ds1621_twi.h** for hardware TWI
- **ds1621.h** for software bit-banged I²C bus.

The appropriate header files for hardware TWI (**twi.h** or **twix.h**) or software bit-banged I²C bus (**i2c.h**) functions prototypes are automatically **#include** -d with the **ds1621_twi.h** or **ds1621.h**.

The **Project|Configure|C Compiler|Libraries|I2C** menu must be used for specifying the I/O port allocation of the **SCL** and **SDA** signals, along the **bit rate** of the **SCL** clock, for bit-banged I²C bus (not the hardware TWI) communication.

Note: For proper operation, the DS1621 Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V (+3.3V for XMEGA devices) on the SCL and SDA signals.

The DS1621 Functions are:

void ds1621_init(unsigned char chip, signed char tlow, signed char thigh, unsigned char pol)

this function initializes the DS1621 chip.

Before calling this function, the TWI hardware, respectively I²C bus, must be initialized by calling the **twi_master_init** (**twi_init**, **twi_master_init** and **ds1621_twi_init** for XMEGA devices), respectively **i2c_init** functions.

This is the first function that must be called prior to using the other DS1621 Functions.

If more then one chip is connected to the I²C bus, then the function must be called for each one, specifying accordingly the function parameter **chip**.

Maximum 8 DS1621 chips can be connected to the I²C bus, their **chip** address can be from 0 to 7.

Besides measuring temperature, the DS1621 functions also like a thermostat.

The Tout output becomes active when the temperature exceeds the **thigh** limit, and leaves the active state when the temperature drops below the **tlow** limit.

Both **tlow** and **thigh** are expressed in °C.

pol represents the polarity of the DS1621 Tout output in active state.

If **pol** is 0, the output is active low and if **pol** is 1, the output is active high.

Refer to the DS1621 data sheet for more information.

void ds1621_twi_init(TWI_MASTER_INFO_t *ptwim)

this function is used to initialize the DS1621 library's internal variables when using the **TWI Functions for Master Mode Operation for XMEGA Devices**.

It is not used for non-XMEGA devices.

The **ptwim** parameter must point to a **TWI_MASTER_INFO_t** structure variable, that is used to hold the information required by the TWI module when operating in master mode.

The **ds1621_twi_init** function must be called before **ds1621_init**.

Refer to the supplied example at the end of this chapter for more details.

unsigned char ds1621_get_status(unsigned char chip)

this function reads the contents of the configuration/status register of the DS1621 with address **chip**.

Refer to the DS1621 data sheet for more information about this register.

void ds1621_set_status(unsigned char chip, unsigned char data)

this function sets the contents of the configuration/status register of the DS1621 with address **chip**.

Refer to the DS1621 data sheet for more information about this register.

void ds1621_start(unsigned char chip)

this functions exits the DS1621, with address **chip**, from the power-down mode and starts the temperature measurements and the thermostat.

void ds1621_stop(unsigned char chip)

this functions enters the DS1621, with address **chip**, in power-down mode and stops the temperature measurements and the thermostat.

int ds1621_temperature_10(unsigned char chip)

this function returns the temperature of the DS1621 sensor with the address **chip**. The temperature is in °C and is multiplied by 10.

Example how to display the temperature of two DS1621 sensors with addresses 0 and 1. The chips are accessed using the **TWI Functions for Master Mode Operation for non-XMEGA Devices**.

```
/* include the DS1621 functions for TWI */
#include <ds1621_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototype for abs */
#include <stdlib.h>

char display_buffer[33];

void main(void)
{
    int t0,t1;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the TWI in master mode with 100 kHz bit rate */
    twi_master_init(100);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the DS1621 sensor with address 0 */
    /* tlow=20°C thigh=25°C */
    ds1621_init(0,20,25,0);
```

```
/* initialize the DS1621 sensor with address 1 */
/* tlow=30°C thigh=35°C */
ds1621_init(1,30,35,0);

/* temperature display loop */
while (1)
{
    /* read the temperature of DS1621 #0 *10°C */
    t0=ds1621_temperature_10(0);

    /* read the temperature of DS1621 #1 *10°C */
    t1=ds1621_temperature_10(1);

    /* prepare the displayed temperatures */
    /* in the display_buffer */
    sprintf(display_buffer,"t0=%-i.%-u%C\nt1=%-i.%-u%C",
    t0/10,abs(t0%10),0xdf,t1/10,abs(t1%10),0xdf);

    /* display the temperatures */
    lcd_clear();
    lcd_puts(display_buffer);
};
}
```

The same example, but the DS1621 chips are accessed using the **TWI Functions for Master Mode Operation for XMEGA Devices**.

The chips are connected to the TWI of PORTD (TWID) of an ATxmega128A1.

```
/* include the DS1621 functions for TWI */
#include <ds1621_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototype for abs */
#include <stdlib.h>

char display_buffer[33];

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000
```

```
void main(void)
{
    int t0,t1;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* general TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
    TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* enable the Low interrupt level */
    PMIC.CTRL|=PMIC_LOLVLEN_bm;

    /* set the DS1621 functions to use TWID */
    ds1621_twi_init(&twid_master);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the DS1621 sensor with address 0 */
    /* tlow=20°C thigh=25°C */
    ds1621_init(0,20,25,0);

    /* initialize the DS1621 sensor with address 1 */
    /* tlow=30°C thigh=35°C */
    ds1621_init(1,30,35,0);

    /* temperature display loop */
    while (1)
    {
        /* read the temperature of DS1621 #0 *10°C */
        t0=ds1621_temperature_10(0);

        /* read the temperature of DS1621 #1 *10°C */
        t1=ds1621_temperature_10(1);

        /* prepare the displayed temperatures */
        /* in the display_buffer */
        sprintf(display_buffer,"t0=%-i.%-u%cC\nt1=%-i.%-u%cC",
        t0/10,abs(t0%10),0xdf,t1/10,abs(t1%10),0xdf);

        /* display the temperatures */
        lcd_clear();
        lcd_puts(display_buffer);
    };
}
```

The same example, but the DS1621 chips are accessed using the **Software Bit-Banged I2C Bus Functions**.

```
/* include the DS1621 functions
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <ds1621.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototype for abs */
#include <stdlib.h>

char display_buffer[33];

void main(void)
{
    int t0,t1;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the I2C bus */
    i2c_init();

    /* initialize the DS1621 sensor with address 0 */
    /* tlow=20°C thigh=25°C */
    ds1621_init(0,20,25,0);

    /* initialize the DS1621 sensor with address 1 */
    /* tlow=30°C thigh=35°C */
    ds1621_init(1,30,35,0);

    /* temperature display loop */
    while (1)
    {
        /* read the temperature of DS1621 #0 *10°C */
        t0=ds1621_temperature_10(0);

        /* read the temperature of DS1621 #1 *10°C */
        t1=ds1621_temperature_10(1);

        /* prepare the displayed temperatures */
        /* in the display_buffer */
        sprintf(display_buffer,"t0=-i.-%u°C\nt1=-i.-%u°C",
            t0/10,abs(t0%10),0xdf,t1/10,abs(t1%10),0xdf);

        /* display the temperatures */
        lcd_clear();
        lcd_puts(display_buffer);
    };
}
```


5.25.7 Maxim DS1820/DS18S20 Temperature Sensors Functions

These functions are intended for easy interfacing between C programs and the DS1820/DS18S20 1 Wire bus temperature sensors.

The prototypes for these functions are placed in the file **ds1820.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

The 1 Wire bus functions prototypes are automatically **#include -d** with the **ds1820.h**.

The 1 Wire functions must be configured, by specifying the I/O port and bit used for communication through the 1 Wire protocol.

This is accomplished in the **Project|Configure|C Compiler|Libraries|1 Wire** menu:

- the **Enable 1 Wire Bus Interface Support** option must be activated
- the **I/O Port** and **Bit** must be specified in **Data Connection**.

Note: Because the 1 Wire Functions require precision time delays for correct operation, the interrupts must be disabled during their execution.

The DS1820/DS18S20 functions are:

unsigned char ds1820_read_spd(unsigned char *addr)

this function reads the contents of the SPD for the DS1820/DS18S20 sensor with the ROM code stored in an array of 8 bytes located at address **addr**.

The functions returns the value 1 on succes and 0 in case of error.

If only one DS1820/DS18S20 sensor is used, no ROM code array is necessary and the pointer **addr** must be NULL (0).

The contents of the SPD will be stored in the structure:

```
struct __ds1820_scratch_pad_struct
{
    unsigned char temp_lsb,temp_msb,
                  temp_high,temp_low,
                  res1,res2,
                  cnt_rem,cnt_c,
                  crc;
} __ds1820_scratch_pad;
```

defined in the **ds1820.h** header file.

int ds1820_temperature_10(unsigned char *addr)

this function returns the temperature of the DS1820/DS18S20 sensor with the ROM code stored in an array of 8 bytes located at address **addr**.

The temperature is measured in °C and is multiplied by 10. In case of error the function returns the value -9999.

If only one DS1820/DS18S20 sensor is used, no ROM code array is necessary and the pointer **addr** must be NULL (0).

If several sensors are used, then the program must first identify the ROM codes for all the sensors. Only after that the **ds1820_temperature_10** function may be used, with the **addr** pointer pointing to the array which holds the ROM code for the needed device.

Example:

```
#include <mega8515.h>

/* the ATmega8515 port and bit used for the 1 Wire bus must be specified in
   the Project|Configure|C Compiler|Libraries 1 Wire menu */

/* include the DS1820/DS18S20 functions prototypes */
#include <ds1820.h>

/* include the printf function prototype */
#include <stdio.h>

/* include the abs function prototype */
#include <stdlib.h>

/* quartz crystal frequency [Hz] */
#define xtal 4000000L

/* Baud rate */
#define baud 9600

/* maximum number of DS1820/DS18S20 connected to the bus */
#define MAX_DEVICES 8

/* DS1820/DS18S20 devices ROM code storage area,
   9 bytes are used for each device
   (see the w1_search function description),
   but only the first 8 bytes contain the ROM code
   and CRC */
unsigned char rom_codes[MAX_DEVICES][9];

main()
{
    unsigned char i, devices;
    int temp;

    /* initialize the USART control register
       TX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x08;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/baud-1) >> 8;
    UBRRL=(xtal/16/baud-1) & 0xFF;

    /* detect how many DS1820/DS18S20 devices
       are connected to the bus and
       store their ROM codes in the rom_codes array */
    devices=w1_search(0xf0, rom_codes);
```

```
/* display the number */
printf("%-u DEVICE(S) DETECTED\n\r", devices);

/* if no devices were detected then halt */
if (devices==0) while (1); /* loop forever */

/* measure and display the temperature(s) */
while (1)
{
    for (i=0; i<devices; )
    {
        temp=ds1820_temperature_10(&rom_codes[i][0]);
        printf("t%-u=%-i.%-u\xf8" "C\n\r", ++i, temp/10,
            abs(temp%10));
    };
};
}
```

unsigned char ds1820_set_alarm(unsigned char *addr, signed char temp_low, signed char temp_high)

this function sets the low (**temp_low**) and high (**temp_high**) temperature alarms of the DS1820/DS18S20.

In case of success the function returns the value 1, else it returns 0.

The alarm temperatures are stored in both the DS1820/DS18S20's scratchpad RAM and its EEPROM. The ROM code needed to address the device is stored in an array of 8 bytes located at address **addr**. If only one DS1820/DS18S20 sensor is used, no ROM code array is necessary and the pointer **addr** must be NULL (0).

The alarm status for all the DS1820/DS18S20 devices on the 1 Wire bus can be determined by calling the **w1_search** function with the Alarm Search (ECh) command.

Example:

```
#include <mega8515.h>

/* the ATmega8515 port and bit used for the 1 Wire bus must be specified in
   the Project|Configure|C Compiler|Libraries 1 Wire menu */

/* include the DS1820/DS18S20 functions prototypes */
#include <ds1820.h>

/* include the printf function prototype */
#include <stdio.h>

/* include the abs function prototype */
#include <stdlib.h>

/* maximum number of DS1820/DS18S20 connected to the bus */
#define MAX_DEVICES 8

/* DS1820/DS18S20 devices ROM code storage area,
   9 bytes are used for each device
   (see the w1_search function description),
   but only the first 8 bytes contain the ROM code and CRC */
unsigned char rom_codes[MAX_DEVICES][9];
```

CodeVisionAVR

```
/* allocate space for ROM codes of the devices
   which generate an alarm */
unsigned char alarm_rom_codes[MAX_DEVICES][9];

#define xtal 4000000L /* quartz crystal frequency [Hz] */
#define baud 9600 /* Baud rate */

main()
{
    unsigned char i, devices;
    int temp;

    /* initialize the USART control register
       TX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x08;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/baud-1) >> 8;
    UBRL=(xtal/16/baud-1) & 0xFF;

    /* detect how many DS1820/DS18S20 devices
       are connected to the bus and
       store their ROM codes in the rom_codes array */
    devices=w1_search(0xf0, rom_codes);

    /* display the number */
    printf("%-u DEVICE(S) DETECTED\n\r", devices);

    /* if no devices were detected then halt */
    if (devices==0) while (1); /* loop forever */

    /* set the temperature alarms for all the devices
       temp_low=25°C temp_high=35°C */
    for (i=0; i<devices; i++)
    {
        printf("INITIALIZING DEVICE #%-u ", i+1);
        if (ds1820_set_alarm(&rom_codes[i][0], 25, 35))
            putsf("OK"); else putsf("ERROR");
    };

    while (1)
    {
        /* measure and display the temperature(s) */
        for (i=0; i<devices; i++)
        {
            temp=ds1820_temperature_10(&rom_codes[i][0]);
            printf("t%-u=%-i. %-u\xfb" "C\n\r", ++i, temp/10,
                abs(temp%10));
        };

        /* display the number of devices which
           generated an alarm */
        printf("ALARM GENERATED BY %-u DEVICE(S)\n\r",
            w1_search(0xec, alarm_rom_codes));
    };
}
```

Refer to the DS1820/DS18S20 data sheet for more information.

5.25.8 Maxim DS18B20 Temperature Sensor Functions

These functions are intended for easy interfacing between C programs and the DS18B20 1 Wire bus temperature sensor.

The prototypes for these functions are placed in the file **ds18b20.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

The 1 Wire bus functions prototypes are automatically **#include -d** with the **ds18b20.h**.

The 1 Wire functions must be configured, by specifying the I/O port and bit used for communication through the 1 Wire protocol.

This is accomplished in the **Project|Configure|C Compiler|Libraries|1 Wire** menu:

- the **Enable 1 Wire Bus Interface Support** option must be activated
- the **I/O Port** and **Bit** must be specified in **Data Connection**.

Note: Because the 1 Wire Functions require precision time delays for correct operation, the interrupts must be disabled during their execution.

The DS18B20 functions are:

unsigned char ds18b20_read_spd(unsigned char *addr)

this function reads the contents of the SPD for the DS18B20 sensor with the ROM code stored in an array of 8 bytes located at address **addr**.

The functions returns the value 1 on succes and 0 in case of error.

If only one DS18B20 sensor is used, no ROM code array is necessary and the pointer **addr** must be NULL (0).

The contents of the SPD will be stored in the structure:

```
struct __ds18b20_scratch_pad_struct
{
    unsigned char temp_lsb,temp_msb,
                temp_high,temp_low,
                conf_register,
                res1,
                res2,
                res3,
                crc;
} __ds18b20_scratch_pad;
```

defined in the **ds18b20.h** header file.

unsigned char ds18b20_init(unsigned char *addr,signed char temp_low,signed char temp_high,unsigned char resolution)

this function sets the low (**temp_low**) and high (**temp_high**) temperature alarms and specifies the temperature measurement **resolution** of the DS18B20.

The resolution argument may take the value of one of the following macros defined in the **ds18b20.h** header file:

DS18B20_9BIT_RES for 9 bit tempearture measurement resolution (0.5°C)
DS18B20_10BIT_RES for 10 bit tempearture measurement resolution (0.25°C)
DS18B20_11BIT_RES for 11 bit tempearture measurement resolution (0.125°C)
DS18B20_12BIT_RES for 12 bit tempearture measurement resolution (0.0625°C)

In case of success the function returns the value 1, else it returns 0.

The alarm temperatures and resolution are stored in both the DS18B20's scratchpad SRAM and its EEPROM.

The ROM code needed to address the device is stored in an array of 8 bytes located at address **addr**. If only one DS18B20 sensor is used, no ROM code array is necessary and the pointer **addr** must be NULL (0).

The alarm status for all the DS18B20 devices on the 1 Wire bus can be determined by calling the **w1_search** function with the Alarm Search (ECh) command.

float ds18b20_temperature(unsigned char *addr)

this function returns the temperature of the DS18B20 sensor with the ROM code stored in an array of 8 bytes located at address **addr**.

The temperature is measured in °C. In case of error the function returns the value -9999.

If only one DS18B20 sensor is used, no ROM code array is necessary and the pointer **addr** must be NULL (0).

Prior on calling the the **ds18b20_temperature** function for the first time, the **ds18b20_init** function must be used to specify the desired temperature measurement resolution.

If more several sensors are used, then the program must first identify the ROM codes for all the sensors.

Only after that the **ds18b20_temperature** function may be used, with the **addr** pointer pointing to the array which holds the ROM code for the needed device.

Example:

```
#include <mega8515.h>

/* the ATmega8515 port and bit used for the 1 Wire bus must be specified in
   the Project|Configure|C Compiler|Libraries 1 Wire menu */

/* include the DS18B20 functions prototypes */
#include <ds18b20.h>

/* include the printf function prototype */
#include <stdio.h>

/* quartz crystal frequency [Hz] */
#define xtal 4000000L

/* Baud rate */
#define baud 9600

/* maximum number of DS18B20 connected to the bus */
#define MAX_DEVICES 8

/* DS18B20 devices ROM code storage area,
   9 bytes are used for each device
   (see the w1_search function description),
   but only the first 8 bytes contain the ROM code
   and CRC */
unsigned char rom_codes[MAX_DEVICES][9];

/* allocate space for ROM codes of the devices
   which generate an alarm */
unsigned char alarm_rom_codes[MAX_DEVICES][9];
```

```
main()
{
    unsigned char i, devices;

    /* initialize the USART control register
       TX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x08;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/baud-1) >> 8;
    UBRL=(xtal/16/baud-1) & 0xFF;

    /* detect how many DS18B20 devices
       are connected to the bus and
       store their ROM codes in the rom_codes array */
    devices=w1_search(0xf0, rom_codes);

    /* display the number */
    printf("%u DEVICE(S) DETECTED\n\r", devices);

    /* if no devices were detected then halt */
    if (devices==0) while (1); /* loop forever */

    /* set the temperature alarms & temperature
       measurement resolutions for all the devices
       temp_low=25°C temp_high=35°C resolution 12bits */
    for (i=0; i<devices; i++)
    {
        printf("INITIALIZING DEVICE #-u ", i+1);
        if (ds18b20_init(&rom_codes[i][0], 25, 35, DS18B20_12BIT_RES))
            putsf("OK"); else putsf("ERROR");
    };

    while (1)
    {
        /* measure and display the temperature(s) */
        for (i=0; i<devices; i++)
            printf("t%u=%+.3f\xf8" "C\n\r", i+1,
                ds18b20_temperature(&rom_codes[i][0]));

        /* display the number of devices which
           generated an alarm */
        printf("ALARM GENERATED BY %-u DEVICE(S)\n\r",
            w1_search(0xec, alarm_rom_codes));
    };
}
```

Refer to the DS18B20 data sheet for more information.

5.25.9 Maxim DS2430 EEPROM Functions

These functions are intended for easy interfacing between C programs and the DS2430 1 Wire bus EEPROM.

The prototypes for these functions are placed in the file **ds2430.h**, located in the `.\INC` subdirectory. This file must be **#include -d** before using the functions.

The 1 Wire bus functions prototypes are automatically **#include -d** with the **ds2430.h**.

The 1 Wire functions must be configured, by specifying the I/O port and bit used for communication through the 1 Wire protocol.

This is accomplished in the **Project|Configure|C Compiler|Libraries|1 Wire** menu:

- the **Enable 1 Wire Bus Interface Support** option must be activated
- the **I/O Port** and **Bit** must be specified in **Data Connection**.

Note: Because the 1 Wire Functions require precision time delays for correct operation, the interrupts must be disabled during their execution.

The DS2430 functions are:

**unsigned char ds2430_read_block(unsigned char *romcode,unsigned char *dest,
unsigned char addr,unsigned char size);**

this function reads a block of **size** bytes starting from the DS2430 EEPROM memory address **addr** and stores it in the string **dest** located in RAM.

It returns 1 if successful, 0 if not.

The DS2430 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2430_read(unsigned char *romcode,unsigned char addr,
unsigned char *data);**

this function reads a byte from the DS2430 EEPROM memory address **addr** and stores it in the RAM memory location pointed by **data**.

It returns 1 if successful, 0 if not.

The DS2430 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2430_write_block(unsigned char *romcode,
unsigned char *source,unsigned char addr,unsigned char size);**

this function writes a block of **size** bytes, from the string **source**, located in RAM, in the DS2430 EEPROM starting from memory address **addr**.

It returns 1 if successful, 0 if not.

The DS2430 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2430_write(unsigned char *romcode,
unsigned char addr,unsigned char data);**

this function writes the byte **data** at DS2430 EEPROM memory address **addr**.

It returns 1 if successful, 0 if not.

The DS2430 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2430_read_appreg_block(unsigned char *romcode,
unsigned char *dest,unsigned char addr,unsigned char size);**

this function reads a block of **size** bytes starting from the DS2430 application register address **addr** and stores it in the string **dest** located in RAM.

It returns 1 if successful, 0 if not.

The DS2430 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2430_write_appreg_block(unsigned char *romcode,
unsigned char *source,unsigned char addr,unsigned char size);**

this function reads a block of **size** bytes starting from the DS2430 application register address **addr** and stores it in the string **dest** located in RAM.

It returns 1 if successful, 0 if not.

The DS2430 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

If only one DS2430 EEPROM is used, no ROM code array is necessary and the pointer **romcode** must be NULL (0).

If several 1 Wire device are used, then the program must first identify the ROM codes for all the devices. Only after that the DS2430 functions may be used, with the **romcode** pointer pointing to the array which holds the ROM code for the needed device.

Example:

```
/* The ATmega8515 port and bit used for the 1 Wire bus must be specified  
   in the Project|Configure|C Compiler|Libraries 1 Wire menu
```

```
The DS2430 devices are connected to  
bit 6 of PORTA of the ATmegaS8515 as follows:
```

[DS2430]		[STK200 PORTA HEADER]
1 GND	-	9 GND
2 DATA	-	7 PA6

```
All the devices must be connected in parallel
```

```
AN 4.7k PULLUP RESISTOR MUST BE CONNECTED  
BETWEEN DATA (PA6) AND +5V !
```

```
*/
```

```
/* include the DS2430 functions */  
#include <ds2430.h>  
#include <mega8515.h>  
#include <stdio.h>
```

```
/* DS2430 devices ROM code storage area,  
   9 bytes are used for each device  
   (see the w1_search function description),  
   but only the first 8 bytes contain the ROM code  
   and CRC */
```

```
#define MAX_DEVICES 8
```

```
unsigned char rom_code[MAX_DEVICES][9];
```

```
char text[]="Hello world!";
char buffer[32];
#define START_ADDR 2

/* ATmega8515 clock frequency [Hz] */
#define xtal 4000000L

/* Baud rate */
#define baud 9600

main() {
    unsigned char i,devices;

    /* initialize the USART control register
       TX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x08;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/baud-1) >> 8;
    UBRL=(xtal/16/baud-1) & 0xFF;

    /* detect how many 1 Wire devices are present on the bus */
    devices=w1_search(0xF0,&rom_code[0][0]);
    printf("%-u 1 Wire devices found\n\r",devices);
    for (i=0;i<devices;i++)
        /* make sure to select only the DS2430 types
           0x14 is the DS2430 family code */
        if (rom_code[i][0]==DS2430_FAMILY_CODE)
        {
            printf("\n\r");
            /* write text in each DS2430 at START_ADDR */
            if (ds2430_write_block(&rom_code[i][0],
                text,START_ADDR,sizeof(text)))
            {
                printf("Data written OK in DS2430 #%-u!\n\r",i+1);
                /* display the text written in each DS2430 */
                if (ds2430_read_block(&rom_code[i][0],buffer,START_ADDR,
                    sizeof(text)))
                    printf("Data read OK!\n\rDS2430 #%-u text: %s\n\r",
                        i+1,buffer);
                else printf("Error reading data from DS2430 #%-u!\n\r",
                    i+1);
            }
            else printf("Error writing data to DS2430 #%-u!\n\r",i+1);
        };
    /* stop */
    while (1);
}
```

Refer to the DS2430 data sheet for more information.

5.25.10 Maxim DS2433 EEPROM Functions

These functions are intended for easy interfacing between C programs and the DS2433 1 Wire bus EEPROM.

The prototypes for these functions are placed in the file **ds2433.h**, located in the `.INC` subdirectory. This file must be **#include -d** before using the functions.

The 1 Wire bus functions prototypes are automatically **#include -d** with the **ds2433.h**.

The 1 Wire functions must be configured, by specifying the I/O port and bit used for communication through the 1 Wire protocol.

This is accomplished in the **Project|Configure|C Compiler|Libraries|1 Wire** menu:

- the **Enable 1 Wire Bus Interface Support** option must be activated
- the **I/O Port** and **Bit** must be specified in **Data Connection**.

Note: Because the 1 Wire Functions require precision time delays for correct operation, the interrupts must be disabled during their execution.

The DS2433 functions are:

**unsigned char ds2433_read_block(unsigned char *romcode,unsigned char *dest,
unsigned int addr,unsigned int size);**

this function reads a block of **size** bytes starting from the DS2433 EEPROM memory address **addr** and stores it in the string **dest** located in RAM.

It returns 1 if successful, 0 if not.

The DS2433 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2433_read(unsigned char *romcode,unsigned int addr,
unsigned char *data);**

this function reads a byte from the DS2433 EEPROM memory address **addr** and stores it in the RAM memory location pointed by **data**.

It returns 1 if successful, 0 if not.

The DS2433 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2433_write_block(unsigned char *romcode,
unsigned char *source,unsigned int addr,unsigned int size);**

this function writes a block of **size** bytes, from the string **source**, located in RAM, in the DS2433 EEPROM starting from memory address **addr**.

It returns 1 if successful, 0 if not.

The DS2433 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

**unsigned char ds2433_write(unsigned char *romcode,unsigned int addr,
unsigned char data);**

this function writes the byte **data** at DS2433 EEPROM memory address **addr**.

It returns 1 if successful, 0 if not.

The DS2433 device is selected using its ROM code stored in an array of 8 bytes located at address **romcode**.

CodeVisionAVR

If only one DS2433 EEPROM is used, no ROM code array is necessary and the pointer **romcode** must be NULL (0).

If several 1 Wire device are used, then the program must first identify the ROM codes for all the devices. Only after that the DS2433 functions may be used, with the **romcode** pointer pointing to the array which holds the ROM code for the needed device.

Example:

```
/* The ATmega8515 port and bit used for the 1 Wire bus must be specified
   in the Project|Configure|C Compiler|Libraries 1 Wire menu
```

```

The DS2433 devices are connected to
bit 6 of PORTA of the ATmega8515 as follows:
```

```
[DS2433]          [STK200 PORTA HEADER]
 1 GND            -   9  GND
 2 DATA          -   7  PA6
```

```

All the devices must be connected in parallel
```

```

AN 4.7k PULLUP RESISTOR MUST BE CONNECTED
BETWEEN DATA (PA6) AND +5V !
```

```
*/
```

```
#asm
```

```
    .equ __w1_port=0x1b
```

```
    .equ __w1_bit=6
```

```
#endasm
```

```
// test the DS2433 functions
```

```
#include <ds2433.h>
```

```
#include <mega8515.h>
```

```
#include <stdio.h>
```

```
/* DS2433 devices ROM code storage area,
   9 bytes are used for each device
   (see the w1_search function description),
   but only the first 8 bytes contain the ROM code
   and CRC */
```

```
#define MAX_DEVICES 8
```

```
unsigned char rom_code[MAX_DEVICES][9];
```

```
char text[]="This is a long text to \
be able to test writing across the \
scratchpad boundary";
```

```
char buffer[100];
```

```
#define START_ADDR 2
```

```
/* ATmega8515 clock frequency [Hz] */
```

```
#define xtal 4000000L
```

```
/* Baud rate */
```

```
#define baud 9600
```

```
main() {
    unsigned char i, devices;

    /* initialize the USART control register
       TX enabled, no interrupts, 8 data bits */
    UCSRA=0x00;
    UCSRB=0x08;
    UCSRC=0x86;

    /* initialize the USART's baud rate */
    UBRRH=(xtal/16/ baud-1) >> 8;
    UBRL=(xtal/16/ baud-1) & 0xFF;

    /* detect how many 1 Wire devices are present on the bus */
    devices=w1_search(0xF0,&rom_code[0][0]);
    printf("%-u 1 Wire devices found\n\r", devices);

    for (i=0; i<devices; i++)
        /* make sure to select only the DS2433 types
           0x23 is the DS2433 family code */
        if (rom_code[i][0]==DS2433_FAMILY_CODE)
        {
            printf("\n\r");
            /* write text in each DS2433 at START_ADDR */
            if (ds2433_write_block(&rom_code[i][0],
                text, START_ADDR, sizeof(text)))
            {
                printf("Data written OK in DS2433 #%-u!\n\r", i+1);
                /* display the text written in each DS2433 */
                if (ds2433_read_block(&rom_code[i][0], buffer, START_ADDR,
                    sizeof(text)))
                    printf("Data read OK!\n\rDS2433 #%-u text: %s\n\r",
                        i+1, buffer);
                else printf("Error reading data from DS2433 #%-u!\n\r", i+1);
            }
            else printf("Error writing data to DS2433 #%-u!\n\r", i+1);
        };
    /* stop */
    while (1);
}
```

Refer to the DS2433 data sheet for more information.

5.25.11 Texas Instruments LM75 Temperature Sensor Functions

These functions are intended for easy interfacing between C programs and the LM75 I²C bus temperature sensor, using both the hardware TWI and software bit-banged I²C bus functions. One of the following header files, located in the .INC subdirectory must be **#include** -d before using these functions:

- **lm75_twi.h** for hardware TWI
- **lm75.h** for software bit-banged I²C bus.

The appropriate header files for hardware TWI (**twi.h** or **twix.h**) or software bit-banged I²C bus (**i2c.h**) functions prototypes are automatically **#include** -d with the **lm75_twi.h** or **lm75.h**.

The **Project|Configure|C Compiler|Libraries|I2C** menu must be used for specifying the I/O port allocation of the **SCL** and **SDA** signals, along the **bit rate** of the **SCL** clock, for bit-banged I²C bus (not the hardware TWI) communication.

Note: For proper operation, the LM75 Functions require the presence of 3.3k - 4.7k pull-up resistors to +5V (+3.3V for XMEGA devices) on the SCL and SDA signals.

The LM75 Functions are:

void lm75_init(unsigned char chip, signed char thyst, signed char tos, unsigned char pol)

this function initializes the LM75 sensor chip.

Before calling this function, the TWI hardware, respectively I²C bus, must be initialized by calling the **twi_master_init** (**twi_init**, **twi_master_init** and **lm75_twi_init** for XMEGA devices), respectively **i2c_init** functions. This is the first function that must be called prior to using the other LM75 Functions.

If more than one chip is connected to the I²C bus, then the function must be called for each one, specifying accordingly the function parameter **chip**.

Maximum 8 LM75 chips can be connected to the I²C bus, their **chip** address can be from 0 to 7.

The LM75 is configured in comparator mode, where it functions like a thermostat.

The O.S. output becomes active when the temperature exceeds the **tos** limit, and leaves the active state when the temperature drops below the **thyst** limit.

Both **thyst** and **tos** are expressed in °C.

pol represents the polarity of the LM75 O.S. output in active state.

If **pol** is 0, the output is active low and if **pol** is 1, the output is active high.

Refer to the LM75 data sheet for more information.

void lm75_twi_init(TWI_MASTER_INFO_t *ptwim)

this function is used to initialize the LM75 library's internal variables when using the **TWI Functions for Master Mode Operation for XMEGA Devices**. It is not used for non-XMEGA devices.

The **ptwim** parameter must point to a **TWI_MASTER_INFO_t** structure variable, that is used to hold the information required by the TWI module when operating in master mode.

The **lm75_twi_init** function must be called before **lm75_init**.

Refer to the supplied example at the end of this chapter for more details.

int lm75_temperature_10(unsigned char chip)

this function returns the temperature of the LM75 sensor with the address **chip**.

The temperature is in °C and is multiplied by 10.

A 300ms delay must be present between two successive calls to the **lm75_temperature_10** function.

Example how to display the temperature of two LM75 sensors with addresses 0 and 1.
The chips are accessed using the **TWI Functions for Master Mode Operation for non-XMEGA Devices**.

```
/* include the LM75 functions for TWI */
#include <lm75_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototype for abs */
#include <stdlib.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[33];

void main(void) {
    int t0,t1;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the TWI in master mode with 100 kHz bit rate */
    twi_master_init(100);

    /* enable interrupts so that TWI can be used */
    #asm("sei")

    /* initialize the LM75 sensor with address 0 */
    /* thyst=20°C tos=25°C */
    lm75_init(0,20,25,0);

    /* initialize the LM75 sensor with address 1 */
    /* thyst=30°C tos=35°C */
    lm75_init(1,30,35,0);

    /* temperature display loop */
    while (1)
    {
        /* read the temperature of sensor #0 *10°C */
        t0=lm75_temperature_10(0);
        /* 300ms delay */
        delay_ms(300);

        /* read the temperature of sensor #1 *10°C */
        t1=lm75_temperature_10(1);
        /* 300ms delay */
        delay_ms(300);
    }
}
```

```
/* prepare the displayed temperatures */
/* in the display_buffer */
sprintf(display_buffer,
        "t0=%-i.%-u%C\nt1=%-i.%-u%C",
        t0/10,abs(t0%10),0xdf,t1/10,abs(t1%10),0xdf);

/* display the temperatures */
lcd_clear();
lcd_puts(display_buffer);
};
}
```

The same example, but the LM75 chips are accessed using the **TWI Functions for Master Mode Operation for XMEGA Devices** using the TWI of PORTD (TWID) of an ATxmega128A1 chip.

```
/* include the LM75 functions for TWI */
#include <lm75_twi.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototype for abs */
#include <stdlib.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[33];

/* structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [Hz] */
#define TWI_CLK_RATE 100000

void main(void) {
    int t0,t1;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* general TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);
```



```
/* enable and initialize the TWID master
   interrupt level: low */
twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

/* enable the Low interrupt level */
PMIC.CTRL|=PMIC_LOLVLEN_bm;

/* set the LM75 functions to use TWID */
lm75_twi_init(&twid_master);

/* enable interrupts so that TWI can be used */
#asm("sei")

/* initialize the LM75 sensor with address 0 */
/* thyst=20°C tos=25°C */
lm75_init(0,20,25,0);

/* initialize the LM75 sensor with address 1 */
/* thyst=30°C tos=35°C */
lm75_init(1,30,35,0);

/* temperature display loop */
while (1)
{
    /* read the temperature of sensor #0 *10°C */
    t0=lm75_temperature_10(0);
    /* 300ms delay */
    delay_ms(300);

    /* read the temperature of sensor #1 *10°C */
    t1=lm75_temperature_10(1);
    /* 300ms delay */
    delay_ms(300);

    /* prepare the displayed temperatures */
    /* in the display_buffer */
    sprintf(display_buffer,
    "t0=%-i.%-u°C\nt1=%-i.%-u°C",
    t0/10,abs(t0%10),0xdf,t1/10,abs(t1%10),0xdf);

    /* display the temperatures */
    lcd_clear();
    lcd_puts(display_buffer);
};
}
```

The same example, but the LM75 chips are accessed using the **Software Bit-Banged I2C Bus Functions**.

```
/* include the LM75 functions
   The I2C bus connections and bit rate must be specified in the
   Project|Configure|C Compiler|Libraries|I2C menu */
#include <lm75.h>

/* include the LCD Functions
   The connections must be specified in the
   Project|Configure|C Compiler|Libraries|Alphanumeric LCD menu */
#include <alcd.h>

/* include the prototype for sprintf */
#include <stdio.h>

/* include the prototype for abs */
#include <stdlib.h>

/* include the prototypes for the delay functions */
#include <delay.h>

char display_buffer[33];

void main(void) {
    int t0,t1;

    /* initialize the LCD, 2 rows by 16 columns */
    lcd_init(16);

    /* initialize the I2C bus */
    i2c_init();

    /* initialize the LM75 sensor with address 0 */
    /* thyst=20°C tos=25°C */
    lm75_init(0,20,25,0);

    /* initialize the LM75 sensor with address 1 */
    /* thyst=30°C tos=35°C */
    lm75_init(1,30,35,0);

    /* temperature display loop */
    while (1)
    {
        /* read the temperature of sensor #0 *10°C */
        t0=lm75_temperature_10(0);
        /* 300ms delay */
        delay_ms(300);

        /* read the temperature of sensor #1 *10°C */
        t1=lm75_temperature_10(1);
        /* 300ms delay */
        delay_ms(300);
    }
}
```

```
/* prepare the displayed temperatures */
/* in the display_buffer */
sprintf(display_buffer,
"t0=%-i.%-u%cC\nt1=%-i.%-u%cC",
t0/10,abs(t0%10),0xdf,t1/10,abs(t1%10),0xdf);

/* display the temperatures */
lcd_clear();
lcd_puts(display_buffer);
};
}
```

5.25.12 Bosch Sensortec BMP085 Digital Pressure Sensor Functions

These functions are intended for easy interfacing between C programs and the Bosch Sensortec BMP085 I²C bus pressure sensor, using the hardware TWI.
The **bmp085_twi.h** header file, located in the .INC subdirectory must be **#include** -d before using these functions.

Notes:

- The appropriate header files for hardware TWI (**twi.h** or **twix.h**) are automatically **#include** -d with **bmp085_twi.h**
- For proper operation, the BMP085 functions require the presence of 4.7k pull-up resistors to **+3.3V** on the SCL and SDA signals
- Before calling the BMP085 functions, the TWI interface must be properly initialized and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

The following low level access BMP085 functions are available:

short bmp085_wrreg(unsigned char reg, unsigned char data)

writes the byte **data** to the BMP085 register **reg**.

Returns one of the following values, defined in **bmp085_twi.h**:

```
#define BMP085_INIT_OK 0 /* The command was successful */
#define BMP085_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

short bmp085_rdreg(unsigned char reg)

reads a byte of data from the BMP085 register **reg**.

Returns:

- In case of success, a positive value in the range 0..255, representing the read byte of data
- In case of error, the negative value defined in **bmp085_twi.h**:

```
#define BMP085_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

The **bmp085_twi.h** header contains the definitions of the BMP085 registers and commands that are accessible using the above mentioned functions:

```
#define BMP085_CHIP_ID_REG 0xD0 /* Chip ID register */
#define BMP085_VERSION_REG 0xD1 /* Chip Version register */
#define BMP085_SOFT_RESET_REG 0xE0 /* Software Reset register */

#define BMP085_CTRL_MEAS_REG 0xF4 /* Control & Measurement register */
#define BMP085_ADC_OUT_MSB_REG 0xF6 /* Read ADC Result register MSB */
#define BMP085_ADC_OUT_LSB_REG 0xF7 /* Read ADC Result register LSB */
#define BMP085_ADC_OUT_XLSB_REG 0xF8 /* Read ADC Result register XLSB */
```

```
/* Addresses of BMP085 calibration parameters */
#define BMP085_CALIB_PARAM_AC1_MSB 0xAA
#define BMP085_CALIB_PARAM_AC1_LSB 0xAB
#define BMP085_CALIB_PARAM_AC2_MSB 0xAC
#define BMP085_CALIB_PARAM_AC2_LSB 0xAD
#define BMP085_CALIB_PARAM_AC3_MSB 0xAE
#define BMP085_CALIB_PARAM_AC3_LSB 0xAF
#define BMP085_CALIB_PARAM_AC4_MSB 0xB0
#define BMP085_CALIB_PARAM_AC4_LSB 0xB1
#define BMP085_CALIB_PARAM_AC5_MSB 0xB2
#define BMP085_CALIB_PARAM_AC5_LSB 0xB3
#define BMP085_CALIB_PARAM_AC6_MSB 0xB4
#define BMP085_CALIB_PARAM_AC6_LSB 0xB5
#define BMP085_CALIB_PARAM_B1_MSB 0xB6
#define BMP085_CALIB_PARAM_B1_LSB 0xB7
#define BMP085_CALIB_PARAM_B2_MSB 0xB8
#define BMP085_CALIB_PARAM_B2_LSB 0xB9
#define BMP085_CALIB_PARAM_MB_MSB 0xBA
#define BMP085_CALIB_PARAM_MB_LSB 0xBB
#define BMP085_CALIB_PARAM_MC_MSB 0xBC
#define BMP085_CALIB_PARAM_MC_LSB 0xBD
#define BMP085_CALIB_PARAM_MD_MSB 0xBE
#define BMP085_CALIB_PARAM_MD_LSB 0xBF

/* Chip ID for BMP085 */
#define BMP085_CHIP_ID 0x55
/* Soft Reset register command for resetting chip */
#define BMP085_SOFT_RESET_CMD 0xB6
/* Control register value for measuring temperature */
#define BMP085_CTRL_TEMP 0x2E
/* Control register value for measuring pressure */
#define BMP085_CTRL_PRES 0x34
```

The following high level access BMP085 functions are available:

For non-Xmega AVR chips:

short bmp085_init(unsigned char mode)

reads the calibration parameters from the device's EEPROM and sets the pressure sensor's measurement **mode**.

The BMP085 measurement modes are defined in **bmp085_twi.h**:

```
/* BMP085 pressure measurement modes (conversion time) */
#define BMP085_ULTRA_LOW_POWER_MODE 0 /* Ultra Low Power Mode (5ms) */
#define BMP085_STANDARD_MODE 1 /* Standard Mode (8ms) */
#define BMP085_HI_RES_MODE 2 /* High Resolution Mode (14ms) */
#define BMP085_ULTRA_HI_RES_MODE 3 /* Ultra High Resolution Mode (26ms) */
#define BMP085_ADVANCED_RES_MODE 4 /* Advanced Resolution Mode (76ms) */
```

Returns one of the following values, defined in **bmp085_twi.h**:

```
#define BMP085_INIT_OK 0 /* The command was successful */
#define BMP085_COMM_ERROR -32768 /* TWI communication with the device
has failed */
#define BMP085_INIT_ERROR -32767 /* TWI initialization parameters
are not correct */
#define BMP085_CALIB_ERROR -32766 /* The calibration data read from
the device PROM is not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_master_init** function from the **TWI Functions for Master Mode Operation for non-XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction. Example:

```
/* BMP085 Pressure sensor functions */
#include <bmp085_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BMP085 pressure sensor */
    bmp085_init(BMP085_ADVANCED_RES_MODE);

    /* Follows the rest of the program */
}
```

For Xmega chips:

short bmp085_init(TWI_MASTER_INFO_t *twi_master, unsigned char mode)

reads the calibration parameters from the device's EEPROM and sets the pressure sensor's measurement **mode**.

The **twi_master** parameter points to the structure that holds the information used by the TWI master Xmega module, used for communication with the pressure sensor, for performing a TWI bus transaction.

Returns one of the following values, defined in **bmp085_twi.h**:

```
#define BMP085_INIT_OK 0 /* The command was successful */
#define BMP085_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define BMP085_INIT_ERROR -32767 /* TWI initialization parameters are not correct */
#define BMP085_CALIB_ERROR -32766 /* The calibration data read from the device EEPROM is not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_init** and **twi_master_init** functions from the **TWI Functions for Master Mode Operation for XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction. Example:

```
/* BMP085 Pressure sensor functions */
#include <bmp085_twi.h>

/* Structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;
```

```
/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

void main(void)
{
    /* General TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* Enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* Enable the Low interrupt level */
    PMIC_CTRL |= PMIC_LOLVLEN_bm;

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BMP085 pressure sensor */
    bmp085_init(&twid_master,BMP085_ADVANCED_RES_MODE);

    /* Follows the rest of the program */

}
```

Note: The calibration parameters read from the device's EEPROM are stored in the **bmp085_calib_param** structure variable, declared in **bmp085_twi.h**:

```
typedef struct
{
    short ac1; /* AC1 parameter */
    short ac2; /* AC2 parameter */
    short ac3; /* AC3 parameter */
    unsigned short ac4; /* AC4 parameter */
    unsigned short ac5; /* AC5 parameter */
    unsigned short ac6; /* AC6 parameter */
    short b1; /* B1 parameter */
    short b2; /* B2 parameter */
    short mb; /* MB parameter */
    short mc; /* MC parameter */
    short md; /* MD parameter */
} BMP085_CALIB_PARAM_t;

extern BMP085_CALIB_PARAM_t bmp085_calib_param;
```

and defined in the **bmp085_twi.lib** library.

float bmp085_temperature(void)

reads the ambient temperature in °C, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **bmp085_twi.h**:

```
#define BMP085_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define BMP085_INIT_ERROR -32767 /* BMP085 initialization was not performed correctly */
```

long bmp085_pressure(void)

reads the absolute pressure in Pa, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **bmp085_twi.h**:

```
#define BMP085_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define BMP085_INIT_ERROR -32767 /* BMP085 initialization was not performed correctly */
```

Example for ATmega328P clocked at 16 MHz:

```
/* I/O registers definitions */
#include <io.h>
/* Standard I/O: printf */
#include <stdio.h>
/* Delay functions */
#include <delay.h>
/* BMP085 Pressure sensor functions */
#include <bmp085_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    float temperature, pressure;

    /* USART initialization
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 (Double Speed Mode) @ 16MHz */
    UCSRA=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
    (0<<UPE0) | (1<<U2X0) | (0<<MPCM0);
    UCSRB=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
    (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSRC=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
    (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRR0H=0x00;
    UBRR0L=0xCF;
```



```
/* TWI initialization
   Mode: TWI Master, Bit Rate: 100 kbps */
twi_master_init(TWI_CLK_RATE);

/* Enable the interrupts */
#asm("sei")

printf("BMP085 Pressure sensor demo\r\n");

/* Initialize the BMP085 pressure sensor
   Use the maximum precision mode */
switch (bmp085_init(BMP085_ADVANCED_RES_MODE))
{
    case BMP085_INIT_OK:
        printf("BMP085 initialized OK\r\n\r\n");
        break;

    case BMP085_COMM_ERROR:
        twi_comm_error:
        printf("TWI communication error\r\n");
        goto halt;

    case BMP085_INIT_ERROR:
        printf("Initialization parameters are not correct\r\n");
        goto halt;

    case BMP085_CALIB_ERROR:
        printf("BMP085 calibration parameters read from EEPROM"
               " are not valid\r\n");

    halt:
        while(1);
}

while (1)
{
    /* Measure the temperature in [°C] */
    temperature=bmp085_temperature();
    /* Check for TWI communication error */
    if (temperature==BMP085_COMM_ERROR) goto twi_comm_error;
    /* Measure the absolute pressure in [Pa] */
    pressure=bmp085_pressure();
    /* Check for TWI communication error */
    if (pressure==BMP085_COMM_ERROR) goto twi_comm_error;
    /* Display the results in [°C] and [hPa] */
    printf("t=%5.1fC P=%7.2fhPa\r\n",temperature,pressure/100.0);
    /* 1 second delay between measurements */
    delay_ms(1000);
}
}
```

CodeVisionAVR

CodeVisionAVR is also supplied with additional functions for calculating the altitude above sea level, defined in the **altitude.h** header file:

float abs_altitude(float p, float p0)

returns the absolute altitude above sea level in [m], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]

p0 - pressure at sea level [Pa]

Note: The standard value for the pressure [Pa] at sea level is defined in the **altitude.h** header:

```
#define PRESSURE_SEA_LEVEL_STD 101325.0
```

float pressure_sea_level(float p, float abs_alt)

returns the pressure at sea level in [Pa], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]

abs_alt - measured absolute altitude above sea level [m].

5.25.13 Bosch Sensortec BMP180 Digital Pressure Sensor Functions

These functions are intended for easy interfacing between C programs and the Bosch Sensortec BMP180 I²C bus pressure sensor, using the hardware TWI.
The **bmp180_twi.h** header file, located in the .INC subdirectory must be **#include** -d before using these functions.

Notes:

- The appropriate header files for hardware TWI (**twi.h** or **twix.h**) are automatically **#include** -d with **bmp180_twi.h**
- For proper operation, the BMP180 functions require the presence of 4.7k pull-up resistors to **+3.3V** on the SCL and SDA signals
- Before calling the BMP180 functions, the TWI interface must be properly initialized and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

The following low level access BMP180 functions are available:

short bmp180_wrreg(unsigned char reg, unsigned char data)

writes the byte **data** to the BMP180 register **reg**.

Returns one of the following values, defined in **bmp180_twi.h**:

```
#define BMP180_INIT_OK 0 /* The command was successful */
#define BMP180_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

short bmp180_rdreg(unsigned char reg)

reads a byte of data from the BMP180 register **reg**.

Returns:

- In case of success, a positive value in the range 0..255, representing the read byte of data
- In case of error, the negative value defined in **bmp180_twi.h**:

```
#define BMP180_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

The **bmp180_twi.h** header contains the definitions of the BMP180 registers and commands that are accessible using the above mentioned functions:

```
#define BMP180_CHIP_ID_REG 0xD0 /* Chip ID register */
#define BMP180_SOFT_RESET_REG 0xE0 /* Software Reset register */

#define BMP180_CTRL_MEAS_REG 0xF4 /* Control & Measurement register */
#define BMP180_ADC_OUT_MSB_REG 0xF6 /* Read ADC Result register MSB */
#define BMP180_ADC_OUT_LSB_REG 0xF7 /* Read ADC Result register LSB */
#define BMP180_ADC_OUT_XLSB_REG 0xF8 /* Read ADC Result register XLSB */
```

```
/* Addresses of BMP180 calibration parameters */
#define BMP180_CALIB_PARAM_AC1_MSB 0xAA
#define BMP180_CALIB_PARAM_AC1_LSB 0xAB
#define BMP180_CALIB_PARAM_AC2_MSB 0xAC
#define BMP180_CALIB_PARAM_AC2_LSB 0xAD
#define BMP180_CALIB_PARAM_AC3_MSB 0xAE
#define BMP180_CALIB_PARAM_AC3_LSB 0xAF
#define BMP180_CALIB_PARAM_AC4_MSB 0xB0
#define BMP180_CALIB_PARAM_AC4_LSB 0xB1
#define BMP180_CALIB_PARAM_AC5_MSB 0xB2
#define BMP180_CALIB_PARAM_AC5_LSB 0xB3
#define BMP180_CALIB_PARAM_AC6_MSB 0xB4
#define BMP180_CALIB_PARAM_AC6_LSB 0xB5
#define BMP180_CALIB_PARAM_B1_MSB 0xB6
#define BMP180_CALIB_PARAM_B1_LSB 0xB7
#define BMP180_CALIB_PARAM_B2_MSB 0xB8
#define BMP180_CALIB_PARAM_B2_LSB 0xB9
#define BMP180_CALIB_PARAM_MB_MSB 0xBA
#define BMP180_CALIB_PARAM_MB_LSB 0xBB
#define BMP180_CALIB_PARAM_MC_MSB 0xBC
#define BMP180_CALIB_PARAM_MC_LSB 0xBD
#define BMP180_CALIB_PARAM_MD_MSB 0xBE
#define BMP180_CALIB_PARAM_MD_LSB 0xBF

/* Chip ID for BMP180 */
#define BMP180_CHIP_ID 0x55
/* Soft Reset register command for resetting chip */
#define BMP180_SOFT_RESET_CMD 0xB6
/* Control register value for measuring temperature */
#define BMP180_CTRL_TEMP 0x2E
/* Control register value for measuring pressure */
#define BMP180_CTRL_PRES 0x34
```

The following high level access BMP180 functions are available:

For non-Xmega AVR chips:

short bmp180_init(unsigned char mode)

reads the calibration parameters from the device's EEPROM and sets the pressure sensor's measurement **mode**.

The BMP180 measurement modes are defined in **bmp180_twi.h**:

```
/* BMP180 pressure measurement modes (conversion time) */
#define BMP180_ULTRA_LOW_POWER_MODE 0 /* Ultra Low Power Mode (5ms) */
#define BMP180_STANDARD_MODE 1 /* Standard Mode (8ms) */
#define BMP180_HI_RES_MODE 2 /* High Resolution Mode (14ms) */
#define BMP180_ULTRA_HI_RES_MODE 3 /* Ultra High Resolution Mode (26ms) */
#define BMP180_ADVANCED_RES_MODE 4 /* Advanced Resolution Mode (76ms) */
```

Returns one of the following values, defined in **bmp180_twi.h**:

```
#define BMP180_INIT_OK 0 /* The command was successful */
#define BMP180_COMM_ERROR -32768 /* TWI communication with the device
                                  has failed */
#define BMP180_INIT_ERROR -32767 /* TWI initialization parameters
                                  are not correct */
#define BMP180_CALIB_ERROR -32766 /* The calibration data read from
                                  the device PROM is not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_master_init** function from the **TWI Functions for Master Mode Operation for non-XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction. Example:

```
/* BMP180 Pressure sensor functions */
#include <bmp180_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BMP180 pressure sensor */
    bmp180_init(BMP180_ADVANCED_RES_MODE);

    /* Follows the rest of the program */
}
```

For Xmega chips:

short bmp180_init(TWI_MASTER_INFO_t *twi_master, unsigned char mode)

reads the calibration parameters from the device's EEPROM and sets the pressure sensor's measurement **mode**.

The **twi_master** parameter points to the structure that holds the information used by the TWI master Xmega module, used for communication with the pressure sensor, for performing a TWI bus transaction.

Returns one of the following values, defined in **bmp180_twi.h**:

```
#define BMP180_INIT_OK 0 /* The command was successful */
#define BMP180_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define BMP180_INIT_ERROR -32767 /* TWI initialization parameters are not correct */
#define BMP180_CALIB_ERROR -32766 /* The calibration data read from the device EEPROM is not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_init** and **twi_master_init** functions from the **TWI Functions for Master Mode Operation for XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction. Example:

```
/* BMP180 Pressure sensor functions */
#include <bmp180_twi.h>

/* Structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;
```

```
/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

void main(void)
{
    /* General TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* Enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* Enable the Low interrupt level */
    PMIC_CTRL |= PMIC_LOLVLEN_bm;

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BMP180 pressure sensor */
    bmp180_init(&twid_master,BMP180_ADVANCED_RES_MODE);

    /* Follows the rest of the program */

}
```

Note: The calibration parameters read from the device's EEPROM are stored in the **bmp180_calib_param** structure variable, declared in **bmp180_twi.h**:

```
typedef struct
{
    short ac1; /* AC1 parameter */
    short ac2; /* AC2 parameter */
    short ac3; /* AC3 parameter */
    unsigned short ac4; /* AC4 parameter */
    unsigned short ac5; /* AC5 parameter */
    unsigned short ac6; /* AC6 parameter */
    short b1; /* B1 parameter */
    short b2; /* B2 parameter */
    short mb; /* MB parameter */
    short mc; /* MC parameter */
    short md; /* MD parameter */
} BMP180_CALIB_PARAM_t;

extern BMP180_CALIB_PARAM_t bmp180_calib_param;
```

and defined in the **bmp180_twi.lib** library.

float bmp180_temperature(void)

reads the ambient temperature in °C, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **bmp180_twi.h**:

```
#define BMP180_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define BMP180_INIT_ERROR -32767 /* BMP180 initialization was not performed correctly */
```

long bmp180_pressure(void)

reads the absolute pressure in Pa, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **bmp180_twi.h**:

```
#define BMP180_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define BMP180_INIT_ERROR -32767 /* BMP180 initialization was not performed correctly */
```

Example for ATmega328P clocked at 16 MHz:

```
/* I/O registers definitions */
#include <io.h>
/* Standard I/O: printf */
#include <stdio.h>
/* Delay functions */
#include <delay.h>
/* BMP180 Pressure sensor functions */
#include <bmp180_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    float temperature, pressure;

    /* USART initialization
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 (Double Speed Mode) @ 16MHz */
    UCSRA=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
    (0<<UPE0) | (1<<U2X0) | (0<<MPCM0);
    UCSRB=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
    (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSRC=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
    (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRR0H=0x00;
    UBRR0L=0xCF;
```

```
/* TWI initialization
   Mode: TWI Master, Bit Rate: 100 kbps */
twi_master_init(TWI_CLK_RATE);

/* Enable the interrupts */
#asm("sei")

printf("BMP180 Pressure sensor demo\r\n");

/* Initialize the BMP180 pressure sensor
   Use the maximum precision mode */
switch (bmp180_init(BMP180_ADVANCED_RES_MODE))
{
    case BMP180_INIT_OK:
        printf("BMP180 initialized OK\r\n\r\n");
        break;

    case BMP180_COMM_ERROR:
        twi_comm_error:
        printf("TWI communication error\r\n");
        goto halt;

    case BMP180_INIT_ERROR:
        printf("Initialization parameters are not correct\r\n");
        goto halt;

    case BMP180_CALIB_ERROR:
        printf("BMP180 calibration parameters read from EEPROM"
               " are not valid\r\n");

        halt:
        while(1);
        }

while (1)
{
    /* Measure the temperature in [°C] */
    temperature=bmp180_temperature();
    /* Check for TWI communication error */
    if (temperature==BMP180_COMM_ERROR) goto twi_comm_error;
    /* Measure the absolute pressure in [Pa] */
    pressure=bmp180_pressure();
    /* Check for TWI communication error */
    if (pressure==BMP180_COMM_ERROR) goto twi_comm_error;
    /* Display the results in [°C] and [hPa] */
    printf("t=%5.1fC P=%7.2fhPa\r\n",temperature,pressure/100.0);
    /* 1 second delay between measurements */
    delay_ms(1000);
}
}
```


CodeVisionAVR

CodeVisionAVR is also supplied with additional functions for calculating the altitude above sea level, defined in the **altitude.h** header file:

float abs_altitude(float p, float p0)

returns the absolute altitude above sea level in [m], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]

p0 - pressure at sea level [Pa]

Note: The standard value for the pressure [Pa] at sea level is defined in the **altitude.h** header:

```
#define PRESSURE_SEA_LEVEL_STD 101325.0
```

float pressure_sea_level(float p, float abs_alt)

returns the pressure at sea level in [Pa], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]

abs_alt - measured absolute altitude above sea level [m].

5.25.14 Bosch Sensortec BMP280 Digital Pressure Sensor Functions

These functions are intended for easy interfacing between C programs and the Bosch Sensortec BMP280 I²C bus pressure sensor, using the hardware TWI.

The **bmp280_twi.h** header file, located in the .\INC subdirectory must be **#include -d** before using these functions.

Notes:

- The appropriate header files for hardware TWI (**twi.h** or **twix.h**) are automatically **#include -d** with **bmp280_twi.h**
- For proper operation, the BMP280 functions require the presence of 4.7k pull-up resistors to **+3.3V** on the SCL and SDA signals
- Before calling the BMP280 functions, the TWI interface must be properly initialized and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

The following low level access BMP280 functions are available:

short bmp280_wrreg(unsigned char reg, unsigned char data)

writes the byte **data** to the BMP280 register **reg**.

Returns one of the following values, defined in **bmp280_twi.h**:

```
#define BMP280_INIT_OK 0 /* The command was successful */
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

short bmp280_rdreg(unsigned char reg)

reads a byte of data from the BMP280 register **reg**.

Returns:

- In case of success, a positive value in the range 0..255, representing the read byte of data
- In case of error, the negative value defined in **bmp280_twi.h**:

```
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

The **bmp280_twi.h** header contains the definitions of the BMP280 registers and commands that are accessible using the above mentioned functions:

```
/* BMP280 calibration data registers: */
#define BMP280_TEMP_CALIB_DIG_T1_LSB_REG 0x88
#define BMP280_TEMP_CALIB_DIG_T1_MSB_REG 0x89
#define BMP280_TEMP_CALIB_DIG_T2_LSB_REG 0x8A
#define BMP280_TEMP_CALIB_DIG_T2_MSB_REG 0x8B
#define BMP280_TEMP_CALIB_DIG_T3_LSB_REG 0x8C
#define BMP280_TEMP_CALIB_DIG_T3_MSB_REG 0x8D
#define BMP280_PRESS_CALIB_DIG_P1_LSB_REG 0x8E
#define BMP280_PRESS_CALIB_DIG_P1_MSB_REG 0x8F
#define BMP280_PRESS_CALIB_DIG_P2_LSB_REG 0x90
#define BMP280_PRESS_CALIB_DIG_P2_MSB_REG 0x91
#define BMP280_PRESS_CALIB_DIG_P3_LSB_REG 0x92
#define BMP280_PRESS_CALIB_DIG_P3_MSB_REG 0x93
#define BMP280_PRESS_CALIB_DIG_P4_LSB_REG 0x94
```

```
#define BMP280_PRESS_CALIB_DIG_P4_MSB_REG 0x95
#define BMP280_PRESS_CALIB_DIG_P5_LSB_REG 0x96
#define BMP280_PRESS_CALIB_DIG_P5_MSB_REG 0x97
#define BMP280_PRESS_CALIB_DIG_P6_LSB_REG 0x98
#define BMP280_PRESS_CALIB_DIG_P6_MSB_REG 0x99
#define BMP280_PRESS_CALIB_DIG_P7_LSB_REG 0x9A
#define BMP280_PRESS_CALIB_DIG_P7_MSB_REG 0x9B
#define BMP280_PRESS_CALIB_DIG_P8_LSB_REG 0x9C
#define BMP280_PRESS_CALIB_DIG_P8_MSB_REG 0x9D
#define BMP280_PRESS_CALIB_DIG_P9_LSB_REG 0x9E
#define BMP280_PRESS_CALIB_DIG_P9_MSB_REG 0x9F

/* BMP280 Registers: */
#define BMP280_CHIP_ID_REG 0xD0 /* Chip ID register */
#define BMP280_SOFT_RESET_REG 0xE0 /* Software Reset register */

#define BMP280_STATUS_REG 0xF3 /* Status register */
#define BMP280_CTRL_MEAS_REG 0xF4 /* Control & Measurement register */
#define BMP280_CONFIG_REG 0xF5 /* Configuration register */

#define BMP280_PRESS_MSB_REG 0xF7 /* Read ADC Pressure Result register
MSB */
#define BMP280_PRESS_LSB_REG 0xF8 /* Read ADC Pressure Result register
LSB */
#define BMP280_PRESS_XLSB_REG 0xF9 /* Read ADC Pressure Result register
XLSB */

#define BMP280_TEMP_MSB_REG 0xFA /* Read ADC Temperature Result register
MSB */
#define BMP280_TEMP_LSB_REG 0xFB /* Read ADC Temperature Result register
LSB */
#define BMP280_TEMP_XLSB_REG 0xFC /* Read ADC Temperature Result register
XLSB */

/* Chip ID for BMP280 */
#define BMP280_CHIP_ID 0x58
/* Soft Reset register command for resetting chip */
#define BMP280_SOFT_RESET_CMD 0xB6
/* Control register value for measuring temperature */
#define BMP280_CTRL_TEMP 0x2E
/* Control register value for measuring pressure */
#define BMP280_CTRL_PRES 0x34
```

The following high level access BMP280 functions are available:

For non-Xmega AVR chips:

short bmp280_init(unsigned char device_address, unsigned char mode, unsigned char filter_coeff)

reads the calibration parameters from the device's EEPROM and initializes the device.

Parameters:

device_address - I²C bus 7-bit device address, defined in **bmp280_twi.h**:

```
#define BMP280_I2C_ADDR_SDO_LOW 0x76 /* The SDO pin is set to logic 0 */
#define BMP280_I2C_ADDR_SDO_HIGH 0x77 /* The SDO pin is set to logic 1 */
```

mode - pressure measurement mode, defined in **bmp280_twi.h**:

```
#define BMP280_ULTRA_LOW_POWER_MODE 0 /* Ultra Low Power Mode */
#define BMP280_LOW_POWER_MODE 1      /* Low Power Mode */
#define BMP280_STANDARD_RES_MODE 2    /* Standard Resolution Mode */
#define BMP280_HI_RES_MODE 3          /* High Resolution Mode */
#define BMP280_ULTRA_HI_RES_MODE 4    /* Ultra High Resolution Mode */
```

filter_coeff - IIR filter coefficient, defined in **bmp280_twi.h**:

```
#define BMP280_FILTER_COEFF_OFF 0x00
#define BMP280_FILTER_COEFF_2 0x01
#define BMP280_FILTER_COEFF_4 0x02
#define BMP280_FILTER_COEFF_8 0x03
#define BMP280_FILTER_COEFF_16 0x04
```

Returns one of the following values, defined in **bmp280_twi.h**:

```
#define BMP280_INIT_OK 0 /* The command was successful */
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device
                                  has failed */
#define BMP280_INIT_ERROR -32767 /* TWI initialization parameters are
                                  not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_master_init** function from the **TWI Functions for Master Mode Operation for non-XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.
Example:

```
/* BMP280 Pressure sensor functions */
#include <bmp280_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BMP280 pressure sensor */
    bmp280_init(BMP280_I2C_ADDR_SDO_LOW, BMP280_ULTRA_HI_RES_MODE, BMP280_FILTER_COEFF_8);

    /* Follows the rest of the program */
}
```

For Xmega chips:

short bmp280_init(TWI_MASTER_INFO_t *twi_master, unsigned char device_address, unsigned char mode, unsigned char filter_coeff)

reads the calibration parameters from the device's EEPROM and initializes the device.

Parameters:

twi_master - points to the structure that holds the information used by the TWI master Xmega module, used for communication with the pressure sensor, for performing a TWI bus transaction

device_address - I²C bus 7-bit device address, defined in **bmp280_twi.h**:

```
#define BMP280_I2C_ADDR_SDO_LOW 0x76 /* The SDO pin is set to logic 0 */
#define BMP280_I2C_ADDR_SDO_HI 0x77 /* The SDO pin is set to logic 1 */
```

mode - pressure measurement mode, defined in **bmp280_twi.h**:

```
#define BMP280_ULTRA_LOW_POWER_MODE 0 /* Ultra Low Power Mode */
#define BMP280_LOW_POWER_MODE 1 /* Low Power Mode */
#define BMP280_STANDARD_RES_MODE 2 /* Standard Resolution Mode */
#define BMP280_HI_RES_MODE 3 /* High Resolution Mode */
#define BMP280_ULTRA_HI_RES_MODE 4 /* Ultra High Resolution Mode */
```

filter_coeff - IIR filter coefficient, defined in **bmp280_twi.h**:

```
#define BMP280_FILTER_COEFF_OFF 0x00
#define BMP280_FILTER_COEFF_2 0x01
#define BMP280_FILTER_COEFF_4 0x02
#define BMP280_FILTER_COEFF_8 0x03
#define BMP280_FILTER_COEFF_16 0x04
```

Returns one of the following values, defined in **bmp280_twi.h**:

```
#define BMP280_INIT_OK 0 /* The command was successful */
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device
has failed */
#define BMP280_INIT_ERROR -32767 /* TWI initialization parameters are
not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_init** and **twi_master_init** functions from the **TWI Functions for Master Mode Operation for XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.
Example:

```
/* BMP280 Pressure sensor functions */
#include <bmp280_twi.h>

/* Structure that holds information used by the TWID master
for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}
```

```
/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

void main(void)
{
/* General TWID initialization
   no external driver interface
   no SDA hold time */
twi_init(&TWID,false,false);

/* Enable and initialize the TWID master
   interrupt level: low */
twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

/* Enable the Low interrupt level */
PMIC.CTRL|=PMIC_LOLVLEN_bm;

/* Enable the interrupts */
#asm("sei")

/* Initialize the BMP280 pressure sensor */
bmp280_init(&twid_master,BMP280_I2C_ADDR_SDO_LOW,BMP280_ULTRA_HI_RES_MODE,B
MP280_FILTER_COEFF_8);

/* Follows the rest of the program */

}
```

Note: The calibration parameters read from the device's EEPROM are stored in the **bmp280_calib_param** structure variable, declared in **bmp280_twi.h**:

```
typedef struct
{
unsigned short dig_T1;
signed short dig_T2;
signed short dig_T3;
unsigned short dig_P1;
signed short dig_P2;
signed short dig_P3;
signed short dig_P4;
signed short dig_P5;
signed short dig_P6;
signed short dig_P7;
signed short dig_P8;
signed short dig_P9;
} BMP280_CALIB_PARAM_t;

extern BMP280_CALIB_PARAM_t bmp280_calib_param;
```

and defined in the **bmp280_twi.lib** library.

float bmp280_temperature(void)

reads the ambient temperature in °C, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **bmp280_twi.h**:

```
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device
                                  has failed */
#define BMP280_INIT_ERROR -32767 /* BMP280 initialization was not
                                  performed correctly */
```

float bmp280_pressure(void)

reads the absolute pressure in Pa, with 0.1 Pa resolution, performing all necessary compensation based on calibration parameters.

Note: calculations are performed on 64-bits with high precision.

In case of error it returns the values defined in **bmp280_twi.h**:

```
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device
                                  has failed */
#define BMP280_INIT_ERROR -32767 /* BMP280 initialization was not
                                  performed correctly */
#define BMP280_MEAS_ERROR -32766 /* Measurement error or calibration
                                  coefficients read from device's
                                  EEPROM are not correct */
```

Example for ATmega328P clocked at 16 MHz:

```
/* I/O registers definitions */
#include <io.h>
/* Standard I/O: printf */
#include <stdio.h>
/* Delay functions */
#include <delay.h>
/* BMP280 Pressure sensor functions */
#include <bmp280_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void check_result(short n)
{
    switch (n)
    {
        case BMP280_COMM_ERROR:
            printf("TWI communication error\r\n");
            goto halt;

        case BMP280_INIT_ERROR:
            printf("Initialization parameters are not correct\r\n");
            goto halt;

        case BMP280_MEAS_ERROR:
            printf("Measurement error\r\n");

        halt:
            while(1);
    }
}
```

```
void main(void)
{
    float temperature,pressure;

    /* USART initialization
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 (Double Speed Mode) @ 16MHz */
    UCSR0A=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
    (0<<UPE0) | (1<<U2X0) | (0<<MPCM0);
    UCSR0B=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
    (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSR0C=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
    (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRR0H=0x00;
    UBRR0L=0xCF;

    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    printf("BMP280 Pressure sensor demo\r\n");

    /* Initialize the BMP280 pressure sensor
       Use the Ultra High Resolution Mode */
    check_result(bmp280_init(BMP280_I2C_ADDR_SDO_LOW,BMP280_ULTRA_HI_RES_MODE,B
    MP280_FILTER_COEFF_8));
    printf("BMP280 initialized OK\r\n\r\n");

    while (1)
    {
        /* Measure the temperature in degrees [C] */
        temperature=bmp280_temperature();
        /* Check for errors */
        check_result(temperature);
        /* Measure the absolute pressure in [Pa] */
        pressure=bmp280_pressure();
        /* Check for errors */
        check_result(pressure);
        /* Calculate the absolute altitude above sea level [m] */
        altitude=abs_altitude(pressure,PRESSURE_SEA_LEVEL_STD);
        /* Display the results */
        printf("t=%5.1fC P=%7.2fhPa
Alt=%6.1fm\r\n",temperature,pressure/100.0,altitude);
        /* 1 second delay between measurements */
        delay_ms(1000);
    }
}
```


long bmp280_pressure_low_res(void)

reads the absolute pressure in Pa, with 1 Pa resolution, performing all necessary compensation based on calibration parameters.

Note: calculations are performed on 32-bits with lower precision.

This function can be used when lower code size and higher execution speed are required.

In case of error it returns the values defined in **bmp280_twi.h**:

```
#define BMP280_COMM_ERROR -32768 /* TWI communication with the device
                                  has failed */
#define BMP280_INIT_ERROR -32767 /* BMP280 initialization was not
                                  performed correctly */
#define BMP280_MEAS_ERROR -32766 /* Measurement error or calibration
                                  coefficients read from device's
                                  EEPROM are not correct */
```

CodeVisionAVR is also supplied with additional functions for calculating the altitude above sea level, defined in the **altitude.h** header file:

float abs_altitude(float p, float p0)

returns the absolute altitude above sea level in [m], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]

p0 - pressure at sea level [Pa]

Note: The standard value for the pressure [Pa] at sea level is defined in the **altitude.h** header:

```
#define PRESSURE_SEA_LEVEL_STD 101325.0
```

float pressure_sea_level(float p, float abs_alt)

returns the pressure at sea level in [Pa], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]

abs_alt - measured absolute altitude above sea level [m].

5.25.15 Bosch Sensortec BME280 Digital Pressure and Humidity Sensor Functions

These functions are intended for easy interfacing between C programs and the Bosch Sensortec BMP280 I²C bus pressure and humidity sensor, using the hardware TWI. The **bme280_twi.h** header file, located in the .\INC subdirectory must be **#include -d** before using these functions.

Notes:

- The appropriate header files for hardware TWI (**twi.h** or **twix.h**) are automatically **#include -d** with **bme280_twi.h**
- For proper operation, the BME280 functions require the presence of 4.7k pull-up resistors to **+3.3V** on the SCL and SDA signals
- Before calling the BME280 functions, the TWI interface must be properly initialized and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

The following low level access BME280 functions are available:

short bme280_wrreg(unsigned char reg, unsigned char data)

writes the byte **data** to the BME280 register **reg**.

Returns one of the following values, defined in **bme280_twi.h**:

```
#define BME280_INIT_OK 0 /* The command was successful */
#define BME280_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

short bme280_rdreg(unsigned char reg)

reads a byte of data from the BME280 register **reg**.

Returns:

- In case of success, a positive value in the range 0..255, representing the read byte of data
- In case of error, the negative value defined in **bme280_twi.h**:

```
#define BME280_COMM_ERROR -32768 /* TWI communication with the device has failed */
```

The **bme280_twi.h** header contains the definitions of the BME280 registers and commands that are accessible using the above mentioned functions:

```
/* BME280 calibration data registers: */
#define BME280_TEMP_CALIB_DIG_T1_LSB_REG 0x88
#define BME280_TEMP_CALIB_DIG_T1_MSB_REG 0x89
#define BME280_TEMP_CALIB_DIG_T2_LSB_REG 0x8A
#define BME280_TEMP_CALIB_DIG_T2_MSB_REG 0x8B
#define BME280_TEMP_CALIB_DIG_T3_LSB_REG 0x8C
#define BME280_TEMP_CALIB_DIG_T3_MSB_REG 0x8D
#define BME280_PRESS_CALIB_DIG_P1_LSB_REG 0x8E
#define BME280_PRESS_CALIB_DIG_P1_MSB_REG 0x8F
#define BME280_PRESS_CALIB_DIG_P2_LSB_REG 0x90
#define BME280_PRESS_CALIB_DIG_P2_MSB_REG 0x91
#define BME280_PRESS_CALIB_DIG_P3_LSB_REG 0x92
#define BME280_PRESS_CALIB_DIG_P3_MSB_REG 0x93
#define BME280_PRESS_CALIB_DIG_P4_LSB_REG 0x94
#define BME280_PRESS_CALIB_DIG_P4_MSB_REG 0x95
```

```
#define BME280_PRESS_CALIB_DIG_P5_LSB_REG 0x96
#define BME280_PRESS_CALIB_DIG_P5_MSB_REG 0x97
#define BME280_PRESS_CALIB_DIG_P6_LSB_REG 0x98
#define BME280_PRESS_CALIB_DIG_P6_MSB_REG 0x99
#define BME280_PRESS_CALIB_DIG_P7_LSB_REG 0x9A
#define BME280_PRESS_CALIB_DIG_P7_MSB_REG 0x9B
#define BME280_PRESS_CALIB_DIG_P8_LSB_REG 0x9C
#define BME280_PRESS_CALIB_DIG_P8_MSB_REG 0x9D
#define BME280_PRESS_CALIB_DIG_P9_LSB_REG 0x9E
#define BME280_PRESS_CALIB_DIG_P9_MSB_REG 0x9F
#define BME280_HUM_CALIB_DIG_H1_REG      0xA1
#define BME280_HUM_CALIB_DIG_H2_LSB_REG 0xE1
#define BME280_HUM_CALIB_DIG_H2_MSB_REG 0xE2
#define BME280_HUM_CALIB_DIG_H3_REG      0xE3
#define BME280_HUM_CALIB_DIG_H4_MSB_REG 0xE4
#define BME280_HUM_CALIB_DIG_H4_LSB_REG 0xE5
#define BME280_HUM_CALIB_DIG_H5_MSB_REG 0xE6
#define BME280_HUM_CALIB_DIG_H6_REG      0xE7

/* BME280 Registers: */
#define BME280_CHIP_ID_REG 0xD0    /* Chip ID register */
#define BME280_SOFT_RESET_REG 0xE0 /* Software Reset register */

#define BME280_CTRL_HUM_REG 0xF2    /* Humidity oversampling control
register */
#define BME280_STATUS_REG 0xF3      /* Status register */
#define BME280_CTRL_MEAS_REG 0xF4    /* Control & Measurement register */
#define BME280_CONFIG_REG 0xF5      /* Configuration register */

#define BME280_PRESS_MSB_REG 0xF7    /* Read ADC Pressure Result
register MSB */
#define BME280_PRESS_LSB_REG 0xF8    /* Read ADC Pressure Result
register LSB */
#define BME280_PRESS_XLSB_REG 0xF9    /* Read ADC Pressure Result
register XLSB */

#define BME280_TEMP_MSB_REG 0xFA      /* Read ADC Temperature Result
register MSB */
#define BME280_TEMP_LSB_REG 0xFB      /* Read ADC Temperature Result
register LSB */
#define BME280_TEMP_XLSB_REG 0xFC      /* Read ADC Temperature Result
register XLSB */

#define BME280_HUM_MSB_REG 0xFD        /* Read ADC Humidity Result
register MSB */
#define BME280_HUM_LSB_REG 0xFE        /* Read ADC Humidity Result
register LSB */

/* Chip ID for BME280 */
#define BME280_CHIP_ID 0x60
/* Soft Reset register command for resetting chip */
#define BME280_SOFT_RESET_CMD 0xB6
/* Control register value for measuring temperature */
#define BME280_CTRL_TEMP 0x2E
/* Control register value for measuring pressure */
#define BME280_CTRL_PRES 0x34
```

The following high level access BME280 functions are available:

For non-Xmega AVR chips:

short bme280_init(unsigned char device_address, unsigned char mode, unsigned char filter_coeff, unsigned char hum_oversampling)

reads the calibration parameters from the device's EEPROM and initializes the device.

Parameters:

device_address - I²C bus 7-bit device address, defined in **bme280_twi.h**:

```
#define BME280_I2C_ADDR_SDO_LOW 0x76 /* The SDO pin is set to logic 0 */
#define BME280_I2C_ADDR_SDO_HIGH 0x77 /* The SDO pin is set to logic 1 */
```

mode - pressure measurement mode, defined in **bme280_twi.h**:

```
#define BME280_PRESSURE_OFF 0 /* Pressure measurement disabled */
#define BME280_ULTRA_LOW_POWER_MODE 1 /* Ultra Low Power Mode */
#define BME280_LOW_POWER_MODE 2 /* Low Power Mode */
#define BME280_STANDARD_RES_MODE 3 /* Standard Resolution Mode */
#define BME280_HI_RES_MODE 4 /* High Resolution Mode */
#define BME280_ULTRA_HI_RES_MODE 5 /* Ultra High Resolution Mode */
```

filter_coeff - IIR filter coefficient, defined in **bme280_twi.h**:

```
#define BME280_FILTER_COEFF_OFF 0x00
#define BME280_FILTER_COEFF_2 0x01
#define BME280_FILTER_COEFF_4 0x02
#define BME280_FILTER_COEFF_8 0x03
#define BME280_FILTER_COEFF_16 0x04
```

hum_oversampling - humidity measurement oversampling mode, defined in **bme280_twi.h**:

```
#define BME280_OVERSAMP_OFF 0x00 /* Humidity measurement disabled */
#define BME280_OVERSAMP_1X 0x01
#define BME280_OVERSAMP_2X 0x02
#define BME280_OVERSAMP_4X 0x03
#define BME280_OVERSAMP_8X 0x04
#define BME280_OVERSAMP_16X 0x05
```

Returns one of the following values, defined in **bme280_twi.h**:

```
#define BME280_INIT_OK 0 /* The command was successful */
#define BME280_COMM_ERROR -32768 /* TWI communication with the device
has failed */
#define BME280_INIT_ERROR -32767 /* TWI initialization parameters
are not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_master_init** function from the **TWI Functions for Master Mode Operation for non-XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

Example:

```
/* BME280 pressure and humidity sensor functions*/
#include <bme280_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BME280 sensor */
    bme280_init(BME280_I2C_ADDR_SDO_LOW,BME280_ULTRA_HI_RES_MODE,BME280_FILTER_
    COEFF_8,BME280_OVERSAMP_2X);

    /* Follows the rest of the program */

}
```

For Xmega chips:

short bme280_init(TWI_MASTER_INFO_t *twi_master, unsigned char device_address, unsigned char mode, unsigned char filter_coeff, unsigned char hum_oversampling)

reads the calibration parameters from the device's EEPROM and initializes the device.

Parameters:

twi_master - points to the structure that holds the information used by the TWI master Xmega module, used for communication with the pressure sensor, for performing a TWI bus transaction

device_address - I²C bus 7-bit device address, defined in **bme280_twi.h**:

```
#define BME280_I2C_ADDR_SDO_LOW 0x76 /* The SDO pin is set to logic 0 */
#define BME280_I2C_ADDR_SDO_HI 0x77 /* The SDO pin is set to logic 1 */
```

mode - pressure measurement mode, defined in **bme280_twi.h**:

```
#define BME280_ULTRA_LOW_POWER_MODE 0 /* Ultra Low Power Mode */
#define BME280_LOW_POWER_MODE 1 /* Low Power Mode */
#define BME280_STANDARD_RES_MODE 2 /* Standard Resolution Mode */
#define BME280_HI_RES_MODE 3 /* High Resolution Mode */
#define BME280_ULTRA_HI_RES_MODE 4 /* Ultra High Resolution Mode */
```

filter_coeff - IIR filter coefficient, defined in **bme280_twi.h**:

```
#define BME280_FILTER_COEFF_OFF 0x00
#define BME280_FILTER_COEFF_2 0x01
#define BME280_FILTER_COEFF_4 0x02
#define BME280_FILTER_COEFF_8 0x03
#define BME280_FILTER_COEFF_16 0x04
```

hum_oversampling - humidity measurement oversampling mode, defined in **bme280_twi.h**:

```
#define BME280_OVERSAMP_OFF 0x00
#define BME280_OVERSAMP_1X 0x01
#define BME280_OVERSAMP_2X 0x02
#define BME280_OVERSAMP_4X 0x03
#define BME280_OVERSAMP_8X 0x04
#define BME280_OVERSAMP_16X 0x05
```

Returns one of the following values, defined in **bme280_twi.h**:

```
#define BME280_INIT_OK 0 /* The command was successful */
#define BME280_COMM_ERROR -32768 /* TWI communication with the device
                                   has failed */
#define BME280_INIT_ERROR -32767 /* TWI initialization parameters
                                   are not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_init** and **twi_master_init** functions from the **TWI Functions for Master Mode Operation for XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.
Example:

```
/* BME280 pressure and humidity sensor functions */
#include <bme280_twi.h>

/* Structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;

/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

void main(void)
{
    /* General TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID, false, false);

    /* Enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master, &TWID, TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_, TWI_CLK_RATE));

    /* Enable the Low interrupt level */
    PMIC.CTRL |= PMIC_LOLVLEN_bm;

    /* Enable the interrupts */
    #asm("sei")
}
```

```
/* Initialize the BME280 sensor */
bme280_init(&twid_master,BME280_I2C_ADDR_SDO_LOW,BME280_ULTRA_HI_RES_MODE,B
ME280_FILTER_COEFF_8,BME280_OVERSAMP_2X);

/* Follows the rest of the program */

}
```

Note: The calibration parameters read from the device's EEPROM are stored in the **bme280_calib_param** structure variable, declared in **bme280_twi.h**:

```
typedef struct
{
unsigned short dig_T1;
signed short dig_T2;
signed short dig_T3;
unsigned short dig_P1;
signed short dig_P2;
signed short dig_P3;
signed short dig_P4;
signed short dig_P5;
signed short dig_P6;
signed short dig_P7;
signed short dig_P8;
signed short dig_P9;
unsigned char dig_H1;
signed short dig_H2;
unsigned char dig_H3;
signed short dig_H4;
signed short dig_H5;
signed char dig_H6;
} BME280_CALIB_PARAM_t;

extern BME280_CALIB_PARAM_t bme280_calib_param;
```

and defined in the **bme280_twi.lib** library.

float bme280_temperature(void)

reads the ambient temperature in °C, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **bme280_twi.h**:

```
#define BME280_COMM_ERROR -32768 /* TWI communication with the device
has failed */
#define BME280_INIT_ERROR -32767 /* BME280 initialization was not
performed correctly */
```

float bme280_pressure(void)

reads the absolute pressure in Pa, with 0.1 Pa resolution, performing all necessary compensation based on calibration parameters.

Note: calculations are performed on 64-bits with high precision.

In case of error it returns the values defined in **bme280_twi.h**:

```
#define BME280_COMM_ERROR -32768 /* TWI communication with the device
                                has failed */
#define BME280_INIT_ERROR -32767 /* BME280 initialization was not
                                performed correctly */
#define BME280_MEAS_ERROR -32766 /* Measurement error or calibration
                                coefficients read from device's
                                EEPROM are not correct */
```

Example for ATmega328P clocked at 16 MHz:

```
/* I/O registers definitions */
#include <io.h>
/* Standard I/O: printf */
#include <stdio.h>
/* Delay functions */
#include <delay.h>
/* BME280 pressure and humidity sensor functions */
#include <bme280_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void check_result(short n)
{
    switch (n)
    {
        case BME280_COMM_ERROR:
            printf("TWI communication error\r\n");
            goto halt;

        case BME280_INIT_ERROR:
            printf("Initialization parameters are not correct\r\n");
            goto halt;

        case BME280_MEAS_ERROR:
            printf("Measurement error\r\n");

        halt:
            while(1);
    }
}

void main(void)
{
    float temperature, humidity, pressure, altitude;

    /* USART initialization
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 (Double Speed Mode) @ 16MHz */
    UCSR0A=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
    (0<<UPE0) | (1<<U2X0) | (0<<MPCM0);
```



```
UCSR0B=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |  
(0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);  
UCSR0C=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |  
(1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);  
UBRR0H=0x00;  
UBRR0L=0xCF;  
  
/* TWI initialization  
   Mode: TWI Master, Bit Rate: 100 kbps */  
twi_master_init(TWI_CLK_RATE);  
  
/* Enable the interrupts */  
#asm("sei")  
  
printf("BME280 Pressure and humidity sensor demo\r\n");  
  
/* Initialize the BME280 sensor  
   Use the Ultra High Resolution Mode for pressure  
   2 times oversampling for humidity */  
check_result(bme280_init(BME280_I2C_ADDR_SDO_LOW,BME280_ULTRA_HI_RES_MODE,B  
ME280_FILTER_COEFF_8,BME280_OVERSAMP_2X));  
printf("BME280 initialized OK\r\n\r\n");  
  
while (1)  
{  
    /* Measure the temperature in degrees [C] */  
    temperature=bme280_temperature();  
    /* Check for errors */  
    check_result(temperature);  
    /* Measure the relative humidity in [%] */  
    humidity=bme280_humidity();  
    /* Check for errors */  
    check_result(humidity);  
    /* Measure the absolute pressure in [Pa] */  
    pressure=bme280_pressure();  
    /* Check for errors */  
    check_result(pressure);  
    /* Calculate the absolute altitude above sea level [m] */  
    altitude=abs_altitude(pressure,PRESSURE_SEA_LEVEL_STD);  
    /* Display the results */  
    printf("t=%5.1fC RH=%3.0f%% P=%7.2fPa  
Alt=%6.1fm\r\n",temperature,humidity,pressure/100.0,altitude);  
    /* 1 second delay between measurements */  
    delay_ms(1000);  
}
```

long bme280_pressure_low_res(void)

reads the absolute pressure in Pa, with 1 Pa resolution, performing all necessary compensation based on calibration parameters.

Note: calculations are performed on 32-bits with lower precision.

This function can be used when lower code size and higher execution speed are required.

In case of error it returns the values defined in **bme280_twi.h**:

```
#define BME280_COMM_ERROR -32768 /* TWI communication with the device
has failed */
#define BME280_INIT_ERROR -32767 /* BME280 initialization was not
performed correctly */
#define BME280_MEAS_ERROR -32766 /* Measurement error or calibration
coefficients read from device's
EEPROM are not correct */
```

float bme280_humidity(void);

reads the compensated relative humidity [%].

In case of error it returns the values defined in **bme280_twi.h**:

```
#define BME280_COMM_ERROR -32768 /* TWI communication with the device
has failed */
#define BME280_INIT_ERROR -32767 /* BME280 initialization was not
performed correctly */
#define BME280_MEAS_ERROR -32766 /* Measurement error or calibration
coefficients read from device's
EEPROM are not correct */
```

CodeVisionAVR is also supplied with additional functions for calculating the altitude above sea level, defined in the **altitude.h** header file:

float abs_altitude(float p, float p0)

returns the absolute altitude above sea level in [m], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]
p0 - pressure at sea level [Pa]

Note: The standard value for the pressure [Pa] at sea level is defined in the **altitude.h** header:

```
#define PRESSURE_SEA_LEVEL_STD 101325.0
```

float pressure_sea_level(float p, float abs_alt)

returns the pressure at sea level in [Pa], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]
abs_alt - measured absolute altitude above sea level [m].

5.25.16 Measurement Specialties MS5611-01BA Digital Pressure Sensor Functions

These functions are intended for easy interfacing between C programs and the Measurement Specialties MS5611-01BA I²C bus pressure sensor, using the hardware TWI.

The **ms5611_twi.h** header file, located in the .\INC subdirectory must be **#include -d** before using these functions.

Notes:

- The appropriate header files for hardware TWI (**twi.h** or **twix.h**) are automatically **#include -d** with **ms5611_twi.h**
- For proper operation, the MS5611-01BA functions require the presence of 4.7k pull-up resistors to **+3.3V** on the SCL and SDA signals
- Before calling the MS5611-01BA functions, the TWI interface must be properly initialized and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

The following MS5611-01BA functions are available:

For non-Xmega AVR chips:

short ms5611_init(unsigned char device_address, unsigned char osr)

reads the calibration parameters from the device's PROM and sets the pressure sensor's I²C bus **device_address** and ADC Over-Sampling Ratio **osr**.

The values for these function parameters are defined in **ms5611_twi.h**:

```
/* MS5611-01BA 7-bit I2C bus addresses */
#define MS5611_BUS_ADDR_CSB_LOW 0x77 /* for CSB pin=0 */
#define MS5611_BUS_ADDR_CSB_HIGH 0x76 /* for CSB pin=1 */

/* MS5611-01BA ADC Over-Sampling Ratio */
#define MS5611_OSR_256 0x00 /* OSR=256 */
#define MS5611_OSR_512 0x01 /* OSR=512 */
#define MS5611_OSR_1024 0x02 /* OSR=1024 */
#define MS5611_OSR_2048 0x03 /* OSR=2048 */
#define MS5611_OSR_4096 0x04 /* OSR=4096 */
```

Returns one of the following values, defined in **ms5611_twi.h**:

```
#define MS5611_INIT_OK 0 /* The command was successful */
#define MS5611_COMM_ERROR -32768 /* TWI communication with the device
                                has failed */
#define MS5611_INIT_ERROR -32767 /* TWI initialization parameters are
                                not correct */
#define MS5611_CRC_ERROR -32766 /* The CRC of the calibration data read
                                from the device PROM is not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_master_init** function from the **TWI Functions for Master Mode Operation for non-XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

Example:

```
/* MS5611-01BA Pressure sensor functions */
#include <ms5611_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the MS5611-01BA pressure sensor */
    ms5611_init(MS5611_BUS_ADDR_CSB_LOW, MS5611_OSR_4096);

    /* Follows the rest of the program */
}
```

For Xmega chips:

short ms5611_init(TWI_MASTER_INFO_t *twi, unsigned char device_address, unsigned char osr)

reads the calibration parameters from the device's PROM and sets the pressure sensor's I²C bus **device_address** and ADC Over-Sampling Ratio **osr**.

The **twi** parameter points to the structure that holds the information used by the TWI master Xmega module, used for communication with the pressure sensor, for performing a TWI bus transaction.

Returns one of the following values, defined in **ms5611_twi.h**:

```
#define MS5611_INIT_OK 0 /* The command was successful */
#define MS5611_COMM_ERROR -32768 /* TWI communication with the device has failed */
#define MS5611_INIT_ERROR -32767 /* TWI initialization parameters are not correct */
#define MS5611_CRC_ERROR -32766 /* The CRC of the calibration data read from the device PROM is not correct */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_init** and **twi_master_init** functions from the **TWI Functions for Master Mode Operation for XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

Example:

```
/* MS5611-01BA Pressure sensor functions */
#include <ms5611_twi.h>

/* Structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;
```

```
/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

void main(void)
{
    /* General TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* Enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* Enable the Low interrupt level */
    PMIC_CTRL |= PMIC_LOLVLEN_bm;

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the MS5611-01BA pressure sensor */
    ms5611_init(&twid_master,MS5611_BUS_ADDR_CSB_LOW,MS5611_OSR_4096);

    /* Follows the rest of the program */

}
```

float ms5611_temperature(void)

reads the ambient temperature in °C, with 0.01°C resolution, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **ms5611_twi.h**:

```
#define MS5611_COMM_ERROR -32768 /* TWI communication with the device
                                   has failed */
#define MS5611_INIT_ERROR -32767 /* MS5611-01BA initialization was not
                                   performed correctly */
```

long ms5611_pressure(void)

reads the absolute pressure in Pa, performing all necessary compensation based on calibration parameters.

In case of error it returns the values defined in **ms5611_twi.h**:

```
#define MS5611_COMM_ERROR -32768 /* TWI communication with the device
                                   has failed */
#define MS5611_INIT_ERROR -32767 /* MS5611-01BA initialization was not
                                   performed correctly */
```

Example for ATmega328P clocked at 16 MHz:

```
/* I/O registers definitions */
#include <io.h>
/* Standard I/O: printf */
#include <stdio.h>
/* Delay functions */
#include <delay.h>
/* MS5611-01BA Pressure sensor functions */
#include <ms5611_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100

void main(void)
{
    float temperature,pressure;

    /* USART initialization
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On
       USART0 Mode: Asynchronous
       USART Baud Rate: 9600 (Double Speed Mode) @ 16MHz */
    UCSR0A=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
    (0<<UPE0) | (1<<U2X0) | (0<<MPCM0);
    UCSR0B=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
    (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSR0C=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
    (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRROH=0x00;
    UBRROL=0xCF;

    /* TWI initialization
       Mode: TWI Master, Bit Rate: 100 kbps */
    twi_master_init(TWI_CLK_RATE);

    /* Enable the interrupts */
    #asm("sei")

    printf("MS5611-01BA Pressure sensor demo\r\n");

    /* Initialize the MS5611-01BA pressure sensor
       Use the maximum precision mode */
    switch (ms5611_init(MS5611_BUS_ADDR_CSB_LOW,MS5611_OSR_4096))
    {
        case MS5611_INIT_OK:
            printf("MS5611-01BA initialized OK\r\n\r\n");
            break;

        case MS5611_COMM_ERROR:
            twi_comm_error:
            printf("TWI communication error\r\n");
            goto halt;

        case MS5611_INIT_ERROR:
            printf("Initialization parameters are not correct\r\n");
            goto halt;
    }
}
```

```
        case MS5611_CRC_ERROR:
            printf("The CRC of MS5611-01BA calibration parameters read"
                  "from PROM is not valid\r\n");

        halt:
        while(1);
    }

while (1)
{
    /* Measure the temperature in [°C] */
    temperature=ms5611_temperature();
    /* Check for TWI communication error */
    if (temperature==MS5611_COMM_ERROR) goto twi_comm_error;
    /* Measure the absolute pressure in [Pa] */
    pressure=ms5611_pressure();
    /* Check for TWI communication error */
    if (pressure==MS5611_COMM_ERROR) goto twi_comm_error;
    /* Display the results in [°C] and [hPa] */
    printf("t=%6.2fC P=%7.2fhPa\r\n",temperature,pressure/100.0);
    /* 1 second delay between measurements */
    delay_ms(1000);
}
}
```

CodeVisionAVR is also supplied with additional functions for calculating the altitude above sea level, defined in the **altitude.h** header file:

float abs_altitude(float p, float p0)

returns the absolute altitude above sea level in [m], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]
p0 - pressure at sea level [Pa]

Note: The standard value for the pressure [Pa] at sea level is defined in the **altitude.h** header:

```
#define PRESSURE_SEA_LEVEL_STD 101325.0
```

float pressure_sea_level(float p, float abs_alt)

returns the pressure at sea level in [Pa], using the International Barometric Formula.

Parameters:

p - measured pressure in [Pa]
abs_alt - measured absolute altitude above sea level [m].

5.25.17 ROHM Semiconductor BH1750FVI Digital Light Sensor Functions

These functions are intended for easy interfacing between C programs and the ROHM Semiconductor BH1750FVI I²C bus light sensor, using the hardware TWI.

The **bh1750_twi.h** header file, located in the .INC subdirectory must be **#include** -d before using these functions.

Notes:

- The appropriate header files for hardware TWI (**twi.h** or **twix.h**) are automatically **#include** -d with **bh1750_twi.h**
- For proper operation, the BH1750FVI functions require the presence of 4.7k pull-up resistors to **+3.3V** on the SCL and SDA signals
- Before calling the BH1750FVI functions, the TWI interface must be properly initialized and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.

The following BH1750FVI functions are available:

For non-Xmega AVR chips:

signed char bh1750_init(unsigned char device_address, unsigned char mt_reg)

initializes the BH1750FVI sensor.

Parameters:

device_address - BH1750FVI 7-bit I2C bus address, defined in the **bh1750_twi.h** header file:

```
#define BH1750_I2C_ADDR0 0x23 /* for ADDR pin=0 */
#define BH1750_I2C_ADDR1 0x5C /* for ADDR pin=1 */
```

mt_reg - initialization value for the measurement time register, valid values are: 31..254.

The default value for **mt_reg** is defined in the **bh1750_twi.h** header file:

```
#define BH1750_MT_REG_DEFAULT 0x45
```

The function returns one the following values, defined in the **bh1750_twi.h** header file:

```
#define BH1750_RES_OK 0 /* The initialization has succeeded */
#define BH1750_COMM_ERROR -1 /* TWI communication with the device
                             has failed */
#define BH1750_INIT_ERROR -2 /* TWI was not initialized before calling
                             the function */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_master_init** function from the **TWI Functions for Master Mode Operation for non-XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.
Example:

```
/* BH1750FVI light sensor functions */
#include <bh1750_twi.h>

/* TWI clock rate [kbps] */
#define TWI_CLK_RATE 100
```



```
void main(void)
{
/* TWI initialization
   Mode: TWI Master, Bit Rate: 100 kbps */
twi_master_init(TWI_CLK_RATE);

/* Enable the interrupts */
asm("sei")

/* Initialize the BH1750FVI light sensor */
bh1750_init(BH1750_I2C_ADDR0,BH1750_MT_REG_DEFAULT);

/* Follows the rest of the program */

}
```

For Xmega AVR chips:

signed char bh1750_init(TWI_MASTER_INFO_t *twi_master, unsigned char device_address, unsigned char mt_reg)

initializes the BH1750FVI sensor.

Parameters:

twi_master - points to the structure that holds the information used by the TWI master Xmega module, used for communication with the light sensor, for performing a TWI bus transaction

device_address - BH1750FVI 7-bit I2C bus address, defined in the **bh1750_twi.h** header file:

```
#define BH1750_I2C_ADDR0 0x23 /* for ADDR pin=0 */
#define BH1750_I2C_ADDR1 0x5C /* for ADDR pin=1 */
```

mt_reg - initialization value for the measurement time register, valid values are: 31..254. The default value for **mt_reg** is defined in the **bh1750_twi.h** header file:

```
#define BH1750_MT_REG_DEFAULT 0x45
```

The function returns one the following values, defined in the **bh1750_twi.h** header file:

```
#define BH1750_RES_OK 0 /* The initialization has succeeded */
#define BH1750_COMM_ERROR -1 /* TWI communication with the device
                               has failed */
#define BH1750_INIT_ERROR -2 /* TWI was not initialized before calling
                               the function */
```

Note: Before calling this function, the TWI interface must be properly initialized, by calling the **twi_init** and **twi_master_init** functions from the **TWI Functions for Master Mode Operation for XMEGA Devices** and the interrupts must be enabled by executing the **#asm("sei")** inline assembly instruction.
Example:

```
/* BH1750FVI light sensor functions */
#include <bh1750_twi.h>

/* Structure that holds information used by the TWID master
   for performing a TWI bus transaction */
TWI_MASTER_INFO_t twid_master;
```

```
/* interrupt service routine for TWID master */
interrupt [TWID_TWIM_vect] void twid_master_isr(void)
{
    twi_master_int_handler(&twid_master);
}

/* TWI clock rate [bps] */
#define TWI_CLK_RATE 100000

void main(void)
{
    /* General TWID initialization
       no external driver interface
       no SDA hold time */
    twi_init(&TWID,false,false);

    /* Enable and initialize the TWID master
       interrupt level: low */
    twi_master_init(&twid_master,&TWID,TWI_MASTER_INTLVL_LO_gc,
        TWI_BAUD_REG(_MCU_CLOCK_FREQUENCY_,TWI_CLK_RATE));

    /* Enable the Low interrupt level */
    PMIC_CTRL |= PMIC_LOLVLEN_bm;

    /* Enable the interrupts */
    #asm("sei")

    /* Initialize the BH1750FVI light sensor */
    bh1750_init(&twid_master,BH1750_I2C_ADDR0,BH1750_MT_REG_DEFAULT);

    /* Follows the rest of the program */

}
```

bool bh1750_wrcmd(unsigned char device_address, unsigned char cmd)

writes a command to the BH1750TVI.

Parameters:

device_address - BH1750FVI 7-bit I2C bus address, defined in the **bh1750_twi.h** header file:

```
#define BH1750_I2C_ADDR0 0x23 /* for ADDR pin=0 */
#define BH1750_I2C_ADDR1 0x5C /* for ADDR pin=1 */
```

cmd - command defined in the **bh1750_twi.h** header file:

```
#define BH1750_POWER_DOWN 0x00 /* Power down */
#define BH1750_POWER_ON 0x01 /* Power on, wait for a measurement
command */
#define BH1750_RESET 0x07 /* Reset the data register */
#define BH1750_CONT_CONV_LOW_RES 0x13 /* Use continous measurement mode
(typ. 16ms) with low resolution
(4lx) */
#define BH1750_CONT_CONV_HIGH_RES 0x10 /* Use continous measurement mode
(typ. 120ms) with high
resolution (1lx) */
```

```
#define BH1750_CONT_CONV_HIGH_RES2 0x11 /* Use continous measurement mode 2
                                         (typ. 120ms) with high
                                         resolution (0.5lx) */
#define BH1750_SINGLE_CONV_LOW_RES 0x23 /* Use single measurement mode
                                         (typ. 16ms) with low
                                         resolution (4lx) */
#define BH1750_SINGLE_CONV_HIGH_RES 0x20 /* Use single measurement mode
                                         (typ. 120ms) with high
                                         resolution (1lx) */
#define BH1750_SINGLE_CONV_HIGH_RES2 0x21 /* Use single measurement mode 2
                                         (typ. 120ms) with high
                                         resolution (0.5lx) */
#define BH1750_MEAS_TIME_LOW_BITS 0x60 /* Set bits 0..4 of measurement
                                         time register */
#define BH1750_MEAS_TIME_HIGH_BITS 0x40 /* Set bits 5..7 of measurement
                                         time register */
```

Commands are explained in detail in the device's datasheet.
The function returns:

true - the command has succeeded
false - TWI communication with the device has failed.

signed char bh1750_start(unsigned char device_address, unsigned char mode)

starts an illuminance measurement.

Parameters:

device_address - BH1750FVI 7-bit I2C bus address, defined in the **bh1750_twi.h** header file:

```
#define BH1750_I2C_ADDR0 0x23 /* for ADDR pin=0 */
#define BH1750_I2C_ADDR1 0x5C /* for ADDR pin=1 */
```

mode - measurement mode defined in the **bh1750_twi.h** header file:

```
#define BH1750_CONT_CONV_LOW_RES 0x13 /* Use continous measurement mode
                                         (typ. 16ms) with low resolution
                                         (4lx) */
#define BH1750_CONT_CONV_HIGH_RES 0x10 /* Use continous measurement mode
                                         (typ. 120ms) with high
                                         resolution (1lx) */
#define BH1750_CONT_CONV_HIGH_RES2 0x11 /* Use continous measurement mode 2
                                         (typ. 120ms) with high
                                         resolution (0.5lx) */
#define BH1750_SINGLE_CONV_LOW_RES 0x23 /* Use single measurement mode
                                         (typ. 16ms) with low
                                         resolution (4lx) */
#define BH1750_SINGLE_CONV_HIGH_RES 0x20 /* Use single measurement mode
                                         (typ. 120ms) with high
                                         resolution (1lx) */
#define BH1750_SINGLE_CONV_HIGH_RES2 0x21 /* Use single measurement mode 2
                                         (typ. 120ms) with high
                                         resolution (0.5lx) */
```

The function returns one the following values, defined in the **bh1750_twi.h** header file:

```
#define BH1750_RES_OK 0      /* The command has succeeded */
#define BH1750_COMM_ERROR -1 /* TWI communication with the device
                             has failed */
#define BH1750_INIT_ERROR -2 /* Device initialization was not performed
                             before calling the function */
```

float bh1750_rdlight(unsigned char device_address)

reads the result in [lx] of an illuminance measurement, previously initiated using the **bh1750_start** function.

Parameter:

device_address - BH1750FVI 7-bit I2C bus address, defined in the **bh1750_twi.h** header file:

```
#define BH1750_I2C_ADDR0 0x23 /* for ADDR pin=0 */
#define BH1750_I2C_ADDR1 0x5C /* for ADDR pin=1 */
```

If read has succeeded, the function returns zero or a positive value.

In case of error it returns one the following values, defined in the **bh1750_twi.h** header file:

```
#define BH1750_COMM_ERROR -1 /* TWI communication with the device
                             has failed */
#define BH1750_INIT_ERROR -2 /* Device initialization was not performed
                             before calling the function */
```

Example for ATmega328P clocked at 16 MHz:

```
/* I/O registers definitions */
#include <io.h>
/* Standard I/O: printf */
#include <stdio.h>
/* Delay functions */
#include <delay.h>
/* BH1750FVI Light sensor functions */
#include <bh1750_twi.h>

void check_result(signed char n)
{
    switch (n)
    {
        case BH1750_COMM_ERROR:
            printf("TWI communication error\r\n");
            goto halt;

        case BH1750_INIT_ERROR:
            printf("Device not properly initialized\r\n");

        halt:
            while(1);
    }
}
```

```
void main(void)
{
    float illuminance;

    /* USART initialization
       Communication Parameters: 8 Data, 1 Stop, No Parity
       USART Receiver: Off
       USART Transmitter: On */
    /* USART0 Mode: Asynchronous
       USART Baud Rate: 9600 (Double Speed Mode) @ 16MHz */
    UCSRA=(0<<RXC0) | (0<<TXC0) | (0<<UDRE0) | (0<<FE0) | (0<<DOR0) |
    (0<<UPE0) | (1<<U2X0) | (0<<MPCM0);
    UCSRB=(0<<RXCIE0) | (0<<TXCIE0) | (0<<UDRIE0) | (0<<RXEN0) | (1<<TXEN0) |
    (0<<UCSZ02) | (0<<RXB80) | (0<<TXB80);
    UCSRC=(0<<UMSEL01) | (0<<UMSEL00) | (0<<UPM01) | (0<<UPM00) | (0<<USBS0) |
    (1<<UCSZ01) | (1<<UCSZ00) | (0<<UCPOL0);
    UBRR0H=0x00;
    UBRR0L=0xCF;

    /* TWI initialization
       Mode: TWI Master
       Bit Rate: 100 kHz */
    twi_master_init(100);

    #asm("sei")

    printf("BH1750FVI Light sensor demo\r\n");

    /* Initialize the BH1750FVI light sensor with ADDR pin=0 */
    check_result(bh1750_init(BH1750_I2C_ADDR0,BH1750_MT_REG_DEFAULT));

    while (1)
    {
        /* Start a single measurement for device with ADDR pin=0
           and high resolution mode */
        check_result(bh1750_start(BH1750_I2C_ADDR0,
        BH1750_SINGLE_CONV_HIGH_RES));

        /* Wait for the measurement to complete */
        delay_ms(120);

        /* Measure the light level */
        illuminance=bh1750_rdlight(BH1750_I2C_ADDR0);

        /* Check for errors */
        check_result(illuminance);

        /* Display the measurement result */
        printf("Illuminance=%7.1flx\r\n",illuminance);

        /* 0.5 second delay between measurements */
        delay_ms(500);
    }
}
```

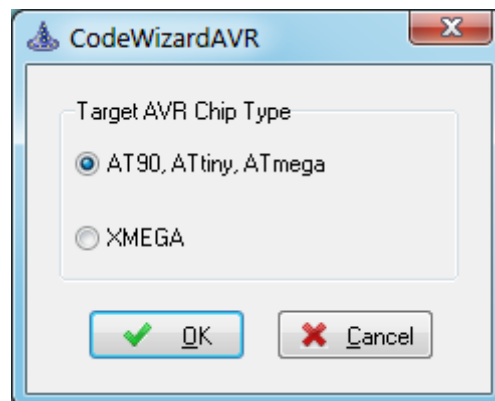
6. CodeWizardAVR Automatic Program Generator

The CodeWizardAVR Automatic Program Generator allows you to easily write all the code needed for implementing the following functions:

- External memory access setup
- Chip reset source identification
- Input/Output Port initialization
- External Interrupts initialization
- Timers/Counters initialization
- Watchdog Timer initialization
- UART initialization and interrupt driven buffered serial communication
- Analog Comparator initialization
- ADC initialization
- SPI Interface initialization
- I²C Bus, LM75 Temperature Sensor, DS1621 Thermometer/Thermostat, PCF8563, PCF8583, DS1302, DS1307 and DS3231 Real Time Clocks initialization
- 1 Wire Bus and DS1820/DS18S20 Temperature Sensors initialization
- Alphanumeric LCD module initialization
- Graphic display module initialization
- Resistive touchscreen controller initialization.

The Automatic Program Generator is invoked using the **Tools|CodeWizardAVR** menu command or by clicking on the  toolbar button.

The following dialog box will open

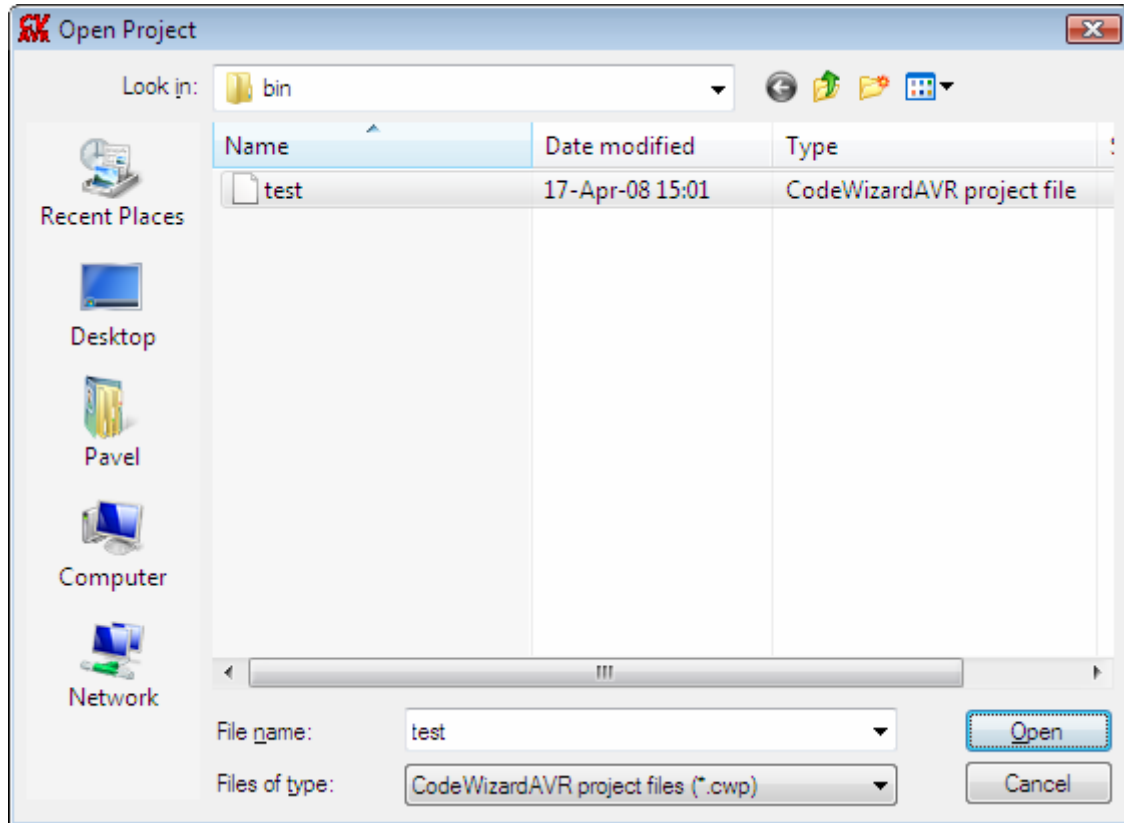


allowing to select between the AVR chip families for which automatic code generation will be performed.

CodeVisionAVR

The **File|New** menu command or the  toolbar button allow creating a new CodeWizardAVR project. This project will be named by default **untitled.cwp**.

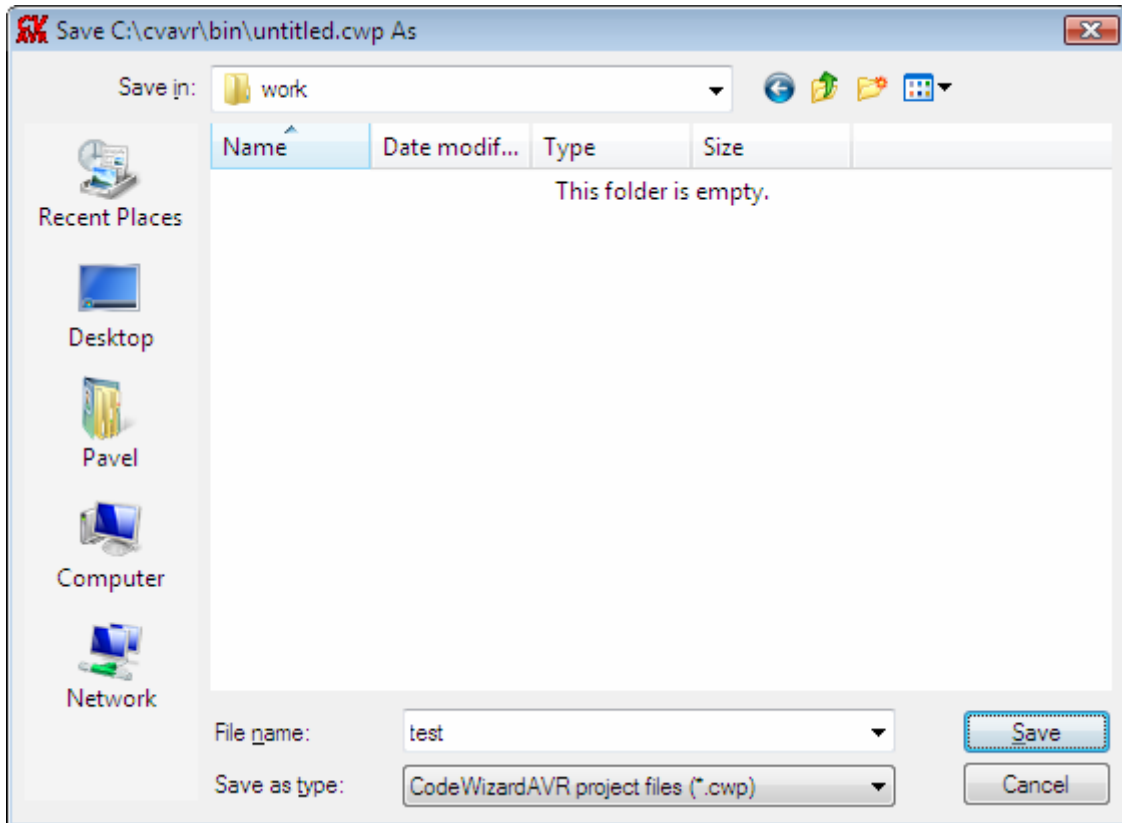
The **File|Open** menu command or the  toolbar button allow loading an existing CodeWizardAVR project:



CodeVisionAVR

The **File|Save** menu command or the  toolbar button allow saving the currently opened CodeWizardAVR project.

The **File|Save As** menu command or the  toolbar button allow saving the currently opened CodeWizardAVR project under a new name:



By selecting the **Program|Generate** menu option or by clicking on the  toolbar button, the code generated by CodeWizardAVR can be viewed in the **Program Preview** window. This may be useful when applying changes to an existing project, as portions of code generated by the CodeWizardAVR can be selected, copied to the clipboard and then pasted in the project's source files.

Note: By default the CodeWizardAVR generates initialization code even for peripherals that are not in use (disabled).

This is a safety measure to configure correctly the chip if a software reset occurred by jumping to address 0.

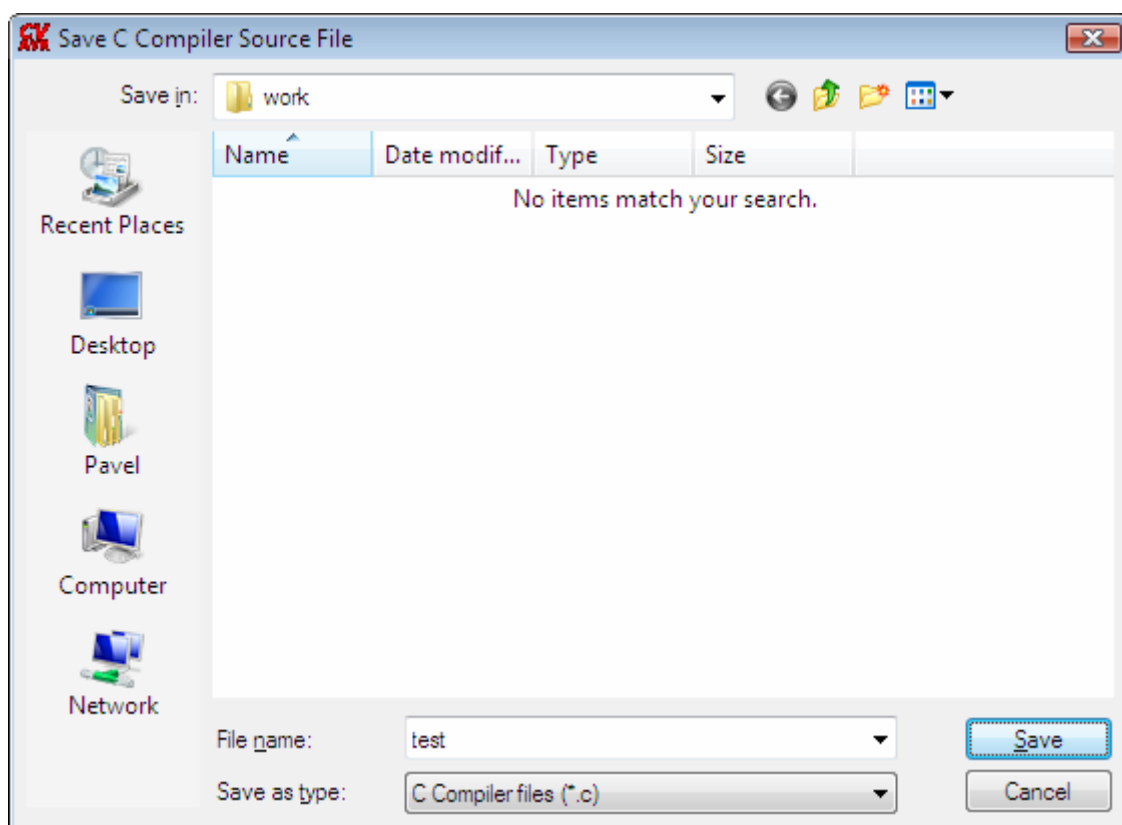
In order to reduce generated program size, this can be disabled by un-checking the **Program|Generate Code for Disabled Peripherals** menu option.

If the **Program|Generate, Save and Exit** menu option is selected or the  toolbar button is clicked, CodeWizardAVR will generate the main .C source and project .PRJ files, save the CodeWizardAVR project .CWP file and return to the CodeVisionAVR IDE.

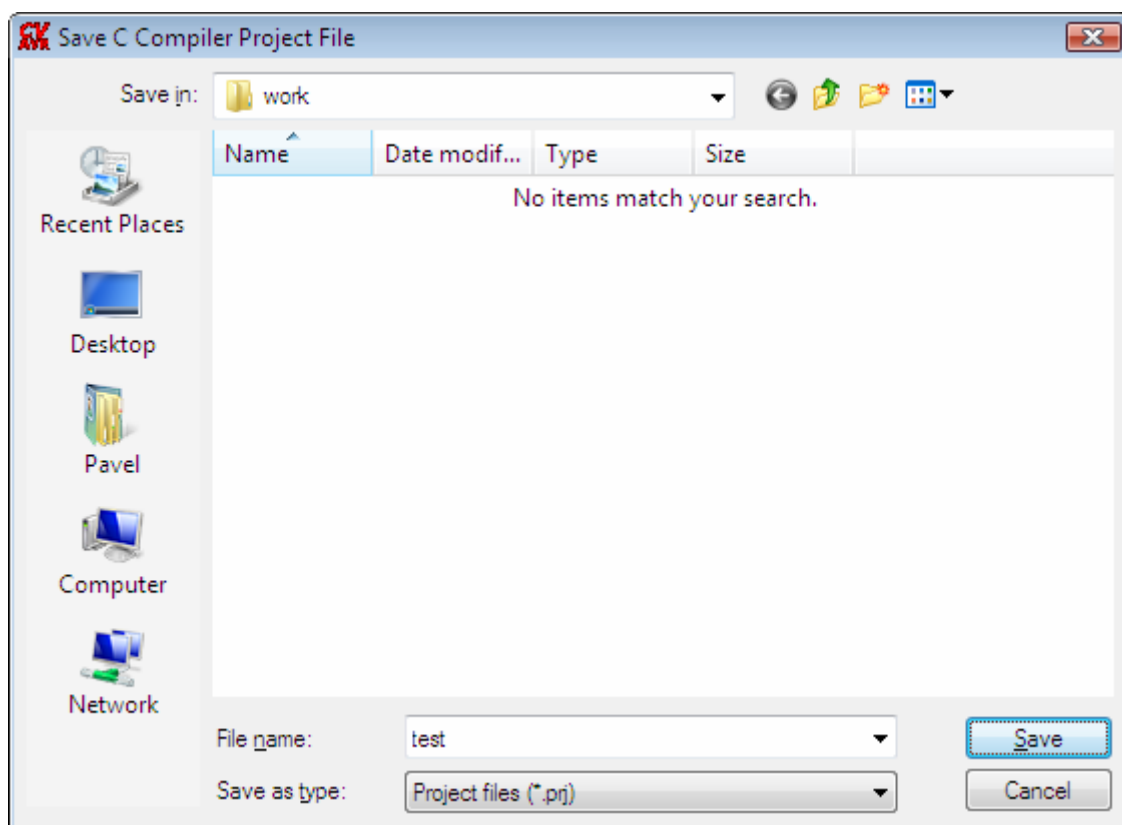
Eventual pin function conflicts will be prompted to the user, allowing him to correct the errors.

CodeVisionAVR

In the course of program generation the user will be prompted for the name of the main C file:



and for the name of the project file:



CodeVisionAVR

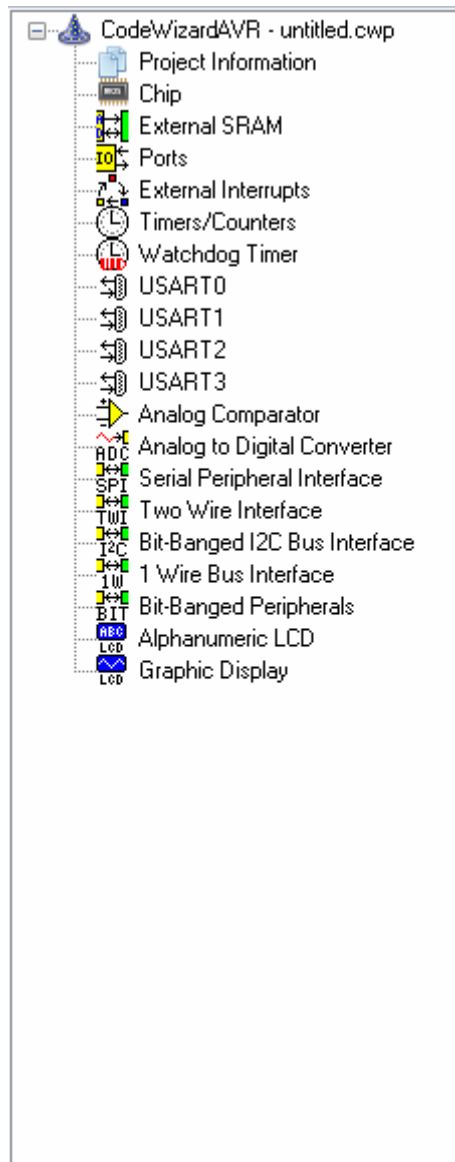
Note: When a **.prj** project for the CodeVisionAVR IDE is created, a corresponding **.cproj** project file for Atmel Studio will be created too.

This allows editing/compiling the same project in both Atmel Studio and CodeVisionAVR IDE.

Selecting the **File|Exit** menu option allows the user to exit the CodeWizardAVR without generating any program files.

By selecting the **Help|Help Topics** menu option, by pressing the F1 key or by clicking on the  toolbar button, the user can see the help topic that corresponds to the current CodeWizardAVR configuration menu.

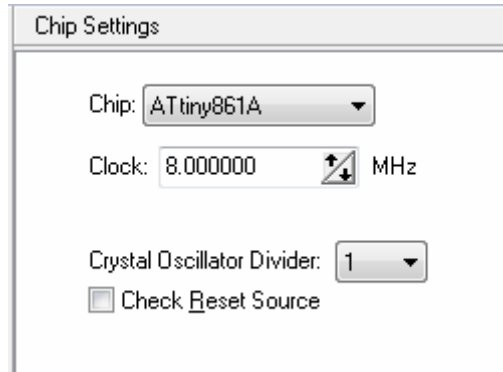
The AVR peripheral that needs to be configured can be selected by clicking on the corresponding node of the CodeWizardAVR selection tree.



If program code was already generated and is available for display in the Program Preview window, clicking on a peripheral node, will position the cursor at the beginning of the initialization code for that peripheral.

6.1 Setting the AVR Chip Options

The AVR chip options can be specified by clicking on the **Chip**  node of the CodeWizardAVR selection tree.



The screenshot shows the 'Chip Settings' dialog box. It contains the following fields:

- Chip:** A dropdown menu with 'ATtiny861A' selected.
- Clock:** A spinedit box with '8.000000' and a unit of 'MHz'.
- Crystal Oscillator Divider:** A dropdown menu with '1' selected.
- ☐ **Check Reset Source**

The chip type can be specified using the **Chip** list box.

The chip clock frequency in MHz can be specified using the **Clock** spinedit box.

For the AVR chips that contain a crystal oscillator divider, a supplementary **Crystal Oscillator Divider Enabled** check box is visible.

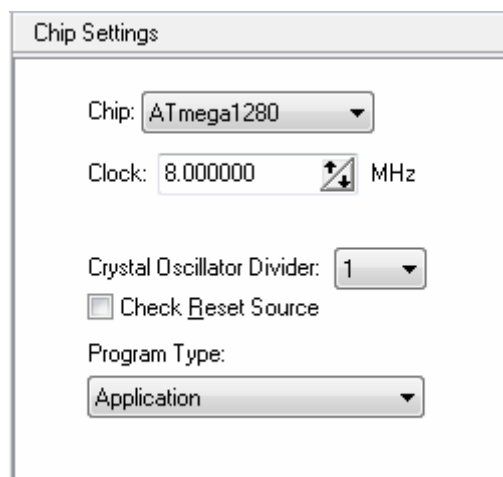
This check box allows you to enable or disable the crystal oscillator divider.

If the crystal oscillator is enabled, you can specify the division ratio using the **Crystal Oscillator Divider** spinedit box.

For the AVR chips that allow the identification of the reset source, a supplementary **Check Reset Source** check box is visible. If it's checked then the CodeWizardAVR will generate code that allows identification of the conditions that caused the chip reset.

For the AVR chips that allow self-programming, a supplementary **Program Type** list box is visible. It allows to select the type of the generated code:

- **Application**
- **Boot Loader**

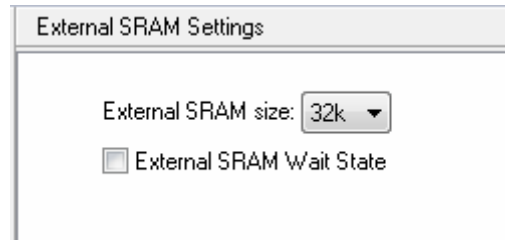


The screenshot shows the 'Chip Settings' dialog box for a different chip. It contains the following fields:

- Chip:** A dropdown menu with 'ATmega1280' selected.
- Clock:** A spinedit box with '8.000000' and a unit of 'MHz'.
- Crystal Oscillator Divider:** A dropdown menu with '1' selected.
- ☐ **Check Reset Source**
- Program Type:** A dropdown menu with 'Application' selected.

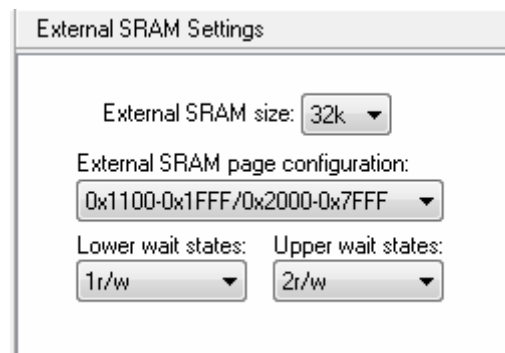
6.2 Setting the External SRAM

For the AVR chips that allow connection of external SRAM, you can specify the size of this memory and wait state insertion by clicking on the **External SRAM** node of the CodeWizardAVR selection tree.



The size of external SRAM can be specified using the **External SRAM Size** list box. Additional wait states in accessing the external SRAM can be inserted by checking the **External SRAM Wait State** check box. The MCUCR register in the startup initialization code is configured automatically according to these settings.

For devices, like the ATmega1280, that allow splitting the external SRAM in two pages, the External SRAM configuration window will look like this:



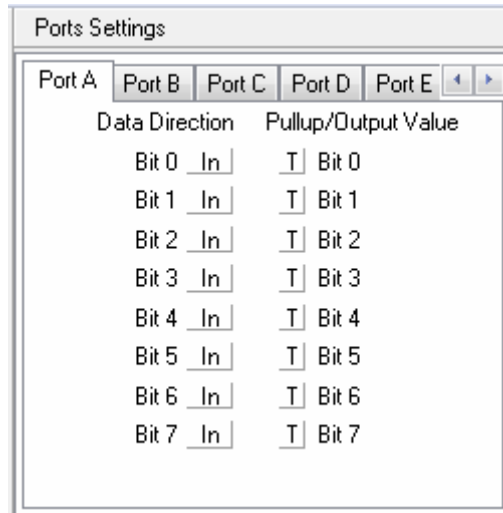
The **External SRAM page configuration** list box allows selection of the splitting address for the two external SRAM pages .

The wait states that are inserted during external SRAM access, can be specified for the lower, respectively upper, memory pages using the **Lower wait states**, respectively **Upper wait states** list boxes.

The MCUCR, EMCUCR, XMCRA registers in the startup initialization code are configured automatically according to these settings.

6.3 Setting the Input/Output Ports

The input/output Ports configuration can be specified by clicking on the **Ports**  node of the CodeWizardAVR selection tree.



You can choose which port you want to configure by selecting the appropriate **PORT x** tab. By clicking on the corresponding **Data Direction** bit you can set the chip pin to be output (Out) or input (In).

The DDRx register will be initialized according to these settings.

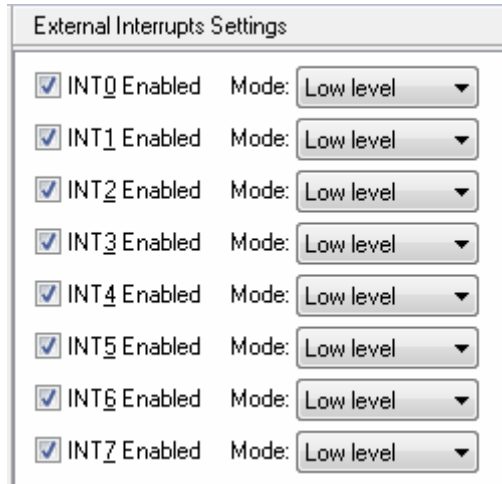
By clicking on the corresponding **Pullup/Output Value** bit you can set the following options:

- if the pin is an input, it can be tri-stated (T) or have an internal pull-up (P) resistor connected to the positive power supply.
- if the pin is an output, its value can be initially set to 0 or 1.

The PORTx register will be initialized according to these settings.

6.4 Setting the External Interrupts

The external interrupt configuration can be specified by clicking on the **External IRQ** node of the CodeWizardAVR selection tree.

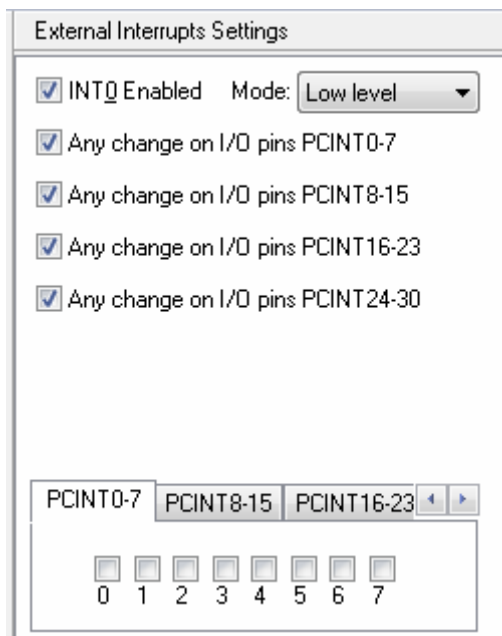


Interrupt	Enabled	Mode
INT0	☒	Low level
INT1	☒	Low level
INT2	☒	Low level
INT3	☒	Low level
INT4	☒	Low level
INT5	☒	Low level
INT6	☒	Low level
INT7	☒	Low level

Checking the appropriate **INTx Enabled** check box enables the corresponding external interrupt. If the AVR chip supports this feature, you can select if the interrupt will be edge or level triggered using the corresponding **Mode** list box.

For each enabled external interrupt the CodeWizardAVR will define an **ext_intx_isr** interrupt service routine, where **x** is the number of the external interrupt.

For some devices, like the ATmega3290, the following options may be present:



PCINT Range	Enabled
Any change on I/O pins PCINT0-7	☒
Any change on I/O pins PCINT8-15	☒
Any change on I/O pins PCINT16-23	☒
Any change on I/O pins PCINT24-30	☒

PCINT Range	0	1	2	3	4	5	6	7
PCINT0-7	☐	☐	☐	☐	☐	☐	☐	☐

The **Any change on I/O pins** check boxes, if checked, will specify which of the PCINT I/O pins will trigger an external interrupt.

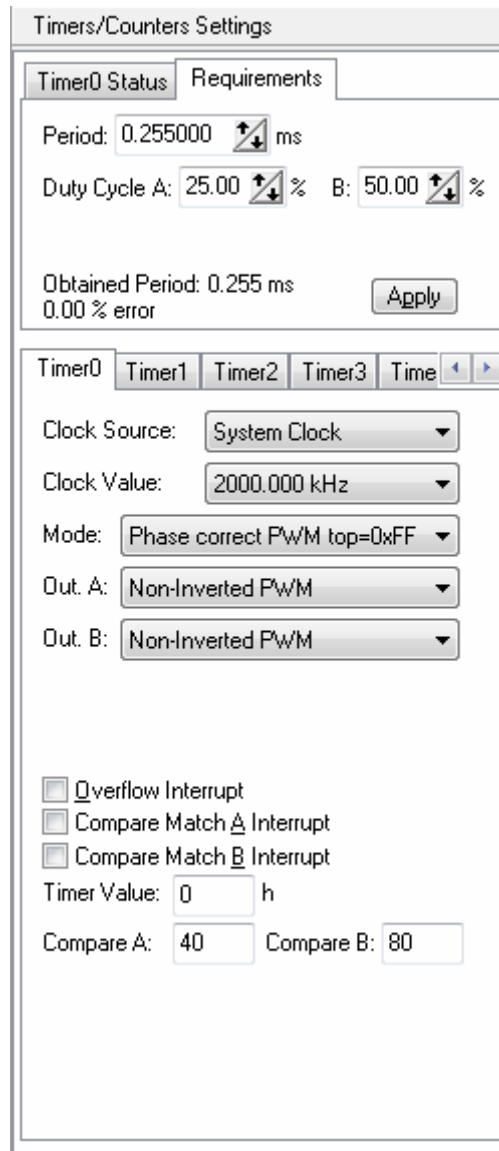
The interrupt service routines for these interrupts will be **pin_change_isr0** for PCINT0-7, **pin_change_isr1** for PCINT8-15, **pin_change_isr2** for PCINT16-23 and **pin_change_isr3** for PCINT24-30.

6.5 Setting the Timers/Counters

The timers/counters configuration can be specified by clicking on the **Timers/Counters**  node of the CodeWizardAVR selection tree.

A number of **Timer** tabs will be displayed according to the AVR chip type.

By selecting the **Timer 0** tab you can have the following options:



The screenshot shows the 'Timers/Counters Settings' dialog box with the 'Timer0 Status' tab selected. The 'Requirements' sub-tab is active, showing configuration for Timer0. The 'Period' is set to 0.255000 ms. The 'Duty Cycle A' is 25.00% and 'Duty Cycle B' is 50.00%. The 'Obtained Period' is 0.255 ms with a 0.00% error. Below this, there are tabs for 'Timer0', 'Timer1', 'Timer2', 'Timer3', and 'Time'. The 'Timer0' tab is selected, showing settings for the timer: 'Clock Source' is 'System Clock', 'Clock Value' is '2000.000 kHz', 'Mode' is 'Phase correct PWM top=0xFF', 'Out. A' is 'Non-Inverted PWM', and 'Out. B' is 'Non-Inverted PWM'. There are three checkboxes for interrupts: 'Overflow Interrupt', 'Compare Match A Interrupt', and 'Compare Match B Interrupt', all of which are currently unchecked. At the bottom, 'Timer Value' is set to 0, 'Compare A' is 40, and 'Compare B' is 80.

- **Clock Source** specifies the timer/counter 0 clock pulse source
- **Clock Value** specifies the timer/counter 0 clock frequency
- **Mode** specifies if the timer/counter 0 functioning mode
- **Outp. A** specifies the function of the timer/counter 0 compare A output and depends of the functioning mode
- **Outp. B** specifies the function of the timer/counter 0 compare B output and depends of the functioning mode
- **Overflow Interrupt** specifies if an interrupt is to be generated on timer/counter 0 overflow

- **Compare Match A Interrupt** specifies if an interrupt is to be generated on timer/counter 0 compare A match
- **Compare Match B Interrupt** specifies if an interrupt is to be generated on timer/counter 0 compare B match
- **Timer Value** specifies the initial value of timer/counter 0 at startup
- **Compare A** specifies the initial value of timer/counter 0 output compare A register
- **Compare B** specifies the initial value of timer/counter 0 output compare B register.

If timer/counter 0 interrupts are used the following interrupt service routines may be defined by the CodeWizardAVR:

- **timer0_ovf_isr** for timer/counter overflow
- **timer0_compa_isr** for timer/counter output compare A match
- **timer0_compb_isr** for timer/counter output compare B match

Note: Depending of the used AVR chip some of these options may not be present.
For more information you must consult the corresponding Atmel data sheet.

The CodeWizardAVR features an automatic timer configurator which is invoked by selecting the **Requirements** tab.

Here the user can enter the required timer period in ms and the duty cycle(s) for the enabled timer's outputs for PWM modes.

By pressing the **Apply** button all the corresponding timer configuration registers are set accordingly, in order to obtain the closest possible values for the required parameters, using the timer operating mode specified by the **Mode** list box.

Selecting the **Timer 0 Status** tab allows to see the obtained output pulse parameters for the currently set timer clock frequency, operating mode and configuration registers values:

Timers/Counters Settings

Timer0 Status

Requirements

Timer Period: 0.255 ms

Output Pulse(s):
OC0A Period: 0.255 ms Width: 0.064 ms
OC0B Period: 0.255 ms Width: 0.128 ms

Timer0

Timer1

Timer2

Timer3

Time

Clock Source: System Clock

Clock Value: 2000.000 kHz

Mode: Phase correct PWM top=0xFF

Out. A: Non-Inverted PWM

Out. B: Non-Inverted PWM

☐ Overflow Interrupt

☐ Compare Match A Interrupt

☐ Compare Match B Interrupt

Timer Value: 0 h

Compare A: 40 Compare B: 80

By selecting the **Timer 1** tab you can have the following options:

The screenshot shows the 'Timers/Counters Settings' dialog box with the 'Timer1' tab selected. The 'Requirements' sub-tab is also active, showing a 'Period' of 1.000000 ms and 'Duty Cycle' values for A (25.00%), B (50.00%), and C (75.00%). Below these, it shows 'Obtained Period: 1 ms' and '0.00 % error'. The 'Apply' button is highlighted. The main 'Timer1' tab shows the 'Clock Source' set to 'System Clock', 'Clock Value' at 16000.000 kHz, and 'Mode' set to 'Ph. & fr. cor. PWM top=ICR1'. Output A, B, and C are all set to 'Non-Inv.'. Under 'Input Capture', both 'Noise Cancel' and 'Rising Edge' are checked. Under 'Interrupt on', both 'Timer1 Overflow' and 'Input Capture' are checked. The 'Value' is set to 0, and 'Inp. Capture' is set to 1F40. Compare registers are set to A: 7D0, B: FA0, and C: 1770.

- **Clock Source** specifies the timer/counter 1 clock pulse source
- **Clock Value** specifies the timer/counter 1 clock frequency
- **Mode** specifies if the timer/counter 1 functioning mode
- **Out. A** specifies the function of the timer/counter 1 output A and depends of the functioning mode
- **Out. B** specifies the function of the timer/counter 1 output B and depends of the functioning mode
- **Out. C** specifies the function of the timer/counter 1 output C and depends of the functioning mode
- **Inp Capt.** specifies the timer/counter 1 capture trigger edge and if the noise canceler is to be used
- **Interrupt on** specifies if an interrupt is to be generated on timer/counter 1 overflow, input capture and compare match
- **Timer Value** specifies the initial value of timer/counter 1 at startup
- **Comp. A, B and C** specifies the initial value of timer/counter 1 output compare registers A, B and C.

If timer/counter 1 interrupts are used, the following interrupt service routines may be defined by the CodeWizardAVR:

- **timer1_ovf_isr** for timer/counter overflow
- **timer1_comp_isr** or **timer1_compa_isr**, **timer1_compb_isr** and **timer1_copmc_isr** for timer/counter output compare match
- **timer1_capt_isr** for timer/counter input capture

Note: Depending of the used AVR chip some of these options may not be present.
For more information you must consult the corresponding Atmel data sheet.

By selecting the **Timer 2** tab you can have the following options:

The screenshot shows the 'Timers/Counters Settings' dialog box with the 'Timer2 Status' tab selected. The 'Requirements' tab is also visible. The 'Period' is set to 1.024000 ms. The 'Duty Cycle A' is 50.00 % and 'Duty Cycle B' is 60.00 %. The 'Obtained Period' is 1.024 ms with a 0.00 % error. The 'Apply' button is highlighted. Below the tabs, the 'Clock Source' is 'System Clock', 'Clock Value' is '250.000 kHz', 'Mode' is 'Fast PWM top=0xFF', 'Out. A' is 'Non-Inverted PWM', and 'Out. B' is 'Non-Inverted PWM'. The 'Overflow Interrupt', 'Compare Match A Interrupt', and 'Compare Match B Interrupt' checkboxes are unchecked. The 'Timer Value' is 0 h, 'Compare A' is 80 h, and 'Compare B' is 99 h.

- **Clock Source** specifies the timer/counter 2 clock pulse source
- **Clock Value** specifies the timer/counter 2 clock frequency
- **Mode** specifies if the timer/counter 2 functioning mode
- **Out. A** specifies the function of the timer/counter 2 output A and depends of the functioning mode
- **Out. B** specifies the function of the timer/counter 2 output B and depends of the functioning mode
- **Overflow Interrupt** specifies if an interrupt is to be generated on timer/counter 2 overflow
- **Compare Match A Interrupt** specifies if an interrupt is to be generated on timer/counter 2 compare register A match
- **Compare Match B Interrupt** specifies if an interrupt is to be generated on timer/counter 2 compare register B match
- **Timer Value** specifies the initial value of timer/counter 2 at startup
- **Compare A** specifies the initial value of timer/counter 2 output compare A register
- **Compare B** specifies the initial value of timer/counter 2 output compare B register

If timer/counter 2 interrupts are used, the following interrupt service routines may be defined by the CodeWizardAVR:

- **timer2_ovf_isr** for timer/counter overflow
- **timer2_comp_isra** and **timer2_compb_isr** for timer/counter output compare match.

Note: Depending of the used AVR chip some of these options may not be present.
For more information you must consult the corresponding Atmel data sheet.

By selecting the **Timer 3** tab you can have the following options:

The screenshot shows the 'Timers/Counters Settings' dialog box with the 'Timer3 Status' tab selected. The 'Requirements' tab is also visible. The 'Period' is set to 1.000000 ms. The 'Duty Cycle' for outputs A, B, and C is set to 10.00%, 20.00%, and 30.00% respectively. The 'Obtained Period' is 1 ms with a 0.00% error. The 'Apply' button is highlighted. Below the tabs, the 'Clock Source' is set to 'System Clock', 'Clock Value' is 16000.000 kHz, and 'Mode' is 'Ph. correct PWM top=ICR3'. The output polarities are 'Non-Inv.' for A and B, and 'Inverted' for C. The 'Input Capture' section has 'Noise Cancel' and 'Rising Edge' options. The 'Interrupt on' section has 'Timer3 Overflow' and 'Input Capture' options. The 'Value' is 0, 'Inp. Capture' is 1F40, and the compare values are 'Comp. A: 320', 'B: 640', and 'C: 15E0'.

- **Clock Source** specifies the timer/counter 3 clock pulse source
- **Clock Value** specifies the timer/counter 3 clock frequency
- **Mode** specifies if the timer/counter 3 functioning mode
- **Out. A** specifies the function of the timer/counter 3 output A and depends of the functioning mode
- **Out. B** specifies the function of the timer/counter 3 output B and depends of the functioning mode
- **Out. C** specifies the function of the timer/counter 3 output C and depends of the functioning mode
- **Inp Capt.** specifies the timer/counter 3 capture trigger edge and if the noise canceler is to be used
- **Interrupt on** specifies if an interrupt is to be generated on timer/counter 3 overflow, input capture and compare match
- **Timer Value** specifies the initial value of timer/counter 3 at startup
- **Comp. A, B and C** specifies the initial value of timer/counter 3 output compare registers A, B and C.

If timer/counter 3 interrupts are used, the following interrupt service routines may be defined by the CodeWizardAVR:

- **timer3_ovf_isr** for timer/counter overflow
- **timer3_comp_isr** or **timer3_compa_isr**, **timer3_compb_isr** and **timer3_compc_isr** for timer/counter output compare match
- **timer3_capt_isr** for timer/counter input capture

Notes:

- Depending of the used AVR chip some of these options may not be present.
- Some AVR chips may have additional timers, which can be configured the same way as described above.

By selecting the **Watchdog** tab you can configure the watchdog timer.

The screenshot shows the 'Timers/Counters Settings' dialog box with the 'Watchdog' tab selected. The 'Watchdog Timer Enabled' checkbox is checked. Below it, the 'Oscillator Prescaler' section contains two columns of radio buttons: OSC/2k (selected), OSC/4k, OSC/8k, OSC/16k, OSC/32k, OSC/64k, OSC/128k, OSC/256k, OSC/512k, and OSC/1024k. At the bottom, the 'Timeout Action' is set to 'Reset' in a dropdown menu.

Checking the **Watchdog Timer Enabled** check box activates the watchdog timer. You will have then the possibility to set the watchdog timer's **Oscillator Prescaler**.

The **Timeout Action** list box allows to specify what action will be performed on watchdog timer overflow:

- hardware **Reset**
- **Interrupt** only
- **Interrupt** and then hardware **Reset**.

If interrupt generation is enabled, the **wdt_timeout_isr** interrupt service function will be created.

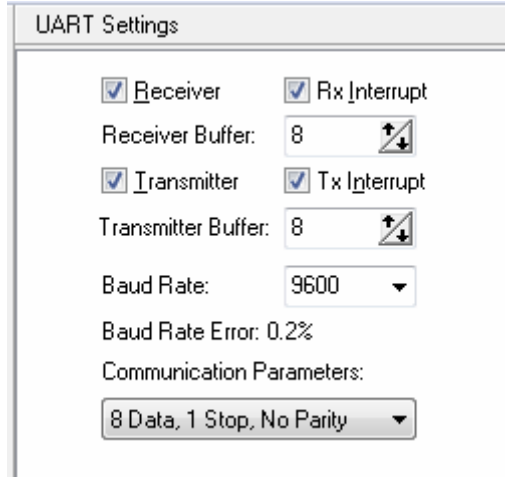
In case the watchdog timer is enabled, you must include yourself the appropriate code sequences to reset it periodically. Example:

```
#asm("wdr")
```

For more information about the watchdog timer you must consult the Atmel data sheet for the chip that you use.

6.6 Setting the UART or USART

The UART or USART configuration can be specified by clicking on the **USART**  node(s) of the CodeWizardAVR selection tree.



The image shows the 'UART Settings' dialog box. It contains several options and fields: 'Receiver' and 'Tx Interrupt' are checked; 'Rx Interrupt' is also checked. 'Receiver Buffer' is set to 8. 'Transmitter' and 'Tx Interrupt' are checked. 'Transmitter Buffer' is set to 8. 'Baud Rate' is set to 9600. 'Baud Rate Error' is 0.2%. 'Communication Parameters' is set to '8 Data, 1 Stop, No Parity'.

Checking the **Receiver** check box activates the UART receiver.

The receiver can function in the following modes:

- polled, the **Rx Interrupt** check box isn't checked
- interrupt driven circular buffer, the **Rx Interrupt** check box is checked.

In the interrupt driven mode you can specify the size of the circular buffer using the **Receiver Buffer** spinedit box.

Checking the **Transmitter** check box activates the UART transmitter.

The transmitter can function in the following modes:

- polled, the **Tx Interrupt** check box isn't checked
- interrupt driven circular buffer, the **Tx Interrupt** check box is checked.

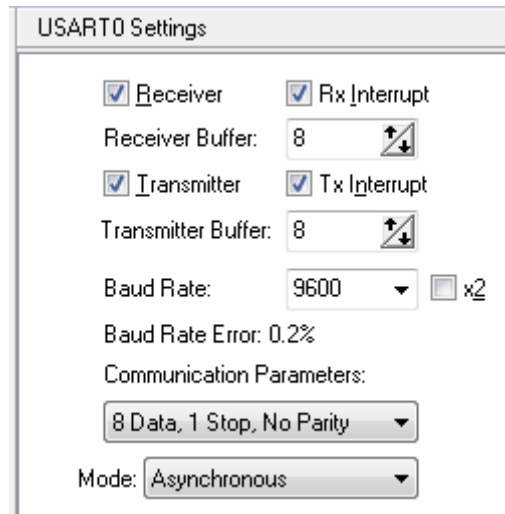
In the interrupt driven mode you can specify the size of the circular buffer using the **Transmitter Buffer** spinedit box.

The communication Baud rate can be specified using the **UART Baud Rate** list box.

CodeWizardAVR will automatically set the UBRR according to the Baud rate and AVR chip clock frequency. The Baud rate error for these parameters will be calculated and displayed.

The **Communications Parameters** list box allows you to specify the number of data bits, stop bits and parity used for serial communication.

For devices featuring an **USART** there will be an additional **Mode** list box.



It allows you to specify the following communication modes:

- Asynchronous
- Synchronous Master, with the UCSRC register's UCPOL bit set to 0
- Synchronous Master, with the UCSRC register's UCPOL bit set to 1
- Synchronous Slave, with the UCSRC register's UCPOL bit set to 0
- Synchronous Slave, with the UCSRC register's UCPOL bit set to 1.

The serial communication is realized using the Standard Input/Output Functions **getchar**, **gets**, **scanf**, **putchar**, **puts** and **printf**.

For interrupt driven serial communication, CodeWizardAVR automatically redefines the basic **getchar** and **putchar** functions.

The receiver buffer is implemented using the global array **rx_buffer**.

The global variable **rx_wr_index** is the **rx_buffer** array index used for writing received characters in the buffer.

The global variable **rx_rd_index** is the **rx_buffer** array index used for reading received characters from the buffer by the **getchar** function.

The global variable **rx_counter** contains the number of characters received in **rx_buffer** and not yet read by the **getchar** function.

If the receiver buffers overflows the **rx_buffer_overflow** global bit variable will be set.

The transmitter buffer is implemented using the global array **tx_buffer**.

The global variable **tx_wr_index** is the **tx_buffer** array index used for writing in the buffer the characters to be transmitted.

The global variable **tx_rd_index** is the **tx_buffer** array index used for reading from the buffer the characters to be transmitted by the **putchar** function.

The global variable **tx_counter** contains the number of characters from **tx_buffer** not yet transmitted by the interrupt system.

For devices with 2 UARTs, respectively 2 USARTs, there will be two tabs present: **UART0** and **UART1**, respectively **USART0** and **USART1**.

The functions of configuration check and list boxes will be the same as described above.

The UART0 (USART0) will use the normal **putchar** and **getchar** functions.

In case of interrupt driven buffered communication, UART0 (USART0) will use the following variables: **rx_buffer0**, **rx_wr_index0**, **rx_rd_index0**, **rx_counter0**, **rx_buffer_overflow0**, **tx_buffer0**, **tx_wr_index0**, **tx_rd_index0**, **tx_counter0**.

The UART1 (USART1) will use the **putchar1** and **getchar1** functions.

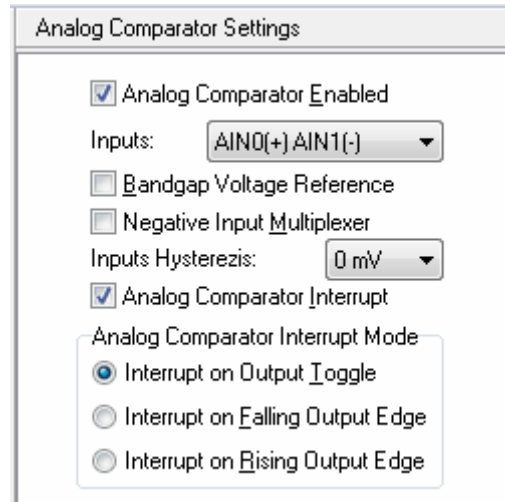
In case of interrupt driven buffered communication, UART1 (USART1) will use the following variables:

rx_buffer1, **rx_wr_index1**, **rx_rd_index1**, **rx_counter1**, **rx_buffer_overflow1**,
tx_buffer1, **tx_wr_index1**, **tx_rd_index1**, **tx_counter1**.

All serial I/O using functions declared in **stdio.h**, will be done using UART0 (USART0).

6.7 Setting the Analog Comparator

The configuration of the **Analog Comparator** can be specified by clicking on the corresponding node  of the CodeWizardAVR selection tree.



Checking the **Analog Comparator Enabled** check box enables the on-chip analog comparator. Checking the **Bandgap Voltage Reference** check box will connect an internal voltage reference to the analog comparator's positive input.

Checking the **Negative Input Multiplexer** check box will connect the analog comparator's negative input to the ADC's analog multiplexer.

If the **Negative Input Multiplexer** option is not enabled, the **Inputs** list box allows to select which of the ADC's analog multiplexer inputs will be connected to the analog comparator's positive and negative inputs.

The **Inputs Hysteresis** list box allows to select the amount of hysteresis of the analog comparator inputs.

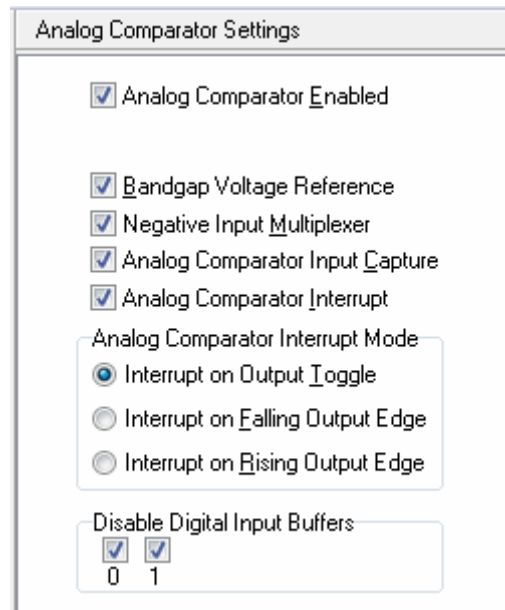
If you want to generate interrupts if the analog comparator's output changes state, then you must check the **Analog Comparator Interrupt** check box.

The type of output change that triggers the interrupt can be specified in the **Analog Comparator Interrupt Mode** settings.

For some AVR chips the analog comparator's output may be to be used for capturing the state of timer/counter 1.

In this case the **Analog Comparator Input Capture** check box must be checked if present.

The **Disable Digital Input Buffer on AIN0**, respectively **Disable Digital Input Buffer on AIN1** check boxes, if checked, will deactivate the digital input buffers on the AIN0, respectively AIN1 pins, thus reducing the power consumption of the chip.



The screenshot shows the 'Analog Comparator Settings' dialog box. It contains several checked options: 'Analog Comparator Enabled', 'Bandgap Voltage Reference', 'Negative Input Multiplexer', 'Analog Comparator Input Capture', and 'Analog Comparator Interrupt'. Under 'Analog Comparator Interrupt Mode', 'Interrupt on Output Toggle' is selected. At the bottom, under 'Disable Digital Input Buffers', there are two checked checkboxes labeled '0' and '1'.

The corresponding bits in the PIN registers will always read 0 in this case.

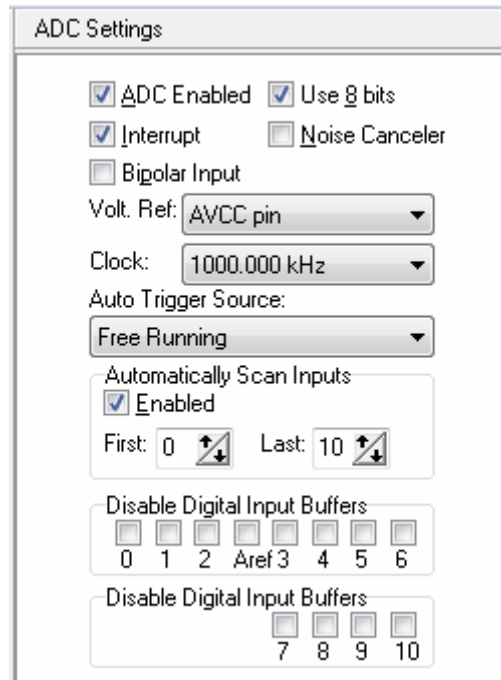
Some of these check boxes may not be present on all the AVR chips.

If the analog comparator interrupt is enabled, the CodeWizardAVR will define the **ana_comp_isr** interrupt service routine.

6.8 Setting the Analog to Digital Converter

Some AVR chips contain an Analog to Digital Converter (ADC).

The ADC configuration can be specified by clicking on the **Analog to Digital Converter**  node of the CodeWizardAVR selection tree.



ADC Settings

☒ ADC Enabled ☒ Use 8 bits

☒ Interrupt ☐ Noise Canceler

☐ Bipolar Input

Volt. Ref: AVCC pin

Clock: 1000.000 kHz

Auto Trigger Source: Free Running

Automatically Scan Inputs

☒ Enabled

First: 0 Last: 10

Disable Digital Input Buffers

☐ 0 ☐ 1 ☐ 2 ☐ Aref ☐ 3 ☐ 4 ☐ 5 ☐ 6

Disable Digital Input Buffers

☐ 7 ☐ 8 ☐ 9 ☐ 10

Checking the **ADC Enabled** check box enables the on-chip ADC.

On some AVR devices only the 8 most significant bits of the AD conversion result can be used. This feature is enabled by checking the **Use 8 bits** check box.

The ADC may be operated in bipolar mode if the **Bipolar Input** check box is checked.

Some AVR devices allow the ADC to use a high speed conversion mode, but with lower precision. This feature is enabled by checking the **High Speed** check box, if present.

If the ADC has an internal reference voltage source, than it can be selected using the **Volt. Ref.** list box or activated by checking the **ADC Bandgap** check box.

The ADC clock frequency can be selected using the **Clock** list box.

If you want to generate interrupts when the ADC finishes the conversion, then you must check the **Interrupt** check box.

If ADC interrupts are used you have the possibility to enable the following functions:

- by checking the **Noise Canceled** check box, the chip is placed in idle mode during the conversion process, thus reducing the noise induced on the ADC by the chip's digital circuitry
- by checking the **Automatically Scan Inputs Enabled** check box, the CodeWizardAVR will generate code to scan an ADC input domain and put the results in an array. The start, respectively the end, of the domain are specified using the **First Input**, respectively the **Last Input**, spinedit boxes.

Some AVR devices allow the AD conversion to be triggered by an event which can be selected using the **Auto Trigger Source** list box.

If the automatic inputs scanning is disabled, then a single analog-digital conversion can be executed using the function:

```
unsigned int read_adc(unsigned char adc_input)
```

This function will return the analog-digital conversion result for the input **adc_input**. The input numbering starts from 0.

If interrupts are enabled the above function will use an additional interrupt service routine **adc_isr**. This routine will store the conversion result in the **adc_data** global variable.

If the automatic inputs scanning is enabled, the **adc_isr** service routine will store the conversion results in the **adc_data** global array. The user program must read the conversion results from this array.

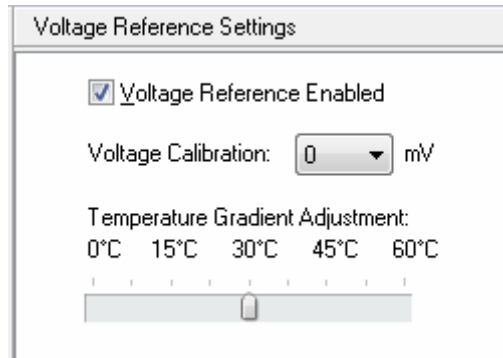
For some chips there is also the possibility to disable the digital input buffers on the inputs used by the ADC, thus reducing the power consumption of the chip.

This is accomplished by checking the corresponding **Disable Digital Input Buffers** check boxes.

If the **Automatically Scan Inputs** option is enabled, then the corresponding digital input buffers are automatically disabled for the ADC inputs in the scan range.

6.9 Setting the ATmega406 Voltage Reference

Some AVR chips, like the ATmega406, contain a low power precision bang-gap voltage reference, which can be configured by clicking on the **Voltage Reference**  node of the CodeWizardAVR selection tree.



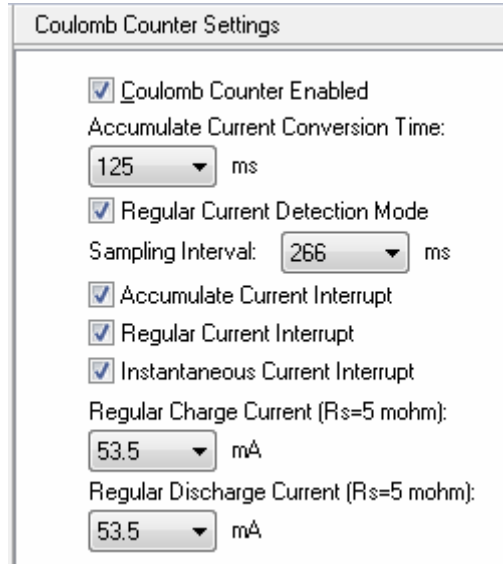
Checking the **Voltage Reference Enabled** check box enables the precision voltage reference. The **Voltage Calibration** list box allows for precision adjustment of the nominal value of the reference voltage in 2mV steps.

The **Temperature Gradient Adjustment** slider allows shifting the top of the V_{REF} versus temperature curve to the center of the temperature range of interest, thus minimizing the voltage drift in this range. The Atmega406 datasheet may be consulted for more details.

6.10 Setting the ATmega406 Coulomb Counter

The ATmega406 chip, contains a dedicated Sigma-Delta ADC optimized for Coulomb Counting to sample the charge or discharge current flowing through an external sense resistor R_s .

This ADC can be configured by clicking on the **Coulomb Counter**  node of the CodeWizardAVR selection tree.



Coulomb Counter Settings

☒ Coulomb Counter Enabled

Accumulate Current Conversion Time:
125 ms

☒ Regular Current Detection Mode

Sampling Interval: 266 ms

☒ Accumulate Current Interrupt

☒ Regular Current Interrupt

☒ Instantaneous Current Interrupt

Regular Charge Current ($R_s=5$ mohm):
53.5 mA

Regular Discharge Current ($R_s=5$ mohm):
53.5 mA

Checking the **Coulomb Counter Enabled** check box enables the Coulomb Counter Sigma-Delta ADC.

The **Accumulate Current Conversion Time** list box specifies the conversion time for the Accumulate Current output.

The **Regular Current Detection Mode** check box specifies that the Coulomb Counter will repeatedly do one instantaneous current conversion, before it is turned off for a timing interval specified by the **Sampling Interval** list box.

The interval selected using the above-mentioned list box includes a sampling time, having a typical value of 16ms.

The **Accumulate Current Interrupt** check box enable the generation of an interrupt after the accumulate current conversion has completed. This interrupt is serviced by the **ccadc_acc_isr** ISR.

The **Regular Current Interrupt** check box enable the generation of an interrupt when the absolute value of the result of the last AD conversion is greater, or equal to, the values of the CADRCC and CADRDC registers. This interrupt is serviced by the **ccadc_reg_cur_isr** ISR.

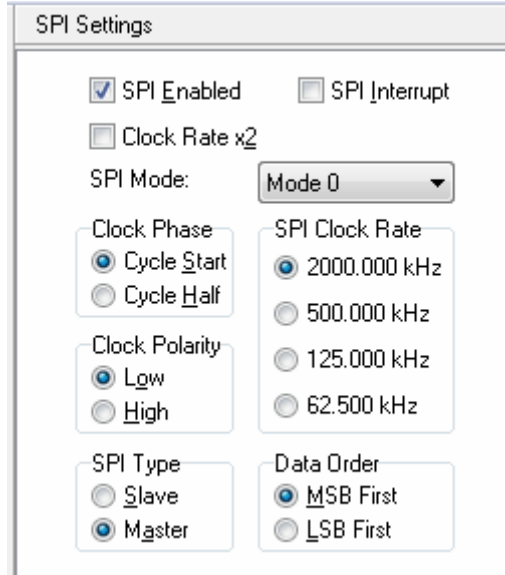
The **Instantaneous Current Interrupt** check box enables the generation of an interrupt when an instantaneous current conversion has completed. This interrupt is serviced by the **ccadc_conv_isr** ISR.

The **Regular Charge Current**, respectively **Regular Discharge Current**, list boxes determine the threshold levels for the *regular charge*, respectively *regular discharge* currents, setting the values for the CADRCC, respectively CADRDC, registers used for generating the *Regular Current Interrupt*.

The Atmega406 datasheet may be consulted for more details about the Coulomb Counter.

6.11 Setting the SPI Interface

The SPI interface configuration can be specified by clicking on the **Serial Peripheral Interface**  node of the CodeWizardAVR selection tree.



Checking the **SPI Enabled** check box enables the on-chip SPI interface.

If you want to generate interrupts upon completion of a SPI transfer, then you must check the **SPI Interrupt** check box.

You have the possibility to specify the following parameters:

- **SPI Clock Rate** used for the serial transfer
- **Clock Phase**: the position of the SCK strobe signal edge relative to the data bit
- **Clock Polarity**: low or high in idle state
- **SPI Type**: the AVR chip is master or slave
- **Data Order** in the serial transfer.

Checking the **Clock Rate x2** check box, available for some AVR chips, will double the **SPI Clock Rate**.

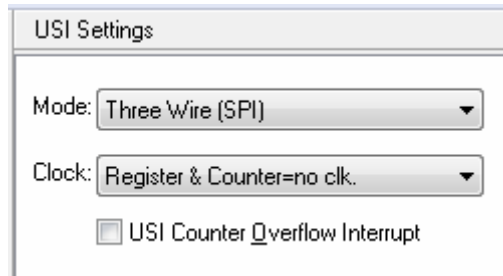
For communicating through the SPI interface, with disabled SPI interrupt, you must use the **SPI Functions**.

If the SPI interrupt is enabled, you must use the **spi_isr** interrupt service routine, declared by the CodeWizardAVR.

6.12 Setting the Universal Serial Interface - USI

The **USI** configuration can be specified by clicking on the corresponding node  of the CodeWizardAVR selection tree.

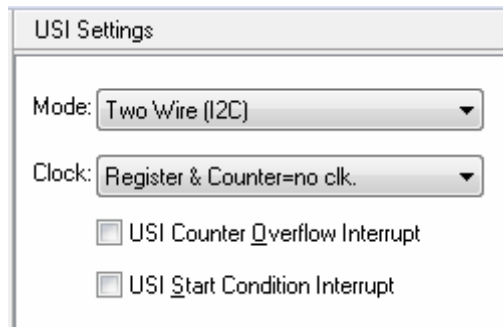
The USI operating mode can be selected using the **Mode** list box.
One of the USI operating modes is the **Three Wire (SPI)** mode:



The dialog box titled "USI Settings" contains the following controls:

- Mode:** A dropdown menu with "Three Wire (SPI)" selected.
- Clock:** A dropdown menu with "Register & Counter=no clk." selected.
- ☐ USI Counter Overflow Interrupt

The USI can also operate in the **Two Wire (I2C)** mode:



The dialog box titled "USI Settings" contains the following controls:

- Mode:** A dropdown menu with "Two Wire (I2C)" selected.
- Clock:** A dropdown menu with "Register & Counter=no clk." selected.
- ☐ USI Counter Overflow Interrupt
- ☐ USI Start Condition Interrupt

The **Shift Reg. Clock** list box sets the clock source for the USI Shift Register and Counter.

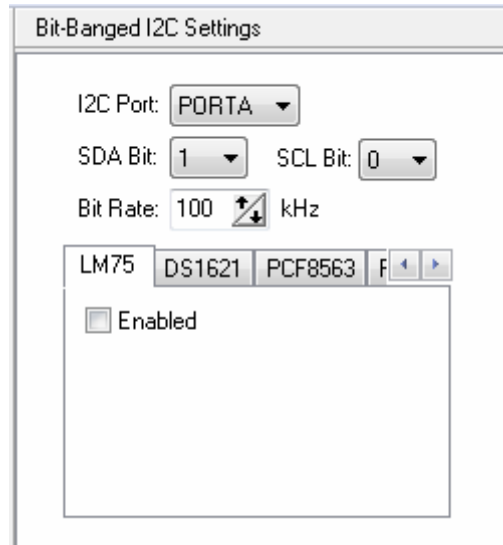
As both the USI Shift Register and Counter are clocked from the same clock source, the USI Counter may be used to count the number of received or transmitted bits and generate an overflow interrupt when the data transfer is complete.

Checking the **USI Counter Overflow Interrupt** check box will generate code for an interrupt service routine that will be executed upon the overflow of the USI Counter.

If the **USI Start Condition Interrupt** check box is checked then the CodeWizardAVR will generate code for an interrupt service routine that will be executed when a Start Condition is detected on the I2C bus in USI **Two Wire** operating mode.

6.13 Setting the Bit-Banged I²C Bus

The I²C bus configuration can be specified by clicking on the **Bit-Banged I²C Bus Interface**  node of the CodeWizardAVR selection tree.



The dialog box titled "Bit-Banged I2C Settings" contains the following controls:

- I2C Port:** A dropdown menu with "PORTA" selected.
- SDA Bit:** A dropdown menu with "1" selected.
- SCL Bit:** A dropdown menu with "0" selected.
- Bit Rate:** A text field with "100" and a spin button, followed by "kHz".
- Component Selection:** A row of buttons: "LM75", "DS1621", "PCF8563", and "F" (with left and right arrow buttons).
- Enabled:** A checkbox that is currently unchecked.

Using the **I²C Port** list box you can specify which port is used for the implementation of the I²C bus. The **SDA Bit** and **SCL Bit** list boxes allow you to specify which port bits the I²C bus uses.

6.13.1 Setting the LM75 devices

If you use the LM75 temperature sensor, you must select the **LM75** tab and check the **LM75 Enabled** check box.

Bit-Banged I2C Settings

I2C Port:

SDA Bit: SCL Bit:

Bit Rate: kHz

LM75

☒ Enabled Address: ☒ 0

☐ Output Active High

Temperature °C

Hyst. : O.S. :

The **LM75 Address** list box allows you to specify the 3 lower bits of the I²C addresses of the LM75 devices connected to the bus. Maximum 8 LM75 devices can be used.

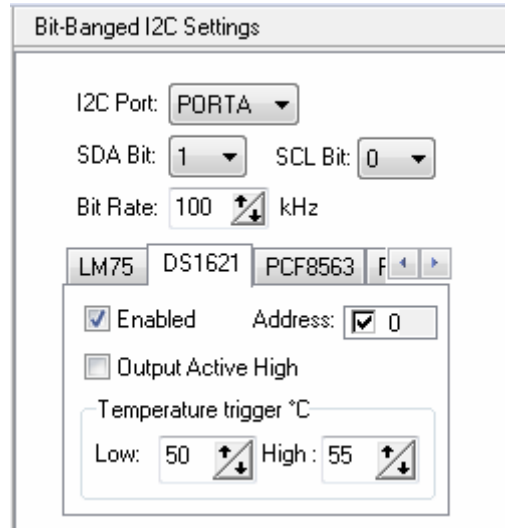
The **Output Active High** check box specifies the active state of the LM75 O.S. output.

The **Hyst.**, respectively **O.S.**, spinedit boxes specify the hysteresis, respectively O.S. temperatures.

The LM75 devices are accessed through the **National Semiconductor LM75 Temperature Sensor Functions**.

6.13.2 Setting the DS1621 devices

If you use the DS1621 thermometer/thermostat, you must select the **DS1621** tab and check the **DS1621 Enabled** check box.



The **Output Active High** check box specifies the active state of the DS1621 Tout output. The **Low**, respectively **High**, spinedit boxes specify the low, respectively high temperatures trigger temperatures for the Tout output.

The DS1621 devices are accessed through the **Maxim DS1621 Thermometer/Thermostat** functions.

6.13.3 Setting the PCF8563 devices

If you use the PCF8563 RTC, you must select the PCF8563 tab and check the PCF8563 Enabled check box.

Bit-Banged I2C Settings

I2C Port: PORTA

SDA Bit: 1 SCL Bit: 0

Bit Rate: 100 kHz

LM75 DS1621 PCF8563 F

☒ Enabled CLKOUT: OFF

☐ Alarm Interrupt

Timer

Clock: OFF ☒ Int. Enabled

Value: 1 ☒ INT Pulses

The **CLKOUT** list box specifies the frequency of the pulses on the CLKOUT output.

The **Alarm Interrupt** check box enables the generation of interrupts, on the INT pin, when the alarm conditions are met.

The **Timer|Clock** list box specifies the countdown frequency of the PCF8563 Timer.

If the **Int. Enabled** check box is checked, an interrupt will be generated when the Timer countdown value will be 0.

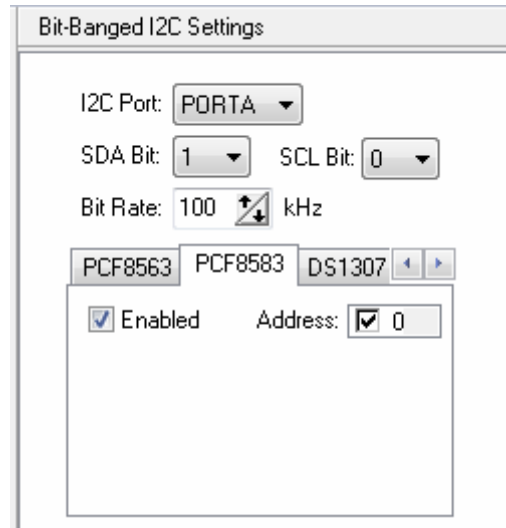
If the **INT Pulses** check box is checked, the INT pin will issue short pulses when the Timer countdown value reaches 0.

The **Timer|Value** spinedit box specifies the Timer reload value when the countdown reaches 0.

The PCF8563 devices are accessed through the **Philips PCF8563 Real Time Clock Functions**.

6.13.4 Setting the PCF8583 devices

If you use the PCF8583 RTC, you must select the **PCF8583** tab and check the **PCF8583 Enabled** check box.



The screenshot shows a dialog box titled "Bit-Banged I2C Settings". It contains the following controls:

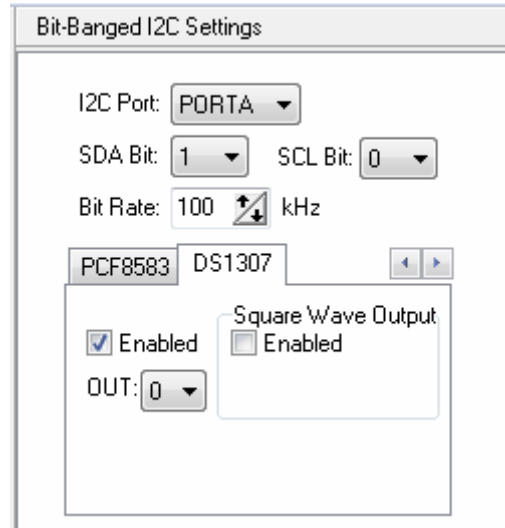
- I2C Port: A dropdown menu set to "PORTA".
- SDA Bit: A dropdown menu set to "1".
- SCL Bit: A dropdown menu set to "0".
- Bit Rate: A numeric input set to "100" with a unit dropdown set to "kHz".
- Device Selection: A row of three buttons labeled "PCF8563", "PCF8583", and "DS1307". The "PCF8583" button is highlighted.
- Enabled: A checked checkbox labeled "Enabled".
- Address: A checked checkbox labeled "Address:" followed by a dropdown menu set to "0".

The **PCF8583 Address** list box allows you to specify the low bit of the I²C addresses of the PCF8583 devices connected to the bus. Maximum 2 PCF8583 devices can be used.

The PCF8583 devices are accessed through the **Philips PCF8583 Real Time Clock Functions**.

6.13.5 Setting the DS1307 devices

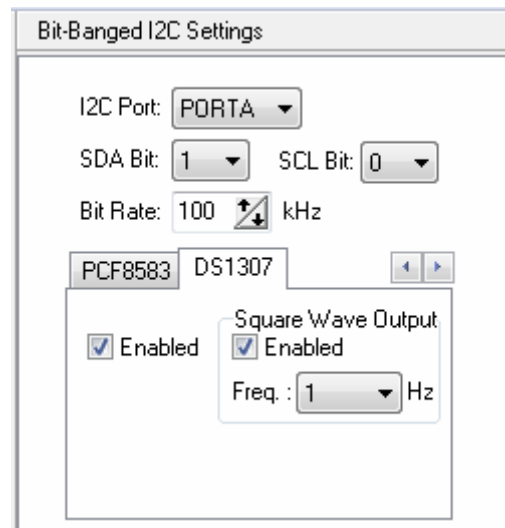
If you use the DS1307 RTC, you must select the **DS1307** tab and check the **DS1307 Enabled** check box.



The DS1307 device is accessed through the **Maxim DS1307 Real Time Clock Functions**.

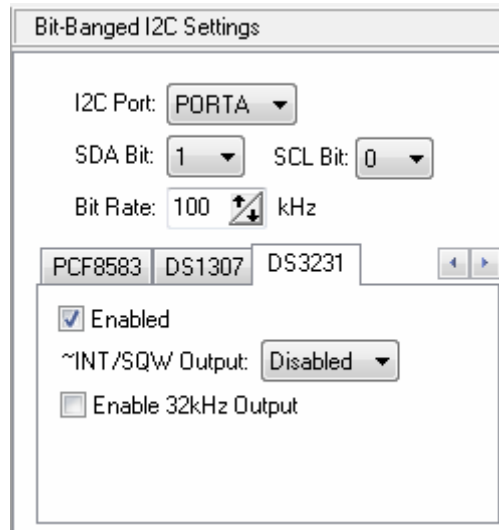
In case the square wave signal output is disabled, the state of the SQW/OUT pin can be specified using the **OUT** list box.

By checking the **Square Wave Output Enabled** check box a square wave signal will be available on the DS1307's SQW/OUT pin. The frequency of the square wave can be selected using the **Freq.** list box:



6.13.6 Setting the DS3231 devices

If you use the DS3231 RTC, you must select the **DS3231** tab and check the **DS3231 Enabled** check box.



The DS3231 device is accessed through the **Maxim DS3231 Real Time Clock Functions**.

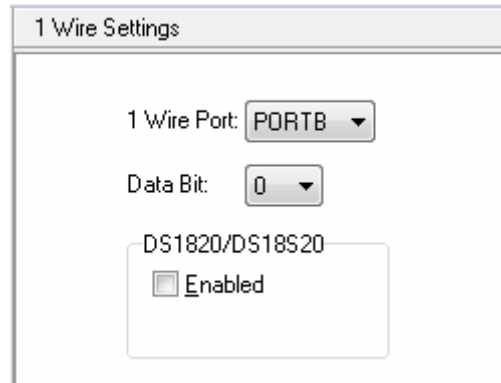
The **~INT/SQW Output** option allows selecting the function of the DS3231's output pin with the same name:

- **Disabled** - the ~INT/SQW output is disabled
- **Interrupt** - a match between the timekeeping registers and either of the alarm registers activates the ~INT/SQW output (if the alarm is also enabled)
- **1 Hz** - SQW outputs a 1Hz square wave
- **1024 Hz** - SQW outputs a 1024Hz square wave
- **4096 Hz** - SQW outputs a 4096Hz square wave
- **8192 HZ** - SQW outputs a 8192Hz square wave.

Activating the **Enable 32kHz Output** generates a 32kHz square wave signal on the DS3231's **32kHz** pin.

6.14 Setting the 1 Wire Bus

The 1 Wire bus configuration can be specified by clicking on the **1 Wire Bus Interface**  node of the CodeWizardAVR selection tree.



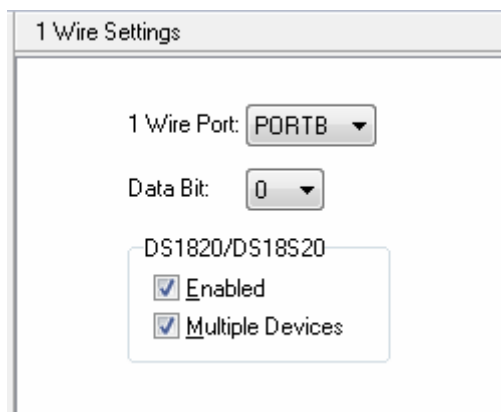
The dialog box titled "1 Wire Settings" contains the following controls:

- 1 Wire Port:** A dropdown menu with "PORTB" selected.
- Data Bit:** A dropdown menu with "0" selected.
- DS1820/DS18S20:** A section containing a single checkbox labeled "Enabled", which is currently unchecked.

Using the **1 Wire Port** list box you can specify which port is used for the implementation of the 1 Wire bus.

The **Data Bit** list box allows you to specify which port bit the 1 Wire bus uses.

If you use the DS1820/DS18S20 temperature sensors, you must check the **DS1820/DS18S20 Enabled** check box.



The dialog box titled "1 Wire Settings" contains the following controls:

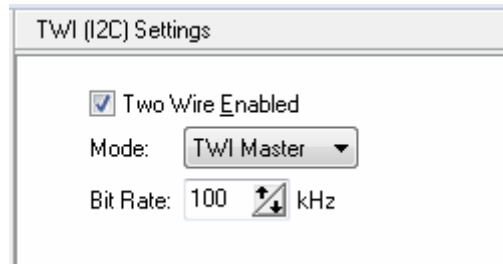
- 1 Wire Port:** A dropdown menu with "PORTB" selected.
- Data Bit:** A dropdown menu with "0" selected.
- DS1820/DS18S20:** A section containing two checkboxes: "Enabled" (checked) and "Multiple Devices" (checked).

If you use several DS1820/DS18S20 devices connected to the 1 Wire bus, you must check the **Multiple Devices** check box. Maximum 8 DS1820/DS18S20 devices can be connected to the bus. The ROM codes for these devices will be stored in the **ds1820_rom_codes** array.

The DS1820/DS18S20 devices can be accessed using the **Maxim DS1820/DS18S20 Temperature Sensors Functions**.

6.15 Setting the Two Wire Bus Interface

The **Two Wire Interface** configuration can be specified by clicking on the corresponding  node of the CodeWizardAVR selection tree.



The screenshot shows the 'TWI (I2C) Settings' dialog box. It has a title bar 'TWI (I2C) Settings'. Inside, there is a checked checkbox 'Two Wire Enabled'. Below it is a 'Mode:' label followed by a dropdown menu showing 'TWI Master'. At the bottom, there is a 'Bit Rate:' label followed by a text box containing '100' and a 'kHz' label.

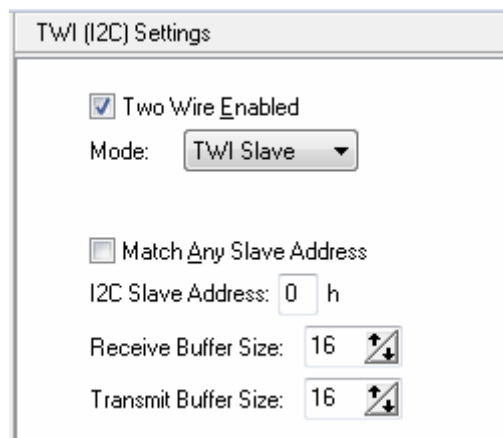
The AVR chip's Two Wire interface can be enabled by checking the **Two Wire Enabled** check box. One of the two operating modes can be selected:

- **TWI Master**
- **TWI Slave**.

In **TWI Master** mode the **Bit Rate** list box allows to specify maximum frequency of the pulses on the SCL Two Wire bus line. This value will be passed to the `twi_master_init` function (`twi.h`), called for initialization, and will affect the value of the **TWBR** register.

When operating in **TWI Master** mode the `twi_master_trans` function from `twi.h` must be used for bus communication.

In **TWI Slave** mode the following options are available:



The screenshot shows the 'TWI (I2C) Settings' dialog box in Slave mode. It has a title bar 'TWI (I2C) Settings'. Inside, there is a checked checkbox 'Two Wire Enabled'. Below it is a 'Mode:' label followed by a dropdown menu showing 'TWI Slave'. Further down is an unchecked checkbox 'Match Any Slave Address'. Below that is an 'I2C Slave Address:' label followed by a text box containing '0' and an 'h' label. At the bottom, there are two labels: 'Receive Buffer Size:' followed by a text box containing '16' and a spin button, and 'Transmit Buffer Size:' followed by a text box containing '16' and a spin button.

The **Slave Address** edit box sets the 7 bit slave address of the Two Wire serial bus unit. This address must be specified in hexadecimal and will be used to initialize the bits 1..7 of the **TWAR** register.

Checking the **Match Any Slave Address** check box, enables the slave to acknowledge for any slave address issued by the master.

The sizes of the **Receive** and **Transmit Buffers** can be set accordingly.

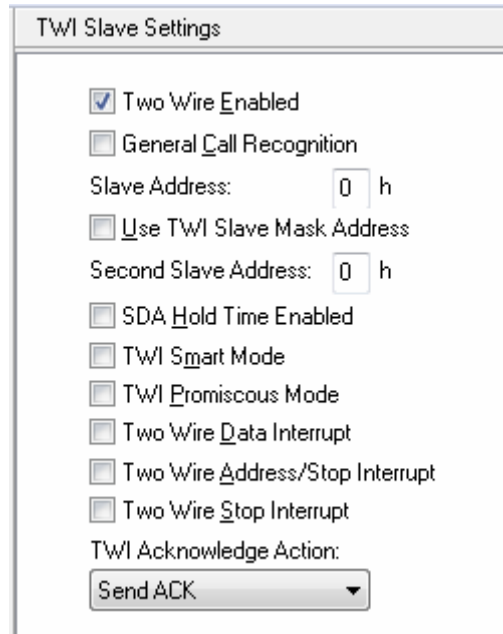
All the above mentioned options will be passed to the `twi_slave_init` function (`twi.h`), called for initialization.

The CodeWizardAVR will also generate code for the `twi_rx_handler` and `twi_tx_handler` functions used for TWI slave reception and transmission.

An example of usage for these functions can be found in the chapter **4.13.2 Two Wire Interface Functions for Slave Mode Operation**.

6.16 Setting the Two Wire Bus Slave Interface for the ATtiny20/40 chips

The **Two Wire Interface** slave configuration for the ATtiny20/40 chips can be specified by clicking on the corresponding  node of the CodeWizardAVR selection tree.



TWI Slave Settings

☒ Two Wire Enabled

☐ General Call Recognition

Slave Address: 0 h

☐ Use TWI Slave Mask Address

Second Slave Address: 0 h

☐ SDA Hold Time Enabled

☐ TWI Smart Mode

☐ TWI Promiscuous Mode

☐ Two Wire Data Interrupt

☐ Two Wire Address/Stop Interrupt

☐ Two Wire Stop Interrupt

TWI Acknowledge Action:

Send ACK

The AVR chip's Two Wire Slave interface can be enabled by checking the **Two Wire Enabled** check box.

If the **General Call Recognition** check box is checked the general call recognition logic is enabled and bit 0 of the TWSA register will be set.

The **Slave Address** edit box sets the slave address of the Two Wire serial bus unit. This address must be specified in hexadecimal and will be used to initialize the bits 1..7 of the TWSA register.

If the **Use TWI Slave Mask Address** option is enabled, the contents of bits 1..7 of the TWSAM register will be used to mask (disable) the corresponding bits in the TWSA register. If the mask bit is one, the address match between the incoming address bit and the corresponding bit in TWSA is ignored. In other words, masked bits will always match.

If the **Use TWI Slave Mask Address** option is disabled, the contents of bits 1..7 of the TWSAM register will be used as a second slave address. In this mode, the slave will match on two unique addresses, one in TWSA register and the other in TWSAM register.

The **Second Slave Address** or **Slave Mask Address** edit box sets the contents of bits 1..7 of the TWSAM register. The value must be specified in hexadecimal.

The **SDA Hold Time Enabled** option specifies if the internal hold time on SDA with respect to the negative edge on SCL must be generated.

If the **TWI Smart Mode** option is enabled, the TWI slave enters Smart Mode, where the TWI Acknowledge Action is sent immediately after the TWI data register (TWSD) has been read.

When the **TWI Promiscuous Mode** option is enabled, the address match logic of the TWI slave responds to all received addresses, ignoring the contents of the TWSA and TWSAM registers.

The **Two Wire Data Interrupt** option enables the generation of an interrupt when a data byte has been successfully received in the TWSD register, i.e. no bus errors or collisions have occurred during the operation.

The **Two Wire Address/Stop Interrupt** option enables the generation of an interrupt when the slave detects that a valid address has been received, a transmit collision or a STOP condition have been detected on the bus.

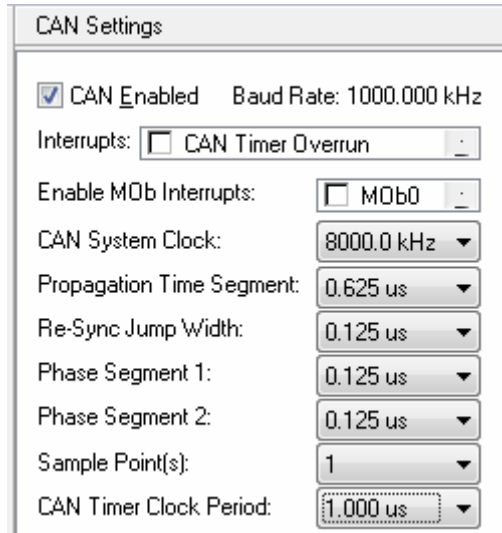
The **Two Wire Stop Interrupt** option enables the generation of an interrupt when a STOP condition has been detected on the bus.

The **TWI Acknowledge Action** list box specifies which action will be performed when a valid command has been written to TWCMD0 and TWCMD1 bits of the TWSCR register, or when the TWSD data register has been read after a data byte has been received from the master.

More details about the TWI Slave Interface can be found in the ATtiny 20 datasheet.

6.17 Setting the CAN Controller

The **CAN Interface** configuration can be specified by clicking on the corresponding  node of the CodeWizardAVR selection tree.



The AVR chip's CAN interface can be enabled by checking the **CAN Enabled** check box. The **Interrupts** list box allows enabling/disabling the following interrupts generated by the CAN controller:

- **CAN Timer Overrun** interrupt, serviced by the `can_timer_isr` function
- **General Errors** (bit error, stuff error, CRC error, form error, acknowledge error) interrupt, serviced by the `can_isr` function
- **Frame Buffer Full** interrupt, serviced by the `can_isr` function
- **MOB Errors** interrupt, serviced by the `can_isr` function
- **Transmit** completed OK interrupt, serviced by the `can_isr` function
- **Receive** completed OK interrupt, serviced by the `can_isr` function
- **Bus Off** interrupt, serviced by the `can_isr` function
- **All** interrupts, except Timer Overrun, serviced by the `can_isr` function

The **Enable MOB Registers** list box allows for individual enabling/disabling of the CAN Message Object registers.

The **Enable MOB Interrupts** list box allows for enabling/disabling the interrupts generated by individual Message Object registers.

The **Highest Interrupt Priority MOB** list box allows selecting the Message Object register that has the highest interrupt priority.

The **CAN System Clock** list box allows selecting the frequency of the CAN controller system clock.

The **Propagation Time Segment** list box allows for compensation of physical delay times within the network. The duration of the propagation time segment must be twice the sum of the signal propagation time on the bus line, the input comparator delay and the output driver delay.

The **Re-Sync Jump Width** list box allows for compensation of phase shifts between clock oscillators of different bus controllers, by controller re-synchronization on any relevant signal edge of the current transmission.

The **Phase Segment 1** and **Phase Segment 2** list boxes allow for compensation of phase edge errors.

The **Sample Point(s)** list box allows selecting the number of times (1 or 3) the bus is sampled.

The **CAN Timer Clock Period** list box allows selecting the period of the CAN timer clock pulses.

The **CAN Baud Rate** is calculated based on the durations of the **CAN System Clock**, **Propagation Time Segment**, **Phase Segment 1** and **Phase Segment 2** parameters.

If the CAN Baud Rate value is correct its value is displayed in black color, otherwise it is displayed in red and must be corrected by modifying the above mentioned parameters.

6.18 Setting the ATmega169/329/3290/649/6490 LCD Controller

The configuration of the **LCD Controller** built in the ATmega169/329/3290/649/6490 chips can be specified by clicking on the corresponding **LCD** node of the CodeWizardAVR selection tree.

The screenshot shows the 'LCD Controller Settings' dialog box. It contains the following settings:

- ☒ **LCD Enabled**
- ☐ **LCD Low Power Waveform**
- ☐ **LCD Frame Complete Interrupt**
- Duty Cycle:** Static
- Bias:** Static
- Clock Source:** System
- Frame Rate:** 50 Hz
- Frame Rate Error:** 2.3%
- Used Segments:** SEG0:12
- Contrast Control:** 2.60V
- Drive Time:** 300 us

The ATmega169V/L on chip LCD controller can be enabled by checking the **LCD Enabled** check box. By checking the **LCD Low Power Waveform** check box, the low power waveform will be outputted on the LCD pins. This allows reducing the power consumption of the LCD.

If the **LCD Frame Complete Interrupt** check box is checked, the LCD controller will generate an interrupt at the beginning of a new frame. In low power waveform mode this interrupt will be generated every second frame. The frame complete interrupt will be serviced by the `lcd_sof_isr` function.

The **LCD Duty Cycle** list box selects one of the following duty cycles: Static, 1/2, 1/3 or 1/4.

The **LCD Bias** list box selects the 1/3 or 1/2 bias. Please refer to the documentation of the LCD manufacturer for bias selection.

The **Clock Source** list box selects the system clock or an external asynchronous clock as the LCD controller clock source.

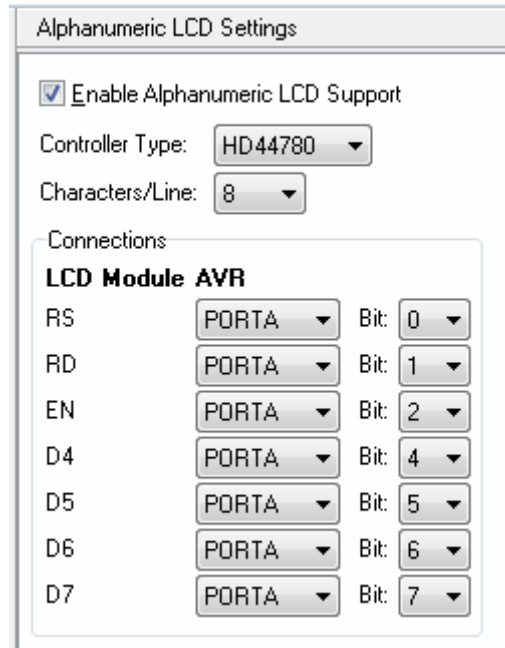
The **Frame Rate** spin edit allows specifying the LCD frame rate. The LCD Frame Rate Register (LCDFRR) is initialized based on the frequency of the clock source and the obtainable frame rate, that is as close as possible to the one that was specified.

The **Frame Rate Error** is calculated based on the specified **Frame Rate** and the real one obtained from LCDFRR.

The **Used Segments** list box setting determine the number of port pins used as LCD segment drivers. The **Contrast Control** list box specifies the maximum voltage on LCD segment and common pins **VLCD**. The **VLCD** range is between 2.60 and 3.35 Vcc.

6.19 Setting the Alphanumeric LCD

The I/O port allocation for the **LCD Functions for displays with up to 2x40 characters** can be configured by clicking on the **Alphanumeric LCD**  node of the CodeWizardAVR selection tree.



The dialog box titled "Alphanumeric LCD Settings" contains the following configuration options:

- ☒ **Enable Alphanumeric LCD Support**
- Controller Type:** HD44780 (dropdown)
- Characters/Line:** 8 (dropdown)
- Connections** (group box)
 - LCD Module AVR**
 - RS: PORTA (dropdown), Bit: 0 (dropdown)
 - RD: PORTA (dropdown), Bit: 1 (dropdown)
 - EN: PORTA (dropdown), Bit: 2 (dropdown)
 - D4: PORTA (dropdown), Bit: 4 (dropdown)
 - D5: PORTA (dropdown), Bit: 5 (dropdown)
 - D6: PORTA (dropdown), Bit: 6 (dropdown)
 - D7: PORTA (dropdown), Bit: 7 (dropdown)

The **Enable Alphanumeric LCD Support** check box activates the configuration specified for the *alcd.h* library functions.

The **Controller Type** option selects the alphanumeric LCD controller to be used:

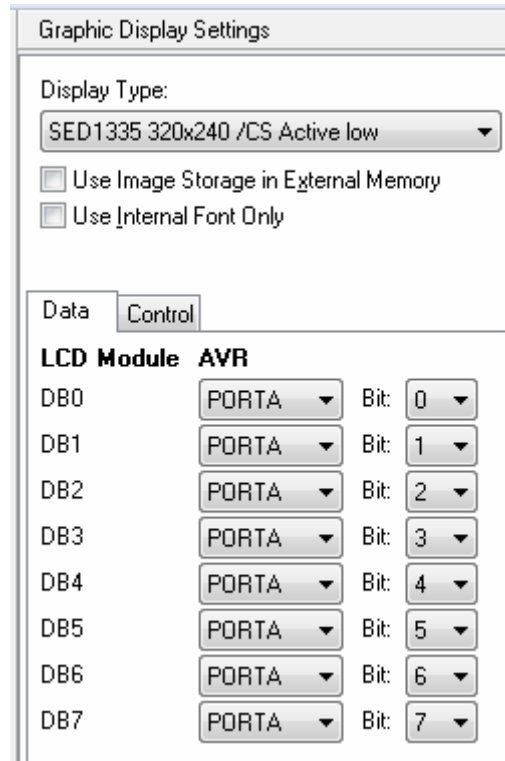
- Hitachi HD44780 or compatible
- Samsung KS0073
- Solomon Systech SSD1803, used in Electronic Assembly's www.lcd-module.de DIP203 display modules.

The **Characters/Line** list box allows to specify the number of characters per line supported by the LCD module.

The connections between the LCD module and the AVR I/O ports can be specified individually for each signal in the **Connections** group box.

6.20 Setting the Graphic Display

The I/O port allocation for the **Graphic Display Functions** can be configured by clicking on the **Graphic Display**  node of the CodeWizardAVR selection tree.



The dialog box titled "Graphic Display Settings" contains the following elements:

- Display Type:** A dropdown menu showing "SED1335 320x240 /CS Active low".
- ☐ **Use Image Storage in External Memory**
- ☐ **Use Internal Font Only**
- Data** and **Control** tabs. The **Data** tab is selected.
- LCD Module AVR** table:

LCD Module	AVR
DB0	PORTA Bit: 0
DB1	PORTA Bit: 1
DB2	PORTA Bit: 2
DB3	PORTA Bit: 3
DB4	PORTA Bit: 4
DB5	PORTA Bit: 5
DB6	PORTA Bit: 6
DB7	PORTA Bit: 7

The **Display Type** list box allows to select the graphic controller type and display resolution.

The **Use Image Storage in External Memory** check box specifies if additional code will be generated for functions needed to read or write data from external memory, used for graphic image storage.

The **Use Internal Font Only** check box specifies for the `glcd_init` function, that only the internal character generator of the controller is used for displaying text.

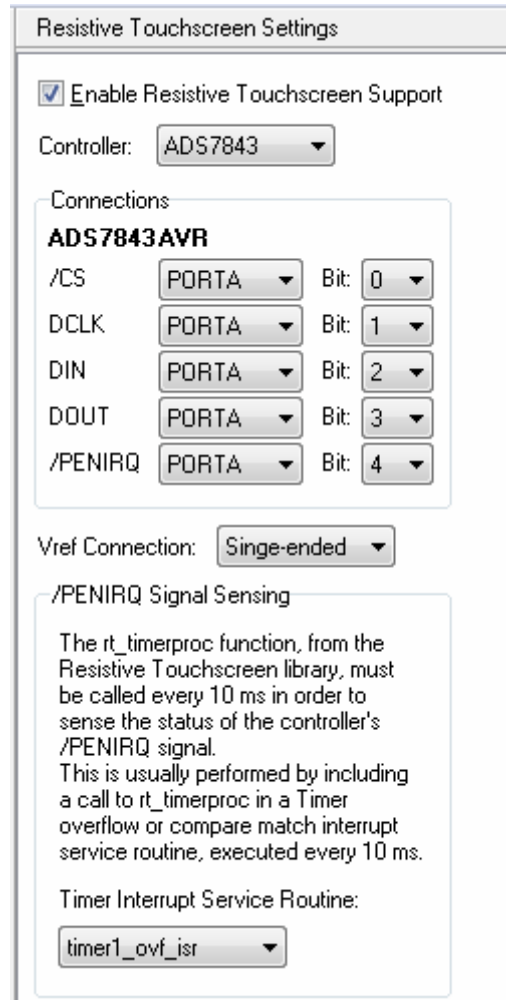
Note: This option is available only for graphic display controllers that have a built-in character generator.

The connections between the graphic display module and the AVR I/O ports can be specified individually for each signal in the **Data** and **Control** tabs.

Note: In order to obtain maximum performance, it is advised to set the display controller's **data bus** bits to match the bits with the same numbers of the same AVR I/O port.

6.21 Setting the Resistive Touchscreen Controller

The Resistive Touchscreen Controller settings can be configured by clicking on the **Resistive Touchscreen** node of the CodeWizardAVR selection tree.



The dialog box titled "Resistive Touchscreen Settings" contains the following configuration options:

- ☒ **Enable Resistive Touchscreen Support**
- Controller:** ADS7843
- Connections:**
 - ADS7843AVR**
 - /CS:** PORTA, Bit: 0
 - DCLK:** PORTA, Bit: 1
 - DIN:** PORTA, Bit: 2
 - DOUT:** PORTA, Bit: 3
 - /PENIRQ:** PORTA, Bit: 4
- Vref Connection:** Single-ended
- /PENIRQ Signal Sensing:**

The `rt_timerproc` function, from the Resistive Touchscreen library, must be called every 10 ms in order to sense the status of the controller's /PENIRQ signal. This is usually performed by including a call to `rt_timerproc` in a Timer overflow or compare match interrupt service routine, executed every 10 ms.

Timer Interrupt Service Routine:

timer1_ovf_isr

The **Enable Resistive Touchscreen Support** check box activates the configuration specified for the *rtouch.h* library functions.

The **Controller** list box selects the type of the resistive touchscreen controller.

The **Connections** between the controller and the AVR I/O ports can be specified individually for each signal.

One of the two connection modes for the touchscreen controller's voltage reference can be selected using the **Vref Connection** list box:

- **Single-ended**
- **Differential.**

In order to sense the state of the **/PENIRQ** output of the touchscreen controller, the *rt_timerproc* function (*rtouch.h*) needs to be called every 10ms by a timer overflow or compare match interrupt service routine, which can be selected using the **Timer Interrupt Service Routine** list box.

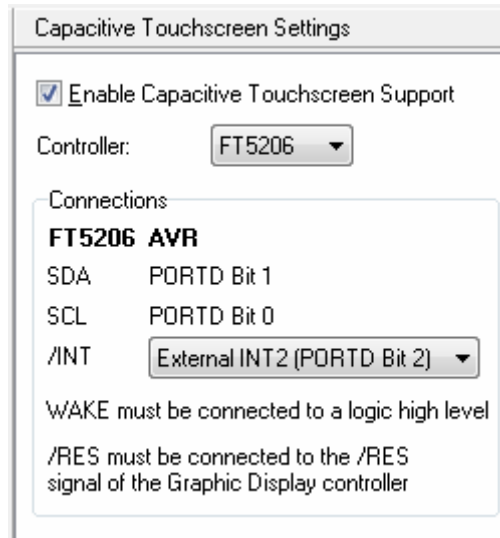
This list box is automatically updated by the CodeWizardAVR when the user enables or disables a timer interrupt.

If no interrupt service routine is selected, an error will be issued during code generation.

The user will be then prompted to go to the **Timer Settings** and configure one of the timers to generate an interrupt every 10 ms.

6.22 Setting the Capacitive Touchscreen Controller

The Capacitive Touchscreen Controller settings can be configured by clicking on the **Capacitive Touchscreen**  node of the CodeWizardAVR selection tree.



Connections	
FT5206 AVR	
SDA	PORTD Bit 1
SCL	PORTD Bit 0
/INT	External INT2 (PORTD Bit 2)

WAKE must be connected to a logic high level

/RES must be connected to the /RES signal of the Graphic Display controller

The **Enable Capacitive Touchscreen Support** check box activates the generation of code for the *ft5x06.h* library functions.

The **Controller** list box selects the type of the capacitive touchscreen controller.

The **Connections** between the controller and the AVR I/O ports can be specified individually for each signal.

Communication with the capacitive touchscreen controller is performed using the hardware **TWI**.

When detecting a touch, the controller produces a high to low transition of the **/INT** signal, which must be sensed by one of the I/O port input pins and produce an external interrupt.

This will be processed by the microcontroller, the corresponding interrupt service routine performing a call to the **ct_inthandler** function from the **Capacitive Touchscreen Functions** library, described in chapter 5.14.

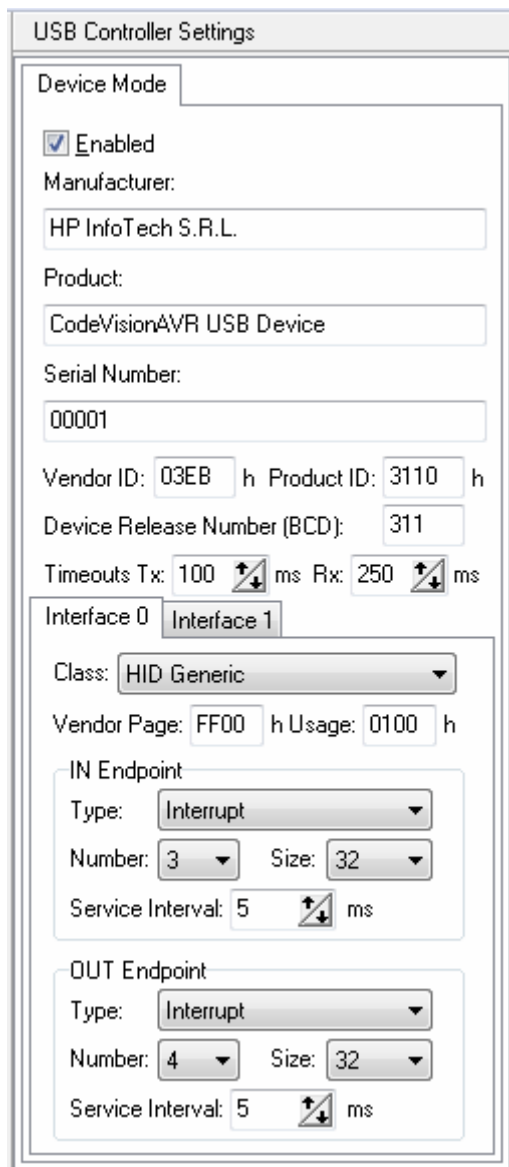
The **WAKE** signal must be connected to a logic high level. Alternatively, it can be connected to an I/O port output pin and set to low level by the user's program, forcing the controller to enter low power consumption mode.

The **/RES** signal must be connected to the corresponding **/RES (/RESET)** reset signal of the graphic display controller.

6.23 Setting the USB Controller

The configuration of the **USB Controller** can be specified by clicking on the corresponding  node of the CodeWizardAVR selection tree.

The USB library currently supports the Device, Full Speed operating mode of the USB controller.



In order to use the USB controller, the **Enabled** option must be checked.

The user must specify the following parameters, that need to be sent to the host:

- **Manufacturer** name
- **Product** name
- **Serial Number** of the product
- **Vendor ID** of the manufacturer, in hexadecimal format
- **Product ID**, in hexadecimal format
- **Device Release Number**, in BCD format.

Notes:

- In order to reduce FLASH memory usage, the **Serial Number** field may be left blank
- The **Vendor ID** and **Product ID** values must match the ones from the Windows **.inf** file used when installing the driver for the USB device.

The **Timeouts Tx**, respectively **RX**, fields allow to specify the transmission, respectively reception, timeouts used when communicating with the host. The values are expressed in ms.

The USB device mode library functions for non-Xmega devices, support operating a maximal number of two interfaces.

This allows for the implementation of composite USB devices, for example mouse and keyboard, using a single USB controller.

The configuration for each interface is selected by clicking on the corresponding tab:

- **Interface 0**
- **Interface 1.**

The **Class** option allows selecting the USB device class to be implemented by the Interface.

The following device classes are currently supported by the USB library:

- **CDC Virtual Serial Port**
- **HID Generic**
- **HID Keyboard**
- **HID Mouse**
- **HID Joystick.**

Notes:

- The CDC Virtual Serial Port requires the usage of both interfaces.

Interface 0 is used for RS232 control signals and **Interface 1** for data communication.

- The **HID Generic** class allows additionally specifying the **Vendor Page** and **Usage**, used in HID reports.

Each interface can have two endpoints (buffers) used for data storage in communication with the host:

- **IN Endpoint** stores the data to be transmitted by the device to the host
- **OUT Endpoint** stores the data received by the device from the host.

Notes:

- For some device classes (**HID Mouse** for example), there may be only one endpoint (IN), as the device may only send data to the host.
- Endpoint 0 is always used for **Control** type transfers.

The **Type** selection allows specifying how the data transfer with the host will be performed:

- **Isochronous** transfers have a guaranteed rate, where the host can request a specific number of bytes to transfer at defined intervals, without error correction
- **Interrupt** transfers have error correction and guaranteed maximum latency, specified by the device. When a driver has requested a data transfer, the host allows no more than the specified maximum latency, to elapse between transfer attempts
- **Bulk** transfers are the fastest, but have no guaranteed timing.

The **Number** setting specifies the endpoint to be used: 1..4.

The endpoint buffer size is specified by the **Size** setting.

The **Service Interval** setting (for **Isochronous** and **Interrupt** endpoints) is the period within which the host must reserve time for an endpoint's transaction.

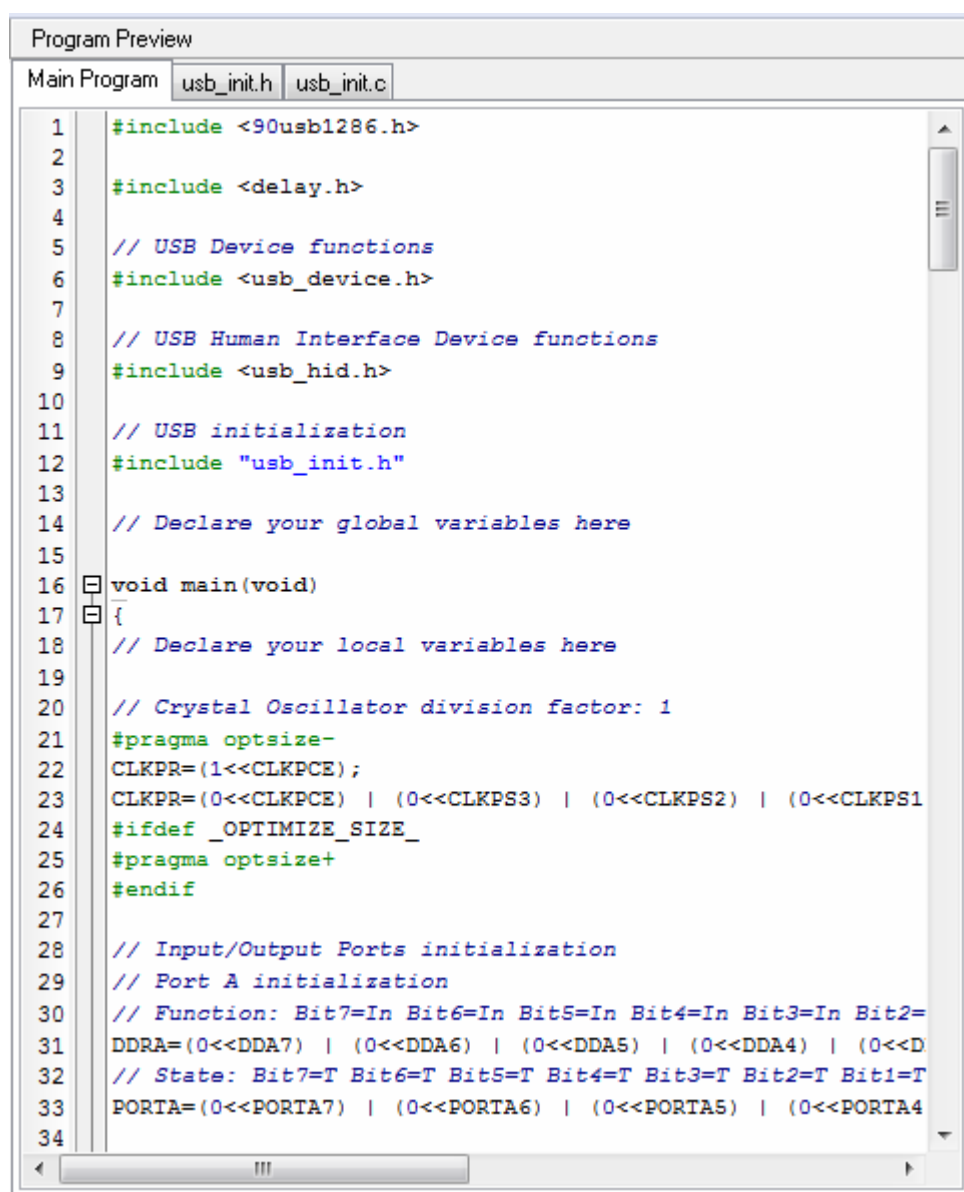
The service interval will be specified by the CodeWizardAVR in the endpoint descriptor.

After the **Program|Generate** menu command is executed, the wizard will create three source files:

- main program file
- usb_init.h
- usb_init.c.

CodeVisionAVR

The contents of each file can be viewed in the **Program Preview** window, by selecting the appropriate tab:



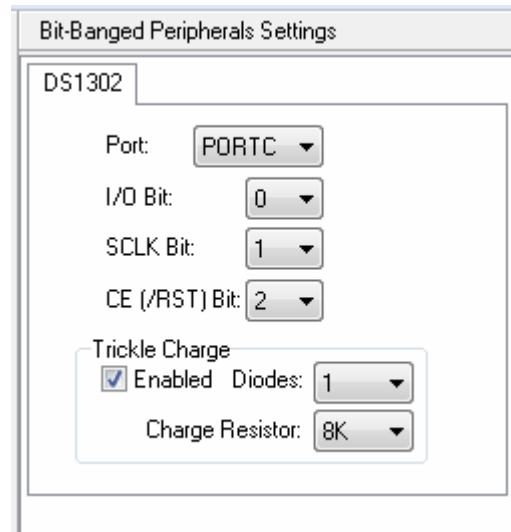
The screenshot shows the 'Program Preview' window with two tabs: 'Main Program' and 'usb_init.c'. The 'usb_init.c' tab is selected, displaying the following C code:

```
1  #include <90usb1286.h>
2
3  #include <delay.h>
4
5  // USB Device functions
6  #include <usb_device.h>
7
8  // USB Human Interface Device functions
9  #include <usb_hid.h>
10
11 // USB initialization
12 #include "usb_init.h"
13
14 // Declare your global variables here
15
16 void main(void)
17 {
18     // Declare your local variables here
19
20     // Crystal Oscillator division factor: 1
21     #pragma optimize-
22     CLKPR=(1<<CLKPCE);
23     CLKPR=(0<<CLKPCE) | (0<<CLKPS3) | (0<<CLKPS2) | (0<<CLKPS1
24     #ifdef _OPTIMIZE_SIZE_
25     #pragma optimize+
26     #endif
27
28     // Input/Output Ports initialization
29     // Port A initialization
30     // Function: Bit7=In Bit6=In Bit5=In Bit4=In Bit3=In Bit2=
31     DDRA=(0<<DDA7) | (0<<DDA6) | (0<<DDA5) | (0<<DDA4) | (0<<D
32     // State: Bit7=T Bit6=T Bit5=T Bit4=T Bit3=T Bit2=T Bit1=T
33     PORTA=(0<<PORTA7) | (0<<PORTA6) | (0<<PORTA5) | (0<<PORTA4
34
```

When creating the new CodeVisionAVR project, the wizard will automatically set the correct options for USB library functions in the **Project|Configure|Libraries|USB** menu.

6.24 Setting Bit-Banged Peripherals

The configuration of the peripherals connected using the bit-banging method can be specified by clicking on the **Bit-Banged Peripherals** node of the CodeWizardAVR selection tree. If you use the DS1302 RTC, you must select the **DS1302** tab.



The screenshot shows the 'Bit-Banged Peripherals Settings' dialog box with the 'DS1302' tab selected. The settings are as follows:

Setting	Value
Port	PORTC
I/O Bit	0
SCLK Bit	1
CE (/RST) Bit	2
Trickle Charge Enabled	☒
Diodes	1
Charge Resistor	8K

Using the **Port** list box you can specify which port is used for connecting with the DS1302. The **I/O Bit**, **SCLK Bit** and **/RST Bit** list boxes allow you to specify which port bits are used for this.

The DS1302's trickle charge function can be activated by checking the **Trickle Charge|Enabled** check box.

The number of diodes, respectively the charge resistor value, can be specified using the **Trickle Charge|Diodes**, respectively **Trickle Charge|Resistors**, list boxes.

The DS1302 device is accessed through the **Maxim DS1302 Real Time Clock Functions**.

6.25 Specifying the Project Information

The information placed in the comment header, located at the beginning of the C source file produced by CodeWizardAVR, can be specified by clicking on the **Project Information**  node of the selection tree.



The image shows a 'Project Information' dialog box. It has a title bar 'Project Information'. Inside, there are several input fields: 'Project Name:' with a text box; 'Version:' with a text box; 'Date:' with a text box containing '14/01/2013'; 'Author:' with a text box; 'Company:' with a text box; and 'Comments:' with a large text area.

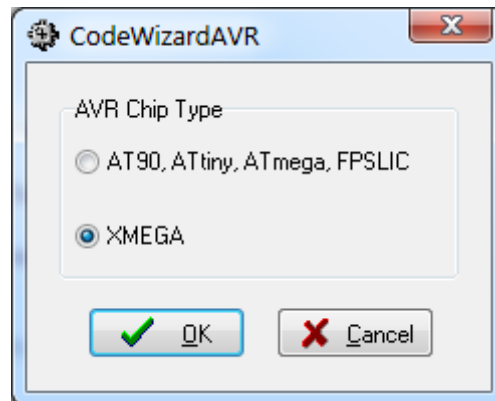
You can specify the **Project Name**, **Date**, **Author**, **Company** and **Comments**.

7. CodeWizardAVR Automatic Program Generator for the XMEGA Chips

The CodeWizardAVR Automatic Program Generator allows you to easily write all the code needed for initializing the XMEGA on-chip peripherals.

The Automatic Program Generator is invoked using the **Tools|CodeWizardAVR** menu command or by clicking on the  toolbar button.

The following dialog box will open

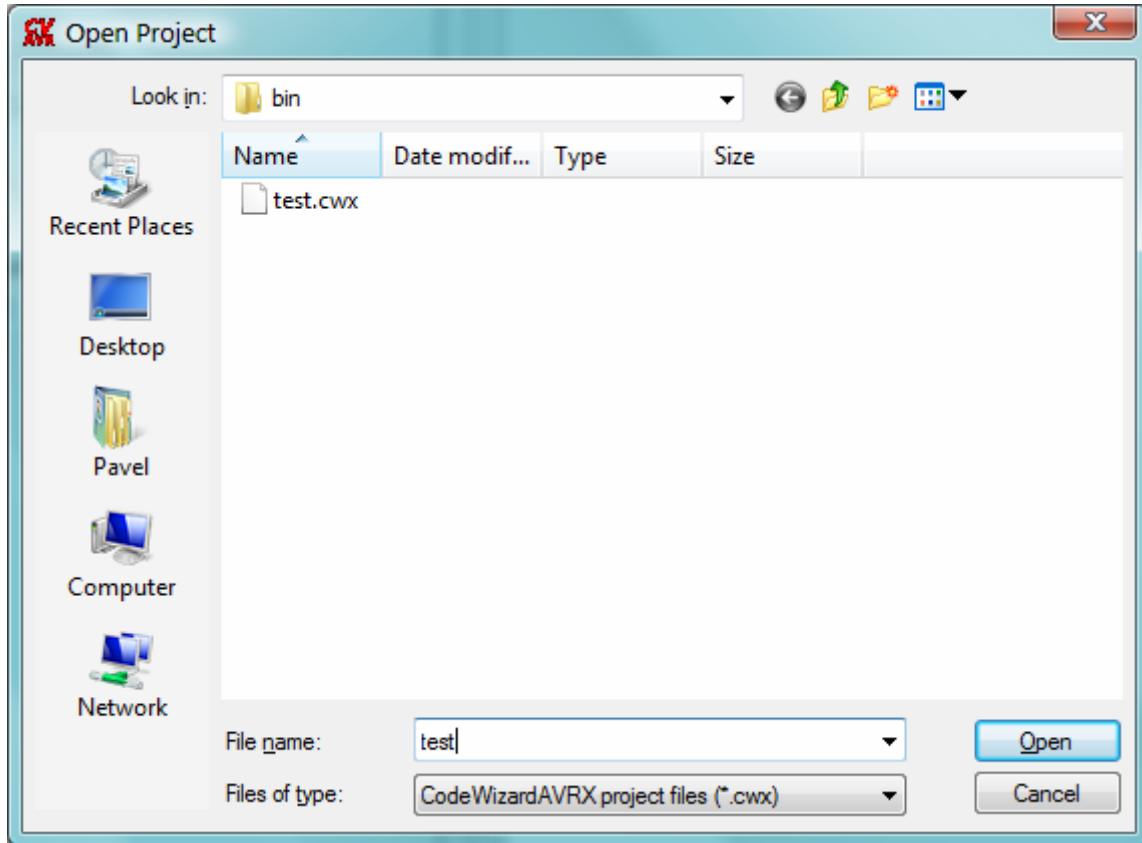


allowing to select between the AVR chip families for which automatic code generation will be performed.

CodeVisionAVR

The **File|New** menu command or the  toolbar button allow creating a new CodeWizardAVR project. This project will be named by default **untitled.cwx**.

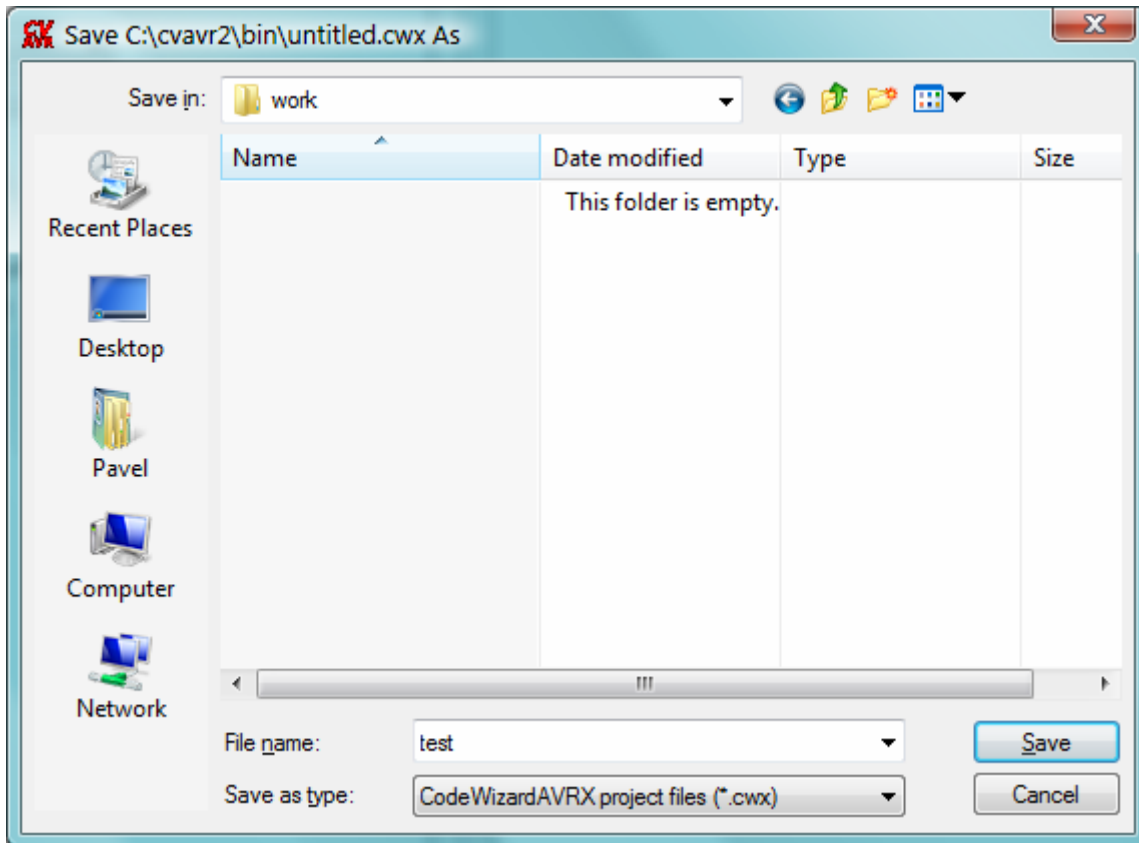
The **File|Open** menu command or the  toolbar button allow loading an existing CodeWizardAVR project:



CodeVisionAVR

The **File|Save** menu command or the  toolbar button allow saving the currently opened CodeWizardAVR project.

The **File|Save As** menu command or the  toolbar button allow saving the currently opened CodeWizardAVR project under a new name:



By selecting the **Program|Generate** menu option or by clicking on the  toolbar button, the code generated by CodeWizardAVR can be viewed in the **Program Preview** window. This may be useful when applying changes to an existing project, as portions of code generated by the CodeWizardAVR can be selected, copied to the clipboard and then pasted in the project's source files.

Note: By default the CodeWizardAVR generates initialization code even for peripherals that are not in use (disabled).

This is a safety measure to configure correctly the chip if a software reset occurred by jumping to address 0.

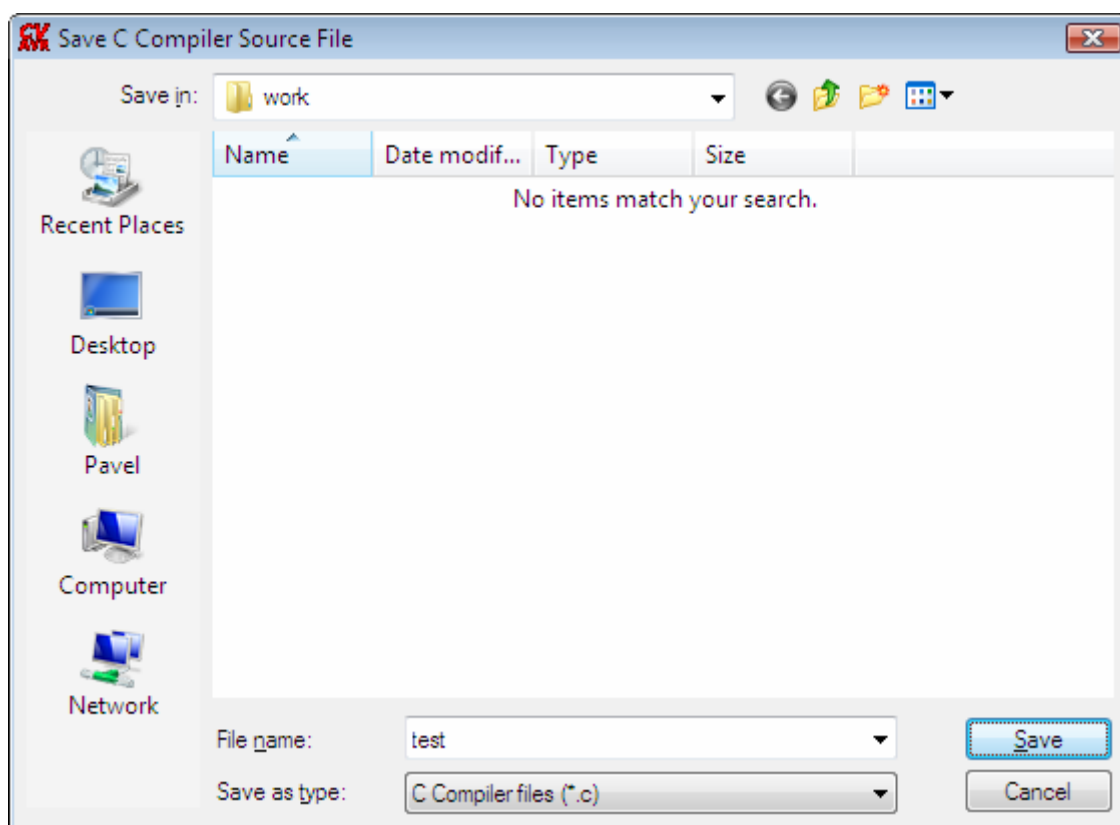
In order to reduce generated program size, this can be disabled by un-checking the **Program|Generate Code for Disabled Peripherals** menu option.

If the **Program|Generate, Save and Exit** menu option is selected or the  toolbar button is clicked, CodeWizardAVR will generate the main .C source and project .PRJ files, save the CodeWizardAVR project .CWX file and return to the CodeVisionAVR IDE.

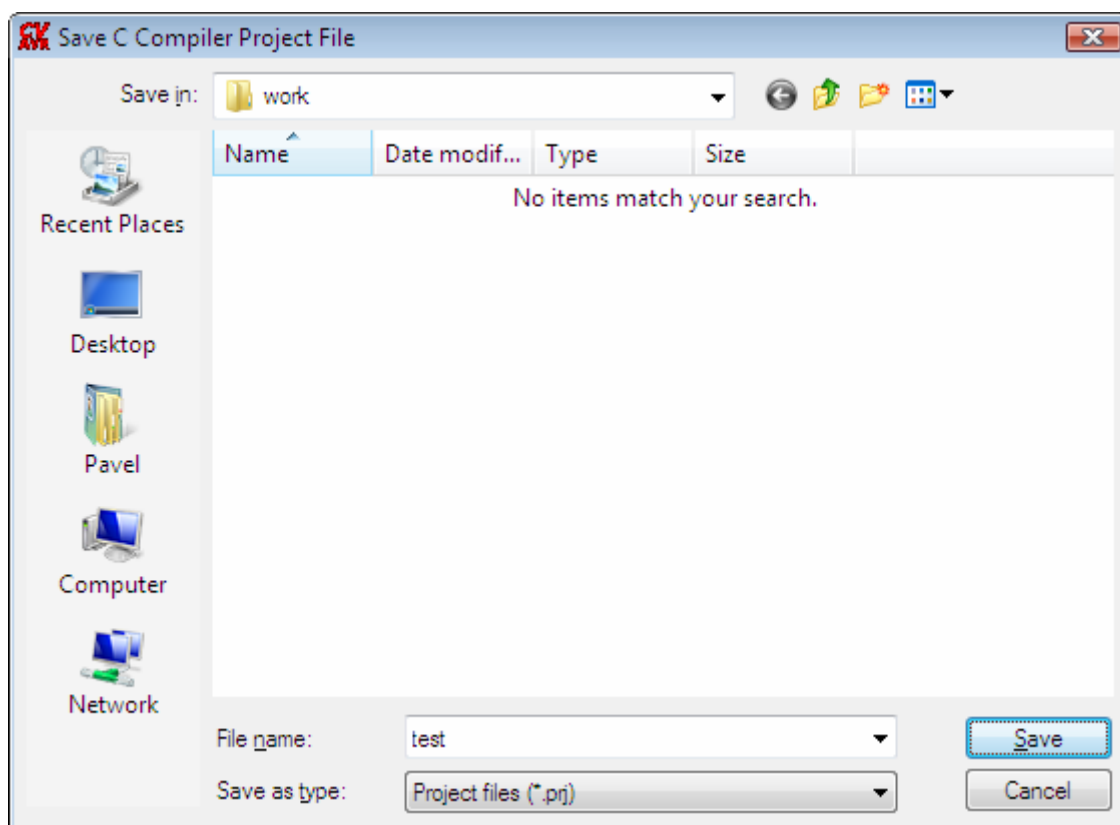
Eventual peripheral configuration conflicts will be prompted to the user, allowing him to correct the errors.

CodeVisionAVR

In the course of program generation the user will be prompted for the name of the main C file:



and for the name of the project file:



CodeVisionAVR

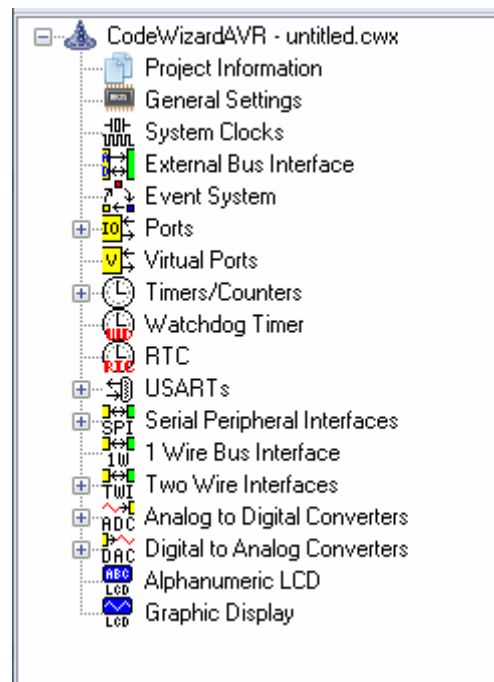
Note: When a **.prj** project for the CodeVisionAVR IDE is created, a corresponding **.cproj** project file for Atmel Studio will be created too.

This allows editing/compiling the same project in both Atmel Studio and CodeVisionAVR IDE.

Selecting the **File|Exit** menu option allows the user to exit the CodeWizardAVR without generating any program files.

By selecting the **Help|Help Topics** menu option, by pressing the F1 key or by clicking on the  toolbar button, the user can see the help topic that corresponds to the current CodeWizardAVR configuration menu.

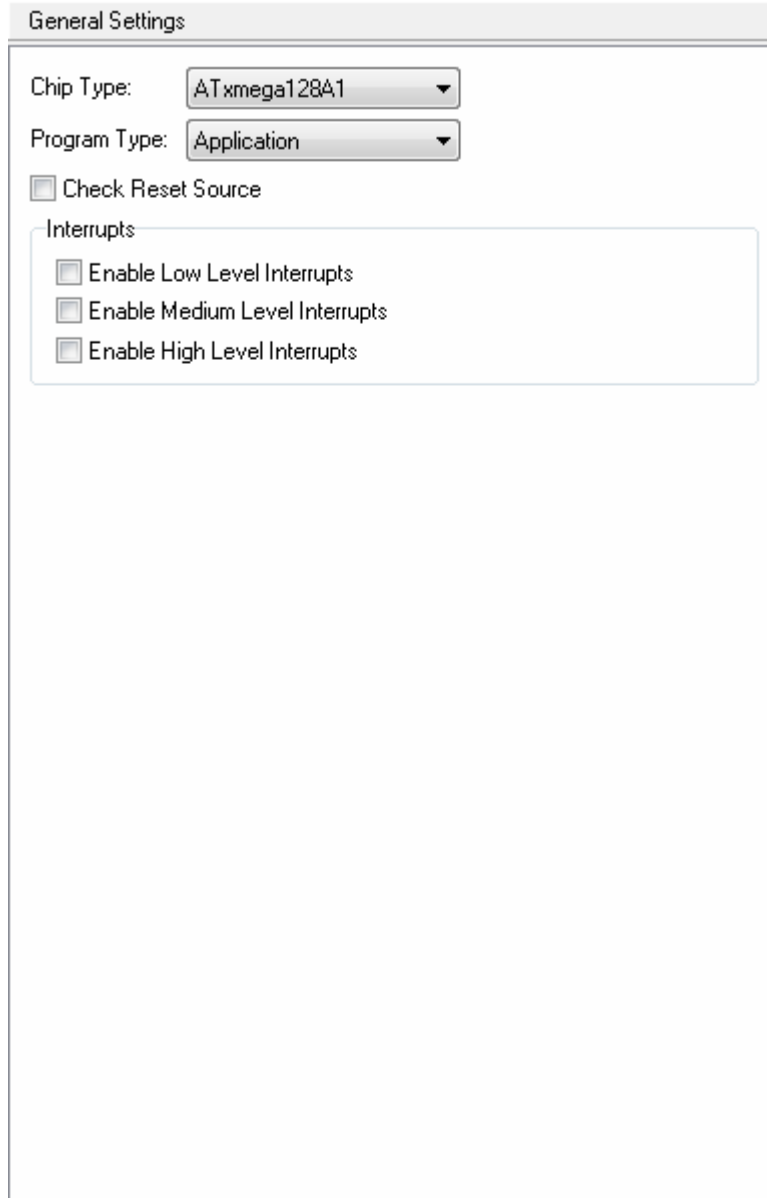
The XMEGA peripheral that needs to be configured can be selected by clicking on the corresponding node of the CodeWizardAVR selection tree.



If program code was already generated and is available for display in the Program Preview window, clicking on a peripheral node, will position the cursor at the beginning of the initialization code for that peripheral.

7.1 Setting the General Chip Options

The general chip options can be specified by clicking on the General Settings  node of the CodeWizardAVR selection tree.



The **Chip Type** list box allows to select the XMEGA device for which code will be generated.

The **Program Type** list box allows to select the type of the generated code:

- Application
- Boot Loader

The **Check Reset Source** check box enables the generation of code that allows the identification of the conditions that caused the XMEGA chip reset:

- Power-On Reset
- External Reset
- Brown Out Reset
- Watchdog Reset
- Program and Debug Interface Reset
- Software Reset.

The **Interrupts** group box allows to specify the settings for **Programmable Multi-level Interrupt Controller** initialization code generation.

The following groups of interrupts can be individually enabled or disabled:

- Low Level Interrupts
- Medium Level Interrupts
- High Level Interrupts.

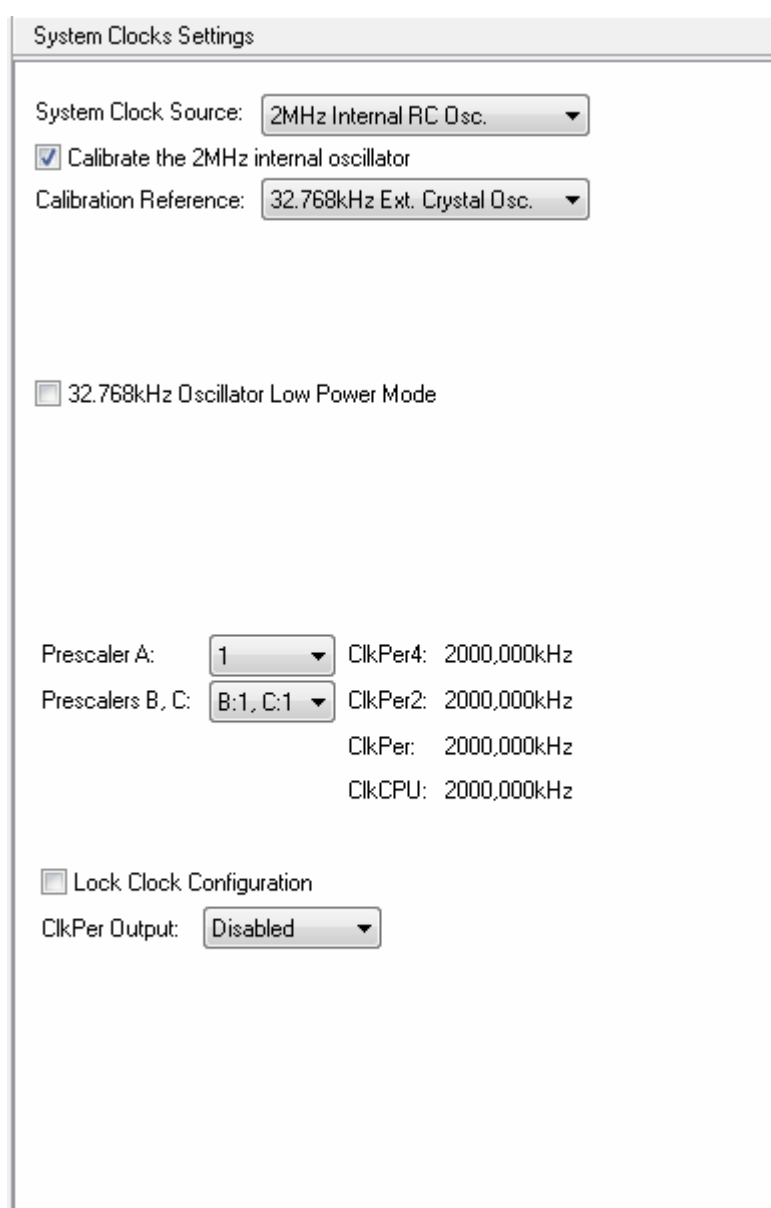
7.2 Setting the System Clocks

The various XMEGA clock source options can be specified by clicking on the **System Clocks**  node of the CodeWizardAVR selection tree.

The **System Clock Source** list box allows to select between the following options:

- 2MHz Internal RC Oscillator
- 32MHz Internal RC Oscillator
- 32.768kHz Internal RC Oscillator
- External Oscillator or Clock
- Phase Locked Loop.

If one of the internal RC oscillators is used as a system clock source, the following options are available:



The screenshot shows the 'System Clocks Settings' dialog box. It contains the following controls:

- System Clock Source:** A dropdown menu currently set to '2MHz Internal RC Osc.'.
- ☒ **Calibrate the 2MHz internal oscillator**
- Calibration Reference:** A dropdown menu currently set to '32.768kHz Ext. Crystal Osc.'.
- ☐ **32.768kHz Oscillator Low Power Mode**
- Prescaler A:** A dropdown menu set to '1'. To its right, the text 'ClkPer4: 2000,000kHz' is displayed.
- Prescalers B, C:** A dropdown menu set to 'B:1, C:1'. To its right, the text 'ClkPer2: 2000,000kHz' is displayed.
- To the right of the 'Prescalers B, C' dropdown, the text 'ClkPer: 2000,000kHz' is displayed.
- To the right of the 'Prescaler A' dropdown, the text 'ClkCPU: 2000,000kHz' is displayed.
- ☐ **Lock Clock Configuration**
- ClkPer Output:** A dropdown menu set to 'Disabled'.

If the **Calibrate Internal Oscillator** option is enabled, the internal 2MHz or 32MHz RC oscillator, used as system clock source, will be calibrated using one of the **Calibration Reference** sources:

- 32.768kHz Internal RC Oscillator
- 32.768kHz External Crystal Oscillator.

The **32.768kHz Oscillator Low Power Mode** option allows to run this external crystal oscillator with reduced voltage swing on the **TOSC2** pin.

The **Prescaler A** option allows to divide the system clock by a factor between 1 and 512, obtaining the **CikPer4** peripheral clock.

The **Prescaler B, C** option allows to divide the **CikPer4** peripheral clock by a factor of 1, 2 or 4, obtaining the **CikPer2**, **CikPer** peripheral clocks and the **CikCPU** clock used by the CPU and Non-Volatile Memory.

If the **Lock Clock Configuration** option is enabled, the system clock selection and prescaler settings are protected against further updates until the next chip reset.

The **CikPer Output** list box allows to specify if the **CikPer** signal will be fed to the bit 7 of **PORTC**, **PORTD** or **PORTE**.

If an **External Oscillator or Clock** is used as **System Clock Source**, the following specific configuration options are available:

System Clocks Settings

System Clock Source: External Osc. or Clock

External Clock: 8000,000 kHz

External Clock Source - Start-up Time:
External Clock on XTAL1 - 6 CLK

Prescaler A: 1 ClkPer4: 8000,000kHz

Prescalers B, C: B:1, C:1 ClkPer2: 8000,000kHz

ClkPer: 8000,000kHz

ClkCPU: 8000,000kHz

☐ External Clock Source Failure Monitor

☐ Lock Clock Configuration

ClkPer Output: Disabled

The **External Clock** option specifies the value of the external clock frequency in kHz.

The **External Clock Source - Start-up Time** list box allows to select the type of external clock source: external clock signal, crystal or ceramic resonator, and its start-up time.

If the **External Clock Source Failure Monitor** option is enabled, the device will perform the following actions if the external clock stops:

- switch to the 2MHz internal oscillator, independently of any clock system lock setting, by resetting the **System Clock Selection Register** to its default value
- reset the **Oscillator Control Register** to its default value
- Set the **External Clock Source Failure Detection Interrupt Flag** in the **XOSC Failure Detection Register**
- Issue a **Non-Maskable Interrupt (NMI)**.

If a **Phase Locked Loop (PLL)** is used as **System Clock Source**, the following specific configuration options are available:

The screenshot shows the 'System Clocks Settings' dialog box. At the top, 'System Clock Source' is set to 'Phase Locked Loop'. Below it, 'Calibrate the 2MHz internal oscillator' is checked, and 'Calibration Reference' is set to '32.768kHz Ext. Crystal Osc.'. There is an unchecked checkbox for '32.768kHz Oscillator Low Power Mode'. A section titled 'Phase Locked Loop' contains 'Clock Source' set to '2MHz Internal Osc.', 'Multiplication Factor' set to '20', and a calculated 'Frequency' of '40,000,000MHz'. Below this, 'Prescaler A' is '1', and 'Prescalers B, C' is 'B:4, C:1'. To the right, calculated frequencies are shown: 'ClkPer4: 40000,000kHz', 'ClkPer2: 10000,000kHz', 'ClkPer: 10000,000kHz', and 'ClkCPU: 10000,000kHz'. At the bottom, 'Lock Clock Configuration' is unchecked, and 'ClkPer Output' is 'Disabled'.

The **Clock Source** list box allows to select one of the following clocks for the **PLL**:

- 2MHz Internal RC Oscillator
- 32MHz Internal RC Oscillator divided by 4
- External Oscillator or Clock.

For the the two internal RC oscillators, we can find the specific calibration options, that were explained previously.

The **Multiplication Factor** list box allows to select a factor between 1 and 31, by which the **PLL** will multiply its clock source frequency.

If an **External Oscillator or Clock** is selected as **PLL** clock source, we can find the specific options, that were explained previously:

The screenshot shows the 'System Clocks Settings' dialog box. The 'System Clock Source' is set to 'Phase Locked Loop'. The 'External Clock' is set to '8000,000 kHz'. The 'External Clock Source - Start-up Time' is set to 'External Clock on XTAL1 - 6 CLK'. The 'Phase Locked Loop' section is expanded, showing 'Clock Source' set to 'External Osc. or Clock', 'Multiplication Factor' set to '4', and 'Frequency' set to '32,000,000MHz'. The 'Prescaler A' is set to '1', resulting in 'ClkPer4: 32000,000kHz'. The 'Prescalers B, C' are set to 'B:4, C:1', resulting in 'ClkPer2: 8000,000kHz', 'ClkPer: 8000,000kHz', and 'ClkCPU: 8000,000kHz'. The 'External Clock Source Failure Monitor' and 'Lock Clock Configuration' checkboxes are unchecked. The 'ClkPer Output' is set to 'Disabled'.

The **System Clocks** initialization is performed by the:

void system_clocks_init(void)

function generated by the CodeWizardAVR.

7.3 Setting the External Bus Interface

The **External Bus Interface (EBI)** program generation options can be specified by clicking on the **External Bus Interface** node of the CodeWizardAVR selection tree.

External Bus Interface Settings

Memory Type and Connection

- ☒ EBI Disabled
- ☐ SDRAM 3 P
- ☐ SRAM 3 P, ALE1 mux. A7:0/A15:8
- ☐ SRAM 3 P, ALE1, ALE2 mux.
- ☐ LPC 2 P, ALE1 mux. A7:0/D7:0
- ☐ LPC 2 P, ALE1, ALE2 mux.
- ☐ LPC 3 P, ALE1 mux. A7:0/D7:0

The check boxes from the **Memory Type and Connection** group allow to specify the **EBI** operating mode and kind of external RAM connected to the chip.

CodeVisionAVR

Depending on the **EBI** operating mode, additional tabs are displayed for the configuration of the **CS0...CS3** chip select signals:

External Bus Interface Settings

Memory Type and Connection

☐ EBI Disabled ☐ SDRAM 3 P

☒ SRAM 3 P, ALE1 mux. A7:0/A15:8

☐ SRAM 3 P, ALE1, ALE2 mux.

☐ LPC 2 P, ALE1 mux. A7:0/D7:0

☐ LPC 2 P, ALE1, ALE2 mux.

☐ LPC 3 P, ALE1 mux. A7:0/D7:0

CS0 CS1 CS2 CS3

☒ Enabled

Base Address: 0 h

Address Space Size: 64k Bytes

SRAM Wait State: 0.000 us

The **Enable** check box activates the usage of the corresponding **CSn** chip select signal.

The **Base Address** represents the starting address, in hexadecimal, of the **Address Space** for which the chip select signal becomes active.

The **Address Space Size** list box allows to specify the address range size for which the chip select signal is active.

The **SRAM Wait State** list box allows inserting additional wait states when accessing slow external memory.

Specific options can be set if **SDRAM** chips are connected to the XMEGA chip:

External Bus Interface Settings

Memory Type and Connection

☐ EBI Disabled ☒ SDRAM 3 P

☐ SRAM 3 P, ALE1 mux. A7:0/A15:8

☐ SRAM 3 P, ALE1, ALE2 mux.

☐ LPC 2 P, ALE1 mux. A7:0/D7:0

☐ LPC 2 P, ALE1, ALE2 mux.

☐ LPC 3 P, ALE1 mux. A7:0/D7:0

SDRAM CS3

Row Bits: 11 Bits

Column Bits: 8 Bits

CAS Latency: 0.063 us

Mode Register Delay: 0.000 us

Row Cycle Delay: 0.000 us

Row to Pre-charge Delay: 0.000 us

Row to Column Delay: 0.000 us

Write Recovery Delay: 0.000 us

Exit Self Refresh Delay: 0.000 us

Initialization Delay: 0.000 us

Refresh Period: 1.000 us

☐ SDRAM Self Refresh

These options are described in detail in Atmel's **XMEGA A Manual** in the **EBI - External Bus Interface** chapter.

Note: All the necessary code for **EBI** setup will be automatically added by the compiler in the startup initialization that is executed immediately after the chip reset. There is no need for the programmer to write his own code for this purpose.

CodeVisionAVR

When **SDRAM** is used as external memory and a different clock source is used instead of the internal 2MHz oscillator, it is necessary to execute the function that configures the system clocks **before** the **EBI** setup sequence, which will ensure that correct timing is used for later **SDRAM** access by the startup code.

This can be achieved by using the `__reset` attribute applied to the clock initialization function:

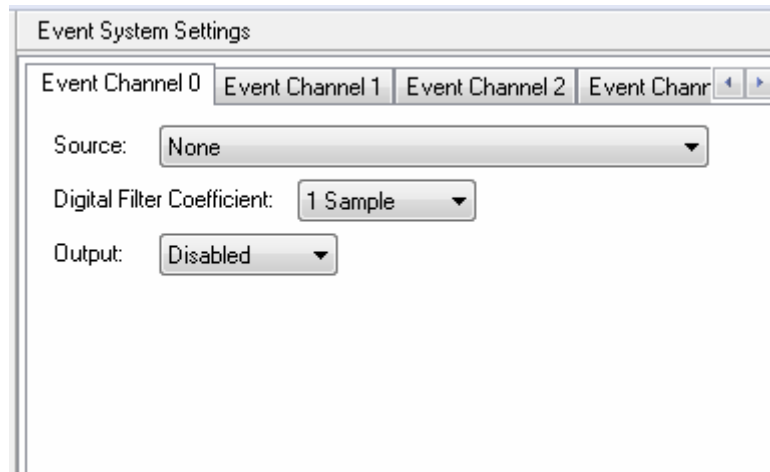
```
__reset void system_clocks_init(void)
{
    // Initialization code ...
}
```

The code generated by the CodeWizardAVR for XMEGA chips, automatically handles such situations.

7.4 Setting the Event System

The XMEGA Event System can be configured by clicking on the **Event System**  node of the CodeWizardAVR selection tree.

The following options are available:



The **Event Channel Source** list box allow to select the events that will trigger the corresponding channel.

The **Digital Filter Coefficient** option allows to specify the length of digital filtering used. Events will be passed through to the event channel, only when the event source has been active and sampled with the same level, for the specified number of peripheral clock cycles.
The **Event Channel 0 Output** list box allows to specify if the signal triggered by **Event Channel 0** will be fed to the bit 7 of **PORTC**, **PORTD** or **PORTE**.

Additional **Event System** specific options are present in the CodeWizardAVR configuration pages for each XMEGA peripheral.

The **Event System** initialization is performed by the:

```
void event_system_init(void)
```

function generated by the CodeWizardAVR.

7.5 Setting the Input/Output Ports

The XMEGA Input/Output Ports can be configured by clicking on the **Ports** and **PORTn**  nodes of the CodeWizardAVR selection tree.

The following options are available for configuring each bit of an I/O port:

The **Direction** list box specifies if the pin associated with the I/O port bit will be an input or output. The input/output data on the port pin can be **Inverted** by enabling this option. The **Limit Output Slew Rate** option will enable slew rate limiting on the corresponding output pin.

The **Output/Pull Configuration** list box allows to specify the corresponding configurations for the port pin.

Output configurations can be:

- Totempole
- Wired OR
- Wired AND.

Pull configurations can be:

- None
- Bus keeper
- Pull down, if the pin is an input
- Pull up, if the pin is an input.

The **Input/Sense Configuration** list box allows to specify how the pin, configured as input, can trigger port interrupts and events.

The **Interrupt 0**, respectively **Interrupt 1**, group boxes allow to individually enable/disable port interrupt 0, respectively port interrupt 1, triggering by each pin.

For both **Interrupt 0** and **Interrupt 1**, the enabled state and priority can be specified by the corresponding **Interrupt Level** list boxes.

The **OUT** group box allows to individually set the values of each bit of the port output register, written during initialization.

The **Input/Output Ports** initialization is performed by the:

void ports_init(void)

function generated by the CodeWizardAVR.

7.6 Setting the Virtual Ports

The XMEGA Virtual Ports can be configured by clicking on the **Virtual Ports**  node of the CodeWizardAVR selection tree.

The following options are available:



Virtual Ports Settings	
VPORT0 Mapping:	PORTA ▼
VPORT1 Mapping:	PORTB ▼
VPORT2 Mapping:	PORTC ▼
VPORT3 Mapping:	PORTD ▼

The **VPORT0 Mapping**, **VPORT1 Mapping**, **VPORT2 Mapping** and **VPORT3 Mapping** list boxes allow to select which I/O port, mapped in the extended I/O memory space, will be mapped virtually to the I/O memory space, allowing it to be accessed using more efficient IN and OUT instructions.

The **Virtual Ports** initialization is performed by the:

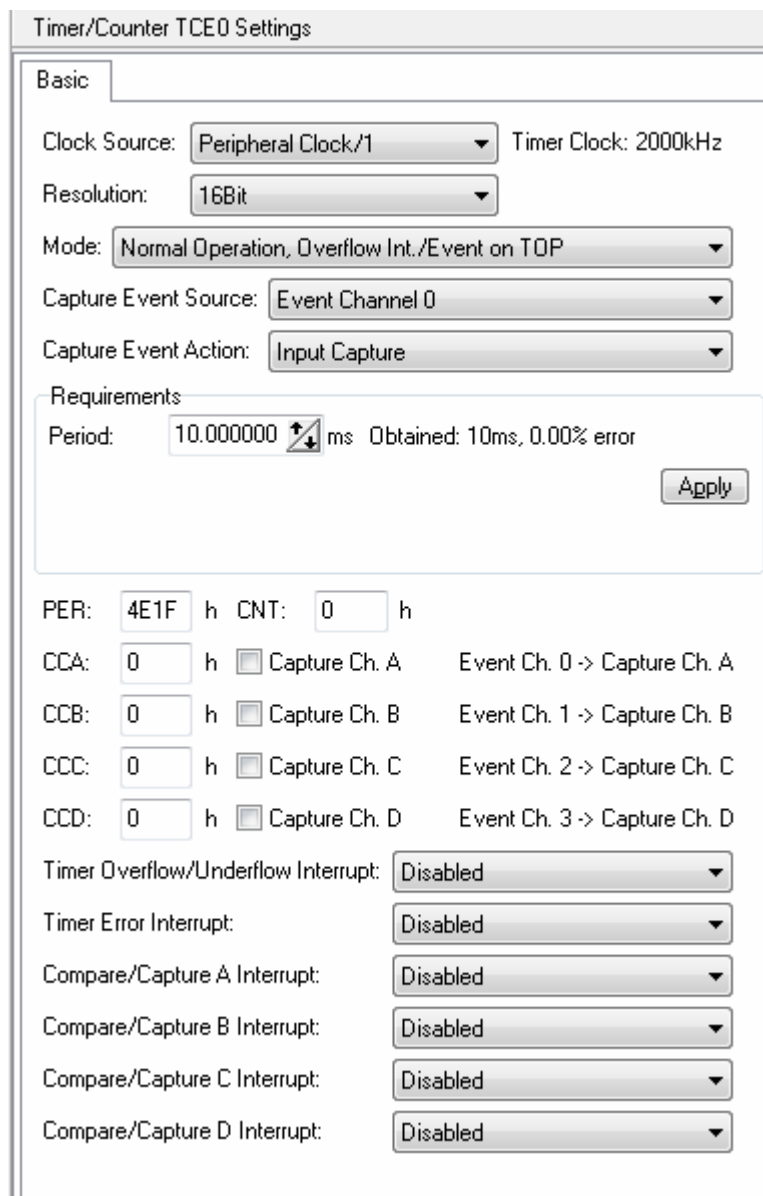
```
void vports_init(void)
```

function generated by the CodeWizardAVR.

7.7 Setting the Timers/Counters

The XMEGA Timers/Counters can be configured by clicking on the **Timers/Counters** and **TCn**  nodes of the CodeWizardAVR selection tree.

The Timer/Counter can be activated by selecting a **Clock Source**:



The clock source can be the **Peripheral Clock** divided by a factor between 1 and 1024 or an event from **Event Channels** 0 to 7.

The **Resolution** list box allows to select one of the following options:

- 16Bit
- 16Bit, with High Resolution Extension enabled
- 8Bit.

The **Mode** list box allows to select one of the following Timer/Counter operating modes:

- Normal Operation
- Frequency Waveform Generation
- Single Slope Pulse Width Modulation (PWM) Generation
- Dual Slope PWM Generation.

In **Normal** operating mode, the timer can capture an event specified by the **Capture Event Action** option.

The **Capture Event Source** option specifies the capture source for **Capture Channel A (CCA)**. The event sources for the rest of the capture channels: **CCB**, **CCC** and **CCD** are the next **Event Channels** in ascending order, as can be seen from the above example picture.

Each **Capture Channel** can be enabled using the corresponding **Capture Ch. A**, **Capture Ch. B**, **Capture Ch. C** or **Capture Ch. D** check boxes.

The initial values of the **CCA**, **CCB**, **CCC** and **CCD** capture channel registers can be specified using the corresponding edit controls.

The **Requirements** group box allows the user to specify the desired timer **Period** in ms.

Pressing the **Apply** button will perform automatic timer configuration (**Clock Source** and **PER** period register values), so that the required timer period will be obtained for a given **Peripheral Clock** value.

The initial value for the Timer/Counter CNT register can be specified using the corresponding edit control.

The Timer/Counter can generate several types of interrupts:

- Timer Overflow/Underflow Interrupt
- Timer Error Interrupt
- Compare/Capture A Interrupt
- Compare/Capture B Interrupt
- Compare/Capture C Interrupt
- Compare/Capture D Interrupt.

Each type of interrupt can be individually enabled and its priority set, using the corresponding list boxes.

In **Frequency Waveform Generation** mode the following specific options are available:

Timer/Counter TCE0 Settings

Basic **Advanced Waveform Extension**

Clock Source: Peripheral Clock/1 Timer Clock: 2000kHz

Resolution: 16Bit

Mode: Frequency Waveform Gen., Overflow Int./Event on TOP

Requirements

Frequency: 10.000000 kHz Obtained: 10kHz, 0.00% error

Apply

PER: 0 h CNT: 0 h

CCA: 63 h ☒ Compare Ch. A Output

CCB: 0 h

CCC: 0 h

CCD: 0 h

Timer Overflow/Underflow Interrupt: Disabled

Timer Error Interrupt: Disabled

Compare/Capture A Interrupt: Disabled

Compare/Capture B Interrupt: Disabled

Compare/Capture C Interrupt: Disabled

Compare/Capture D Interrupt: Disabled

The **Requirements** group box allows the user to specify the desired timer **Frequency** in kHz. Pressing the **Apply** button will perform automatic timer configuration (**Clock Source** and **CCA** register values), so that the required timer frequency will be obtained for a given **Peripheral Clock** value.

Note: The **PER** register is not used in this operating mode.

If the **Compare Ch. A Output** option is enabled, the corresponding waveform generation (WG) output will be toggled on each compare match between the **CNT** and **CCA** registers. The duty cycle of this signal will be 50%.

In **Single Slope PWM Generation** and **Double Slope PWM Generation** modes the following specific options are available:

Timer/Counter TCE0 Settings

Basic Advanced Waveform Extension

Clock Source: Peripheral Clock/1 Timer Clock: 2000kHz

Resolution: 16Bit

Mode: Dual Slope PWM Gen., Overflow Int./Event on TOP

Requirements

Period: 10.000000 ms Obtained: 10ms, 0.00% error

Duty Cycle Ch. A: 0.00 % Duty Cycle Ch. B: 25.00 % Apply

Duty Cycle Ch. C: 50.00 % Duty Cycle Ch. D: 75.00 %

PER: 2710 h CNT: 0 h

CCA: 0 h ☐ Compare Ch. A Output

CCB: 9C4 h ☐ Compare Ch. B Output

CCC: 1388 h ☐ Compare Ch. C Output

CCD: 1D4C h ☐ Compare Ch. D Output

Timer Overflow/Underflow Interrupt: Disabled

Timer Error Interrupt: Disabled

Compare/Capture A Interrupt: Disabled

Compare/Capture B Interrupt: Disabled

Compare/Capture C Interrupt: Disabled

Compare/Capture D Interrupt: Disabled

The **Requirements** group box allows the user to specify the desired timer **Period** in ms and the **Duty Cycles** for the **Compare/Capture Channels** A, B, C and D.

Pressing the **Apply** button will perform automatic timer configuration (**Clock Source**, **PER**, **CCA**, **CCB**, **CCC** and **CCD** register values), so that the required timer period and duty cycles will be obtained for a given **Peripheral Clock** value.

If the **Compare Ch. A Output** option is enabled, the corresponding waveform generation (WG) output will be activated for compare matches between the **CNT** and **CCA** registers.

The same applies for the **Compare Ch. B Output**, **Compare Ch. C Output** and **Compare Ch. D Output** options and the corresponding **CCB**, **CCC** and **CCD** registers.

CodeVisionAVR

When operating in waveform generation modes the Timer/Counter can also use the **Advanced Waveform Extension (AWeX)** that provides some additional features. It can be accessed by selecting the **Advanced Waveform Extension** tab:

Timer/Counter TCE0 Settings

Basic Advanced Waveform Extension

☐ Enable Pattern Generation ☐ Lock Configuration Registers

Dead Time Insertion

Low Side Dead Time: 0 ClkPer Cycles Duration: 0.000 us

High Side Dead Time: 0 ClkPer Cycles Duration: 0.000 us

☐ Enable Dead Time Insertion for Compare Channel A Output

☐ Enable Dead Time Insertion for Compare Channel B Output

☐ Enable Dead Time Insertion for Compare Channel C Output

☐ Enable Dead Time Insertion for Compare Channel D Output

Dead Time Insertion PORTE Override

☐ Common Waveform Channel Mode Enabled

☐ CCA DTI Low Side -> OUT.0 ☐ CCC DTI Low Side -> OUT.4

☐ CCA DTI High Side -> OUT.1 ☐ CCC DTI High Side -> OUT.5

☐ CCB DTI Low Side -> OUT.2 ☐ CCD DTI Low Side -> OUT.6

☐ CCB DTI High Side -> OUT.3 ☐ CCD DTI High Side -> OUT.7

Fault Protection

Input Sources

☐ Event Channel 0 ☐ Event Channel 4

☐ Event Channel 1 ☐ Event Channel 5

☐ Event Channel 2 ☐ Event Channel 6

☐ Event Channel 3 ☐ Event Channel 7

Action: None (Fault protection disabled)

Restart Mode: Latched Mode

☒ On-Chip Debug Break Request Triggers a Fault Condition

The **Dead Time Insertion** group box contains the settings for the **Dead Time Insertion (DTI)** unit, that enables the generation of the non-inverted **Low Side (LS)** and inverted **High Side (HS)** waveforms on the corresponding I/O port pins.

Dead times are inserted between **LS** and **HS** switching. These can be specified using the **Low Side Dead Time** and **High Side Dead Time** edit boxes.

Dead time insertion can be individually activated for each compare channel, using the corresponding **Enable Dead Time Insertion for Compare Channel Output** option.

The **Dead Time Insertion PORT Override** group box allows to individually specify which **LS** or **HS** waveforms will be outputted on the I/O port associated with the timer.

If the **Common Waveform Channel Mode Enabled** option is activated, the **Compare Channel A** waveform will be used as input for all the dead time generators. The waveforms of **Compare Channels B, C and D** will be ignored.

CodeVisionAVR

If the **Enable Pattern Generation** option is activated, the pattern generator extension will be used to produce a synchronized bit pattern on the I/O port associated with the timer. The **DTI** unit is not activated in this case, its registers will be used by the pattern generator.

The pattern can be specified using the **Pattern Generation** check boxes. This value will be used to initialize the **DTIHS** register.

The **Pattern Generation PORT Override** check boxes allow to specify to which I/O port pins, the waveform generated by the **Compare Channel A** will be outputted when an UPDATE condition is set by the waveform generation mode. This value will be used to initialize the **DTILS** register.

The screenshot shows the 'Timer/Counter TCE0 Settings' dialog box with the 'Advanced Waveform Extension' tab selected. The 'Basic' tab is also visible. The 'Advanced Waveform Extension' tab contains the following sections:

- Enable Pattern Generation** (checked) and **Lock Configuration Registers** (unchecked).
- Pattern Generation**: A row of 8 checkboxes labeled 7, 6, 5, 4, 3, 2, 1, 0. All are currently unchecked.
- Pattern Generation PORTE Override**: A group of 8 checkboxes labeled CCA WG Out -> OUT.0 through OUT.7. All are currently unchecked.
- Fault Protection**: A group containing:
 - Input Sources**: A group of 8 checkboxes labeled Event Channel 0 through Event Channel 7. All are currently unchecked.
 - Action**: A dropdown menu set to 'None (Fault protection disabled)'.
 - Restart Mode**: A dropdown menu set to 'Latched Mode'.
 - On-Chip Debug Break Request Triggers a Fault Condition** (checked).

The **Fault Protection** group box allows to specify the **Input Sources** and **Action** to be performed when a fault is detected. The fault protection being event controlled, any event from the **Event System** can be used to trigger a fault action.

The following event **Actions** are possible:

- **None**
- **Clear all Override Enable Bits** in the **OUTOVEN** register, disabling the output override on all Timer/Counter outputs
- **Clear all Direction Bits** in the I/O port **DIR** register, setting all port pins as tri-stated inputs.

The **Restart Mode** list box allows to specify how the **AWeX** and Timer/Counter can return from the fault state and restore normal operation, when the fault condition is no longer active:

- **Latched Mode** - the waveform output will remain in the fault state until the the fault condition is no longer active and the fault detection flag **FDF** in the **AWEXn.STATUS** register will be cleared by software. When both these conditions are met, the waveform will return to normal operation at the next **UPDATE** condition.
- **Cycle-by-Cycle Mode** - the waveform output will remain in the fault state until the the fault condition is no longer active. When this condition is met, the waveform will return to normal operation at the next **UPDATE** condition.

The **On-Chip Debug Break Request Triggers a Fault Condition** option specifies if an OCD break request will be treated as a fault.

The **Change Protection** option allows to prevent unintentional changes to the Timer/Counter: **CTRLA** and AWeX: **OUTOVEN**, **FDEMASK** registers.

In order to initialize enabled Timers/Counters the CodeWizardAVR generates the functions:

void tcmn_init(void)

where: *m* - is the lowercase suffix of the I/O port where the Timer/Counter is implemented
n - is the number of the Timer/Counter on the port, starting with 0.

An unused Timer/Counter of type 0 can be disabled by calling the function:

void tc0_disable(TC0_t *ptc)

where **ptc** is a pointer to the corresponding **TC0_t** structure.

Example:

```
/* TCC0 is not used, so disable it */  
tc0_disable(&TCC0);
```

An unused Timer/Counter of type 1 can be disabled by calling the function:

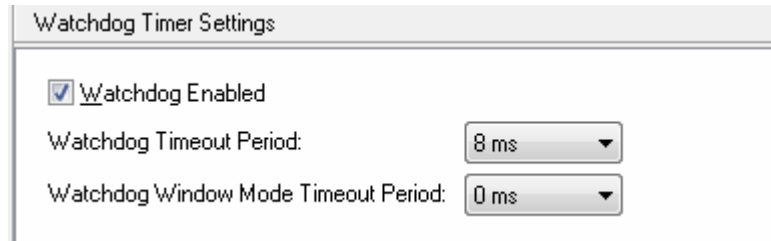
void tc1_disable(TC1_t *ptc)

where **ptc** is a pointer to the corresponding **TC1_t** structure.

7.8 Setting the Watchdog Timer

The XMEGA Watchdog Timer (WDT) can be configured by clicking on the **Watchdog Timer**  node of the CodeWizardAVR selection tree.

The following options are available:



Watchdog Timer Settings

☒ Watchdog Enabled

Watchdog Timeout Period: 8 ms ▼

Watchdog Window Mode Timeout Period: 0 ms ▼

The **Watchdog Enabled** option allows to activate the **WDT**.

The **Watchdog Timeout Period** list box allows to specify the **open window** time period *after* which the **WDT** will issue a system reset (in **Normal** and **Window** operating modes), if the application code has not reset the **WDT** using the **WDR** instruction.

The **Watchdog Window Mode Timeout Period** allows to specify the length of the **closed window** time period (in **Window** operating mode), in which if the application code uses the **WDR** instruction, to try to reset the **WDT**, the **WDT** will issue a system reset.

If the application code resets the **WDT** *after* the **closed window** time elapses, but during the **open window**, no system reset will occur.

Note: If the **Watchdog Window Mode Timeout Period** is set to 0, the **WDT** will operate in **Normal** mode.

The **WDT** initialization is performed by the:

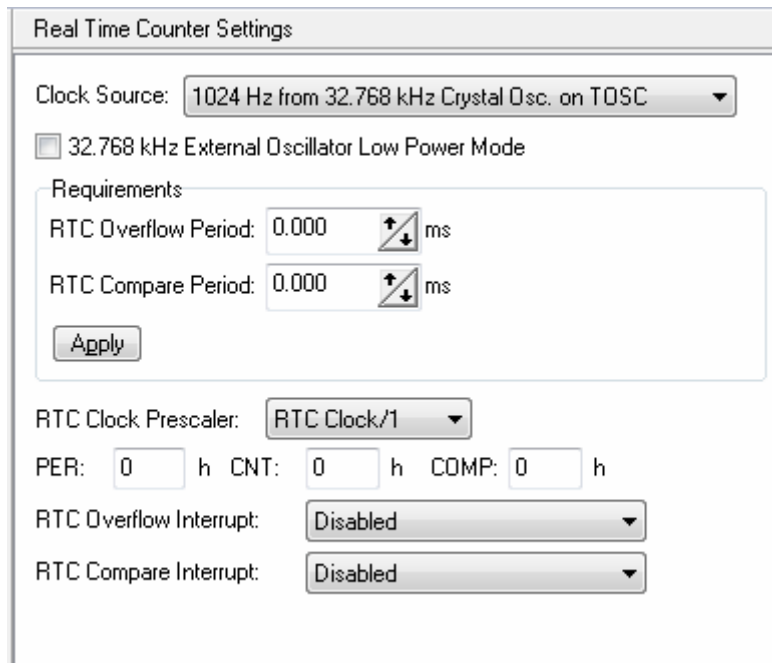
```
void watchdog_init(void)
```

function generated by the CodeWizardAVR.

7.9 Setting the 16-Bit Real Time Counter

The XMEGA 16-Bit Real Time Counter (RTC) can be configured by clicking on the **Real Time Counter**  node of the CodeWizardAVR selection tree.

The following options are available:



The dialog box titled "Real Time Counter Settings" contains the following controls:

- Clock Source:** A dropdown menu showing "1024 Hz from 32.768 kHz Crystal Osc. on TOSC".
- ☐ **32.768 kHz External Oscillator Low Power Mode**
- Requirements** group box:
 - RTC Overflow Period:** A text box with "0.000" and a spinner icon, followed by "ms".
 - RTC Compare Period:** A text box with "0.000" and a spinner icon, followed by "ms".
 - Apply** button.
- RTC Clock Prescaler:** A dropdown menu showing "RTC Clock/1".
- PER:** 0 **h** **CNT:** 0 **h** **COMP:** 0 **h**
- RTC Overflow Interrupt:** A dropdown menu showing "Disabled".
- RTC Compare Interrupt:** A dropdown menu showing "Disabled".

The **Clock Source** list box allows to select the signal that will be used as **RTC** clock:

- 1024 Hz obtained from the 32 kHz internal Ultra Low Power oscillator
- 1024 Hz obtained from the 32.768 kHz external crystal oscillator on the TOSC1 and TOSC2 pins
- 1024 Hz obtained from the 32 kHz internal RC oscillator
- 32.768 kHz obtained from the 32.768 kHz external crystal oscillator on the TOSC1 and TOSC2 pins.

If the 32.768 kHz external crystal oscillator is used, it can be configured to operate in **Low Power Mode** by checking the appropriate option.

The **RTC** can be configured automatically by specifying the **RTC Overflow** and **RTC Compare** periods and clicking on the **Apply** button from the **Requirements** group box.

This will set the optimal values for the **RTC Clock Prescaler** list box, **PER** (period) and **COMP** (compare) 16-bit registers.

The initial value for the **CNT** (count) 16-bit register can be specified in hexadecimal, using the appropriate edit box.

The **RTC** can generate two types of interrupts:

- RTC Overflow Interrupt
- RTC Compare Interrupt.

Each type of interrupt can be individually enabled and its priority set, using the corresponding list boxes.

The **RTC** initialization is performed by the:

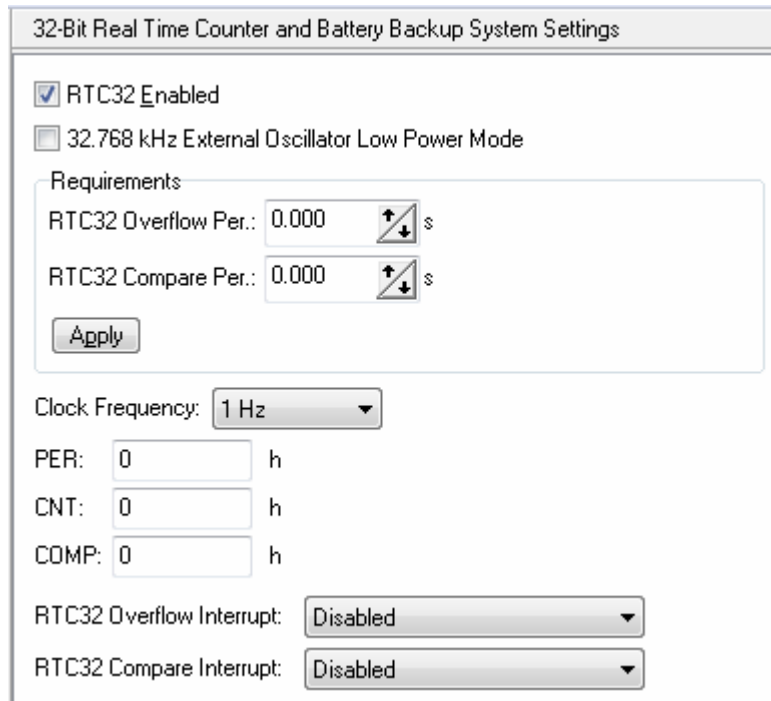
void rtcxm_init(void)

function generated by the CodeWizardAVR.

7.10 Setting the 32-Bit Real Time Counter and Battery Backup System

The XMEGA 32-Bit Real Time Counter (RTC32) and Battery Backup System can be configured by clicking on the **RTC32 and Battery Backup**  node of the CodeWizardAVR selection tree.

The following options are available:



The screenshot shows the '32-Bit Real Time Counter and Battery Backup System Settings' dialog box. It contains the following elements:

- ☒ **RTC32 Enabled**
- ☐ **32.768 kHz External Oscillator Low Power Mode**
- A group box labeled **Requirements** containing:
 - RTC32 Overflow Per.: 0.000 s (with up/down arrows)
 - RTC32 Compare Per.: 0.000 s (with up/down arrows)
 - An **Apply** button
- Clock Frequency:** 1 Hz (dropdown menu)
- PER:** 0 h
- CNT:** 0 h
- COMP:** 0 h
- RTC32 Overflow Interrupt:** Disabled (dropdown menu)
- RTC32 Compare Interrupt:** Disabled (dropdown menu)

The **RTC32 Enabled** option allows to activate the operation the 32-Bit Real Time Counter and associated Battery Backup System.

The **RTC32** can be clocked by a 1 Hz or 1024 Hz signal, selected using the **Clock Frequency** list box. This signal is obtained by dividing the output of the 32.768 kHz external crystal oscillator, which can be configured to operate in **Low Power Mode** by checking the appropriate option.

The **RTC32** can be configured automatically by specifying the **RTC32 Overflow** and **RTC32 Compare** periods and clicking on the **Apply** button from the **Requirements** group box. This will set the optimal values for the **Clock Frequency** list box, **PER** (period) and **COMP** (compare) 32-bit registers.

The initial value for the **CNT** (count) 32-bit register can be specified in hexadecimal, using the appropriate edit box.

The **RTC32** can generate two types of interrupts:

- RTC32 Overflow Interrupt
- RTC32 Compare Interrupt.

Each type of interrupt can be individually enabled and its priority set, using the corresponding list boxes.

When it is enabled, the **RTC32** initialization is performed by the:

void rtc32_battery_backup_init(void)

function generated by the CodeWizardAVR.

If the **RTC32** is disabled, the initialization is performed by the:

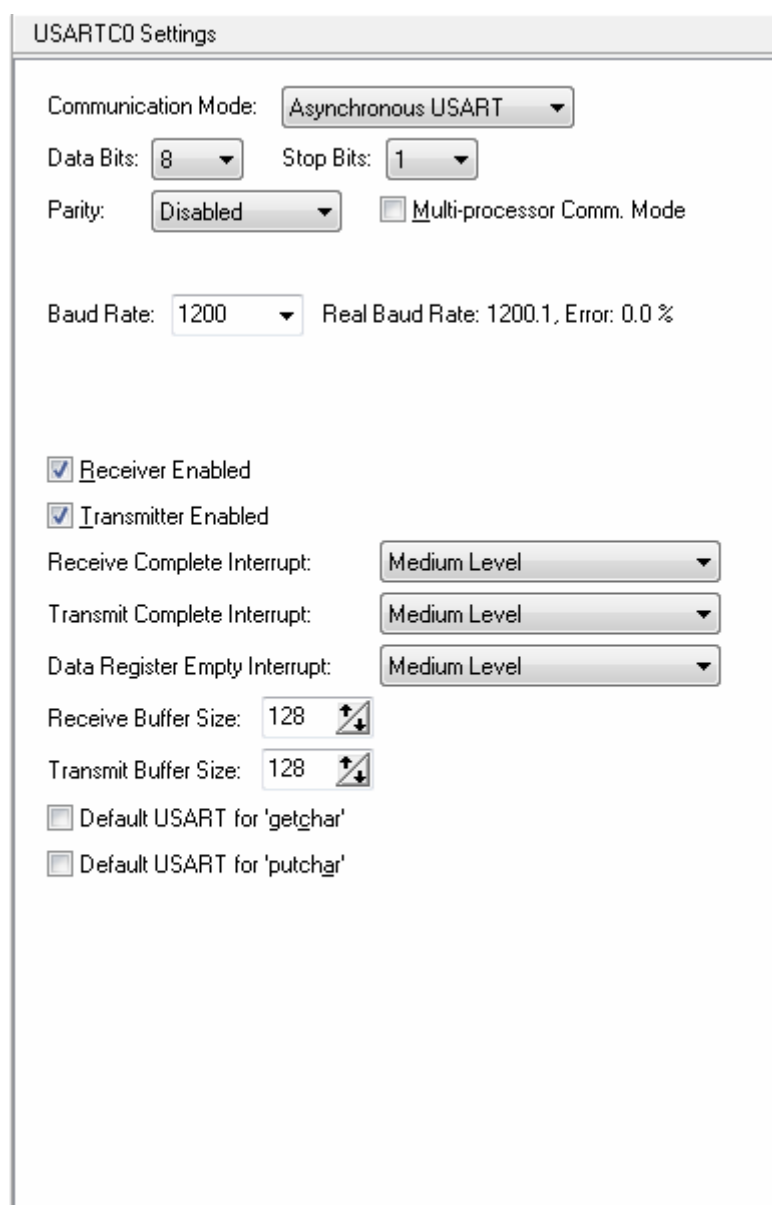
void rtc32_battery_backup_disable(void)

function.

7.11 Setting the USARTs

The XMEGA USARTs can be configured by clicking on the **USARTs** and **USARTn**  nodes of the CodeWizardAVR selection tree.

The following options are available for configuring each USART:



The screenshot shows the 'USARTC0 Settings' dialog box. It contains the following fields and options:

- Communication Mode:** A dropdown menu set to 'Asynchronous USART'.
- Data Bits:** A dropdown menu set to '8'.
- Stop Bits:** A dropdown menu set to '1'.
- Parity:** A dropdown menu set to 'Disabled'.
- Multi-processor Comm. Mode:** An unchecked checkbox.
- Baud Rate:** A dropdown menu set to '1200'.
- Real Baud Rate:** A text field showing '1200.1, Error: 0.0 %'.
- Receiver Enabled:** A checked checkbox.
- Transmitter Enabled:** A checked checkbox.
- Receive Complete Interrupt:** A dropdown menu set to 'Medium Level'.
- Transmit Complete Interrupt:** A dropdown menu set to 'Medium Level'.
- Data Register Empty Interrupt:** A dropdown menu set to 'Medium Level'.
- Receive Buffer Size:** A text field set to '128' with a spin button.
- Transmit Buffer Size:** A text field set to '128' with a spin button.
- Default USART for 'getchar':** An unchecked checkbox.
- Default USART for 'putchar':** An unchecked checkbox.

The **Communication Mode** list box allows to select one of the following operating modes:

- Asynchronous USART
- Synchronous USART
- Infrared Module (IRDA 1.4)
- Master SPI.

CodeVisionAVR

For the **Asynchronous**, **Synchronous** and **Infrared Module**, the following specific options are available:

The **Data Bits** option specifies the number of data bits in a data frame: 5 to 9.

The **Stop Bits** option specifies the number of stop bits in a data frame: 1 or 2.

The **Parity** bit in a data frame can be:

- Disabled
- Even
- Odd.

If the **Multi-processor Comm. Mode** option is enabled, a dedicated bit in the frame is used to indicate whether the frame is an address or data frame.

If the Receiver is set up to receive frames that contain 5 to 8 data bits, the first stop bit is used to indicate the frame type. If the Receiver is set up for frames with 9 data bits, the ninth bit is used for this purpose.

The **Baud Rate** list box allows to select the communication data rate.

The CodeWizardAVR automatically calculates the values for the **BSEL** and **SCALE**, for the current **Baud Rate** and **Peripheral Clock** values.

The **Real Baud Rate** and **Error** are displayed.

The Receiver, respectively Transmitter, can be activated using the **Receiver Enabled**, respectively **Transmitter Enabled** check boxes.

The USART can generate several types of interrupts:

- Receive Complete Interrupt
- Transmit Complete Interrupt
- Data Register Empty Interrupt.

Each type of interrupt can be individually enabled and its priority set, using the corresponding list boxes.

If buffered interrupt driven serial communication will be used, the sizes of the Receiver, respectively Transmitter, buffers can be specified using the **Receiver Buffer Size**, respectively **Transmitter Buffer Size** edit boxes.

In order to allow receiving, respectively transmitting data using the USART, the CodeWizardAVR will define the **getchar_usart pn** , respectively **putchar_usart pn** functions, where **p** is the I/O port letter and **n** is the USART number in the port.

One of the USARTs can be chosen as the default communication device to be used by the **getchar**, respectively **putchar**, **Standard C Input/Output Functions** by enabling the **Default USART for 'getchar'**, respectively the **Default USART for 'putchar'** options.

In this situation the standard **getchar** and **putchar** functions are redefined in the generated program.

For interrupt driven serial communication, some additional global variables will be declared during code generation.

The receiver buffer is implemented using the global array **rx_buffer_usart pn** .

The global variable **rx_wr_index_usart pn** is the **rx_buffer_usart pn** array index used for writing received characters in the buffer.

The global variable **rx_rd_index_usart pn** is the **rx_buffer_usart pn** array index used for reading received characters from the buffer by the **getchar_usart pn** function.

The global variable **rx_counter_usart pn** contains the number of characters received in **rx_buffer_usart pn** and not yet read by the **getchar_usart pn** function.

If the receiver buffers overflows the **rx_buffer_overflow_usart pn** global bit variable will be set.

CodeVisionAVR

The transmitter buffer is implemented using the global array `tx_buffer_usartpn`.

The global variable `tx_wr_index_usartpn` is the `tx_buffer_usartpn` array index used for writing in the buffer the characters to be transmitted.

The global variable `tx_rd_index_usartpn` is the `tx_buffer_usartpn` array index used for reading from the buffer the characters to be transmitted by the `putchar_usartpn` function.

If the **Infrared Module** communication mode is used, some specific options are available:

The screenshot shows the 'USARTC0 Settings' dialog box. It contains the following settings:

- Communication Mode: Infrared Module (IrDA 1.4)
- Data Bits: 8
- Stop Bits: 1
- Parity: Disabled
- Baud Rate: 57600
- Real Baud Rate: 57554.0, Error: 0.1 %
- IRCOM Receiver Pulse Length: Filtering Disabled
- IRCOM Transmitter Pulse Length: 3.258 us
- ☒ Receiver Enabled
- IRCOM Receiver Input: RX Pin
- ☒ Transmitter Enabled
- Receive Complete Interrupt: Medium Level
- Transmit Complete Interrupt: Medium Level
- Data Register Empty Interrupt: Medium Level
- Receive Buffer Size: 128
- Transmit Buffer Size: 128
- ☐ Default USART for 'getchar'
- ☐ Default USART for 'putchar'

The **IRCOM Receiver Pulse Length** option sets the filter coefficient for the IRCOM Receiver. If enabled, it represents the number of samples required for a pulse to be accepted.

The **IRCOM Transmitter Pulse Length** sets the pulse modulation scheme for the IRCOM Transmitter.

The **IRCOM Receiver Input** list box allows to select if the input of the IRCOM Receiver will be connected to the **RX** port pin or to one of the **Event System Channels** 0 to 7.

If the **Master SPI** communication mode is used, some specific options are available:

The screenshot shows the 'USARTC0 Settings' dialog box. It contains the following settings:

- Communication Mode: Master SPI (dropdown)
- SPI Mode: 0 (dropdown)
- XCK Leading Edge: Rising, XCK Trailing Edge: Falling (text)
- Sample Data: Data Setup (text)
- Data Order: MSB First (dropdown)
- Baud Rate: 100000 (dropdown), Real Baud Rate: 100000.0, Error: 0.0 % (text)
- ☒ Receiver Enabled
- ☒ Transmitter Enabled
- Receive Complete Interrupt: Medium Level (dropdown)
- Transmit Complete Interrupt: Medium Level (dropdown)
- Data Register Empty Interrupt: Medium Level (dropdown)
- Receive Buffer Size: 128 (spin box)
- Transmit Buffer Size: 128 (spin box)
- ☐ Default USART for 'getchar'
- ☐ Default USART for 'putchar'

The **SPI Mode** can be:

- Mode 0
- Mode 1
- Mode 2
- Mode 3.

The **Data Order** in the frame can be:

- MSB First
- LSB First.

For enabled **USARTs** the CodeWizardAVR generates the functions:

void usartmn_init(void)

where: *m* - is the lowercase suffix of the I/O port where the **USART** is implemented
n - is the number of the **USART** on the port, starting with 0.

An unused **USART** can be disabled by calling the function:

void usart_disable(USART_t *pu)

where **pu** is a pointer to the corresponding **USART_t** structure.

Example:

```
/* USARTC1 is not used, so disable it */  
usart_disable(&USARTC1);
```

For transmitting data the CodeWizardAVR generates the functions:

void putchar_usartmn(char c)

where: *c* - is the character to be transmitted
m - is the lowercase suffix of the I/O port where the **USART** is implemented
n - is the number of the **USART** on the port, starting with 0.

For receiving data the CodeWizardAVR generates the functions:

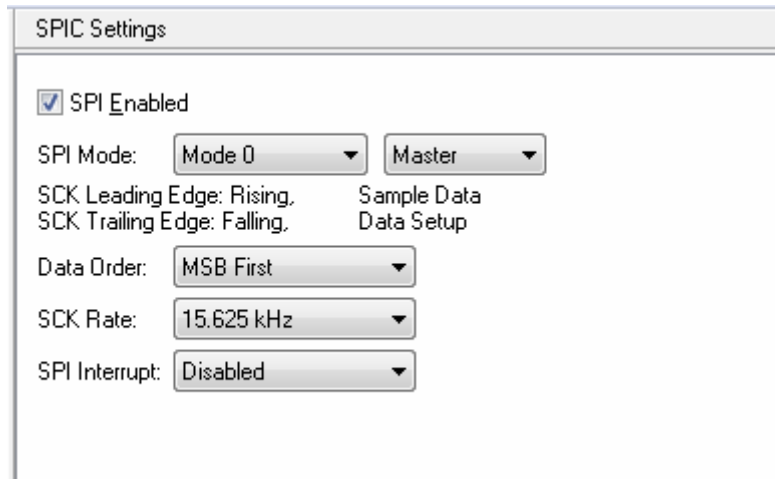
char getchar_usartmn(void)

where: *m* - is the lowercase suffix of the I/O port where the **USART** is implemented
n - is the number of the **USART** on the port, starting with 0.

7.12 Setting the Serial Peripheral Interfaces

The XMEGA Serial Peripheral Interfaces (SPI) can be configured by clicking on the **Serial Peripheral Interfaces**  nodes of the CodeWizardAVR selection tree.

The following options are available:



The image shows a dialog box titled "SPIC Settings". It contains the following controls:

- A checked checkbox labeled "SPI Enabled".
- A dropdown menu for "SPI Mode" set to "Mode 0".
- A dropdown menu for "Master/Slave" set to "Master".
- Text labels for "SCK Leading Edge: Rising," and "SCK Trailing Edge: Falling,".
- Text labels for "Sample Data" and "Data Setup".
- A dropdown menu for "Data Order" set to "MSB First".
- A dropdown menu for "SCK Rate" set to "15.625 kHz".
- A dropdown menu for "SPI Interrupt" set to "Disabled".

The **SPI Enabled** check box allows to activate the corresponding Serial Peripheral Interface.

The **SPI Mode** can be:

- Mode 0
- Mode 1
- Mode 2
- Mode 3.

The **SPI** can operate as:

- Master
- Slave.

The **Data Order** in the frame can be:

- MSB First
- LSB First.

If the **SPI** operates as a **Master**, it will generate the **SCK** clock signal for the slave(s).

The frequency of this signal, obtained by dividing the **ClkPer** peripheral clock, can be selected using the **SCK Rate** list box.

The **SPI Interrupt** can be enabled and its priority set, using the corresponding list box.

The initialization of each **SPI** peripheral is performed by the:

void spim_init(void)

functions generated by the CodeWizardAVR, where *m* is the lowercase suffix of the I/O port where the **SPI** is implemented.

If the **SPI Interrupt** is disabled, the **SPI** will operate in polled mode.

The following transmit/receive function will be generated by the CodeWizardAVR for this situation for **Master** mode:

unsigned char spim_master_tx_rx(unsigned char c)

where: *m* - is the lowercase suffix of the I/O port where the **SPI** is implemented
c - is the byte to be transmitted to the slave.

The function will return the byte received from the slave.

The **SPI** being operated in polled mode, this function will be blocking, as the state of the **SPIF** flag from the **STATUS** register will be tested in an endless loop, until one byte will be transmitted/received.

Note: The **spim_master_tx_rx** function doesn't control the **/SS** signal.

The **/SS** line must be set low in order to select the slave before calling this function.

The **SET_SPIM_SS_LOW** macro is defined by the CodeWizardAVR for this purpose, where *M* is the suffix of the I/O port where the **SPI** is implemented.

After all communication is finished on the bus, the **/SS** line must be set high in order to deselect the slave.

This is accomplished using the **SET_SPIM_SS_HIGH** macro defined by the CodeWizardAVR for this purpose, where *M* is the suffix of the I/O port where the **SPI** is implemented.

Example for **SPIC** operating as a master:

```
/* Select the SPI slave */
SET_SPIC_SS_LOW
/* Send two bytes of data to the slave */
spic_master_tx_rx(0x12);
spic_master_tx_rx(0x34);
/* Deselect the SPI slave */
SET_SPIC_SS_HIGH
```

When operating as a **Slave**, the CodeWizardAVR will generate the function:

unsigned char spim_slave_tx_rx(unsigned char c)

where: *m* - is the lowercase suffix of the I/O port where the **SPI** is implemented
c - is the byte to be transmitted to the master.

The function will return the byte received from the master.

The **SPI** being operated in polled mode, this function will be blocking, as the state of the **SPIF** flag from the **STATUS** register will be tested in an endless loop, until one byte will be transmitted/received.

In order to prevent such situations it is recommended to enable the **SPI Interrupt**.

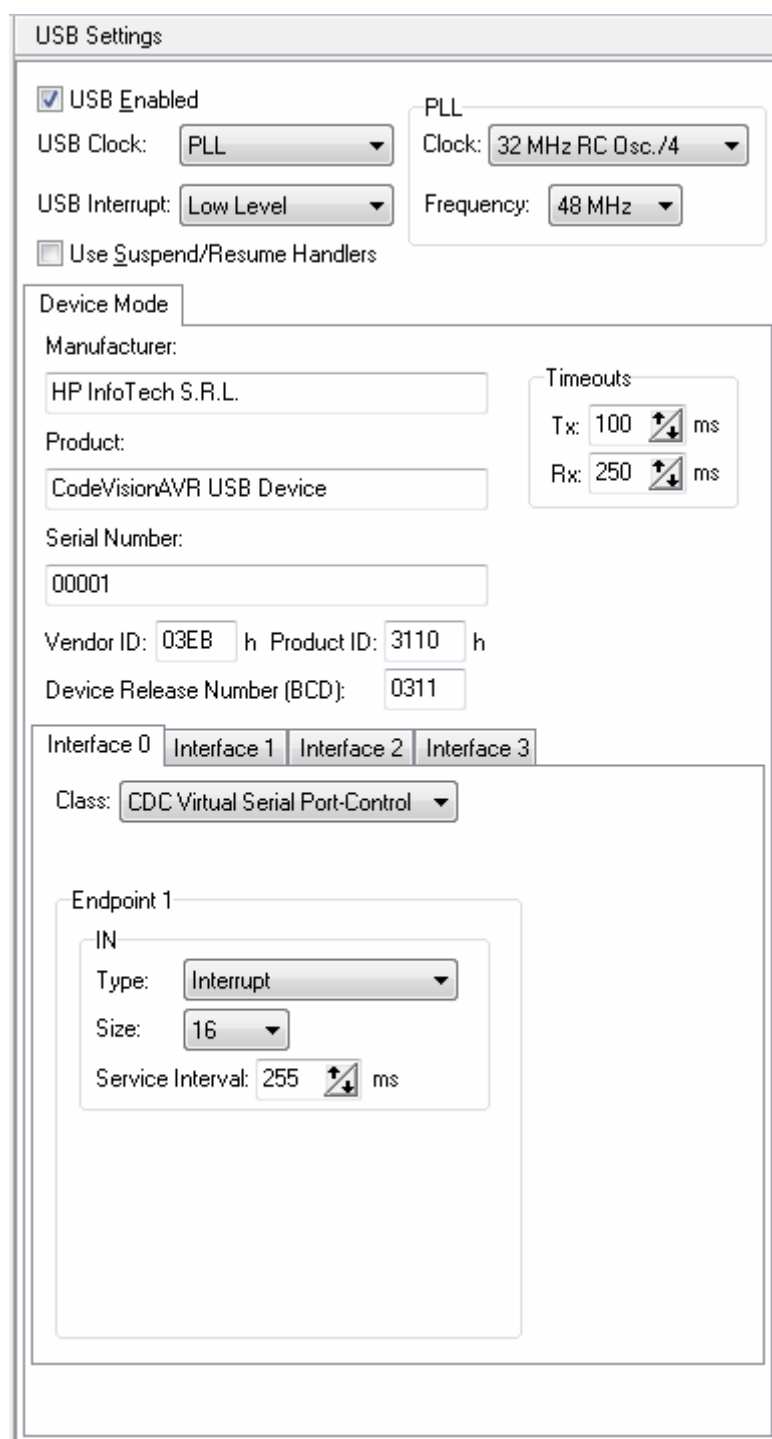
The CodeWizardAVR will then generate the **spim_isr** **SPI** interrupt service routine, where *m* is the lowercase suffix of the I/O port where the **SPI** is implemented.

Inside this function, the received data will be processed only when its received, and new data will be prepared to be transmitted, without blocking the execution of the rest of the application.

7.13 Setting the USB Interface

The configuration of the **USB Interface** controller can be specified by clicking on the corresponding  node of the CodeWizardAVR selection tree.

The USB library currently supports the Device, Full Speed operating mode of the USB controller.



The screenshot shows the 'USB Settings' dialog box. It has a title bar 'USB Settings'. Inside, there's a section with a checked checkbox 'USB Enabled'. Below it, 'USB Clock' is set to 'PLL' and 'USB Interrupt' is set to 'Low Level'. To the right, there's a 'PLL' section with 'Clock' set to '32 MHz RC Osc./4' and 'Frequency' set to '48 MHz'. Below these is an unchecked checkbox 'Use Suspend/Resume Handlers'. The 'Device Mode' section contains fields for 'Manufacturer' (HP InfoTech S.R.L.), 'Product' (CodeVisionAVR USB Device), 'Serial Number' (00001), 'Vendor ID' (03EB h), 'Product ID' (3110 h), and 'Device Release Number (BCD)' (0311). To the right of these are 'Timeouts' for 'Tx' (100 ms) and 'Rx' (250 ms). The 'Interface' section has tabs for 'Interface 0', 'Interface 1', 'Interface 2', and 'Interface 3', with 'Interface 0' selected. Below the tabs, 'Class' is set to 'CDC Virtual Serial Port-Control'. The 'Endpoint 1' section is expanded, showing 'IN' type, 'Type' set to 'Interrupt', 'Size' set to '16', and 'Service Interval' set to '255 ms'.

In order to use the USB controller, the **USB Enabled** option must be checked.

The **USB Clock** option allows to select the clock source used by the USB controller:

- Internal 32 MHz RC oscillator, calibrated and adjusted to 48 MHz using the DFLL and USB Start Of Frame
- PLL running at 48 or 96 MHz.

If the PLL is used as USB controller clock source, then its reference **Clock** can be selected as:

- Internal 2 MHz RC Oscillator
- Internal 32 MHz RC Oscillator output divided by 4
- External Oscillator or Clock.

The PLL output **Frequency** can be set to:

- 48 MHz
- 96 MHz.

The **Interrupt** option specifies the interrupt priority level used by the USB controller.

By enabling the **Use Suspend/Resume Handlers** option, special code can be generated for functions to be called when the device enters or exits the suspended state.

The user must specify the following parameters, that need to be sent to the host:

- **Manufacturer** name
- **Product** name
- **Serial Number** of the product
- **Vendor ID** of the manufacturer, in hexadecimal format
- **Product ID**, in hexadecimal format
- **Device Release Number**, in BCD format.

Notes:

- In order to reduce FLASH memory usage, the **Serial Number** field may be left blank
- The **Vendor ID** and **Product ID** values must match the ones from the Windows **.inf** file used when installing the driver for the USB device.

The **Timeouts Tx**, respectively **RX**, fields allow specifying the transmission, respectively reception, timeouts used when communicating with the host. The values are expressed in ms.

The USB device mode library functions for Xmega devices, support operating a maximal number of four interfaces.

This allows for the implementation of composite USB devices, for example virtual serial port, mouse and keyboard, using a single USB controller.

The configuration for each interface is selected by clicking on the corresponding tab:

- **Interface 0**
- **Interface 1**
- **Interface 2**
- **Interface 3.**

The **Class** option allows selecting the USB device class to be implemented by the Interface.

The following device classes are currently supported by the USB library:

- **CDC Virtual Serial Port**
- **HID Generic**
- **HID Keyboard**
- **HID Mouse**
- **HID Joystick.**

Notes:

- Up to two CDC Virtual Serial Ports: 0 and 1 are supported. Each port requires the usage of two interfaces. **Interface 0**, respectively **Interface 2**, is used for RS232 control signals and **Interface 1**, respectively **Interface 3**, for data communication.
- The **HID Generic** class allows additionally specifying the **Vendor Page** and **Usage**, used in HID reports.

Each interface can have two endpoints (buffers) used for data storage in communication with the host:

- **IN Endpoint** stores the data to be transmitted by the device to the host
- **OUT Endpoint** stores the data received by the device from the host.

Notes:

- For some device classes (**HID Mouse** for example), there may be only one endpoint (IN), as the device may only send data to the host.
- Endpoint 0 is always used for **Control** type transfers.

The **Type** selection allows to specify how the data transfer with the host will be performed:

- **Isochronous** transfers have a guaranteed rate, where the host can request a specific number of bytes to transfer at defined intervals, without error correction
- **Interrupt** transfers have error correction and guaranteed maximum latency, specified by the device. When a driver has requested a data transfer, the host allows no more than the specified maximum latency, to elapse between transfer attempts
- **Bulk** transfers are the fastest, but have no guaranteed timing.

The endpoint buffer size is specified by the **Size** setting.

The **Service Interval** setting (for **Isochronous** and **Interrupt** endpoints) is the period within which the host must reserve time for an endpoint's transaction.

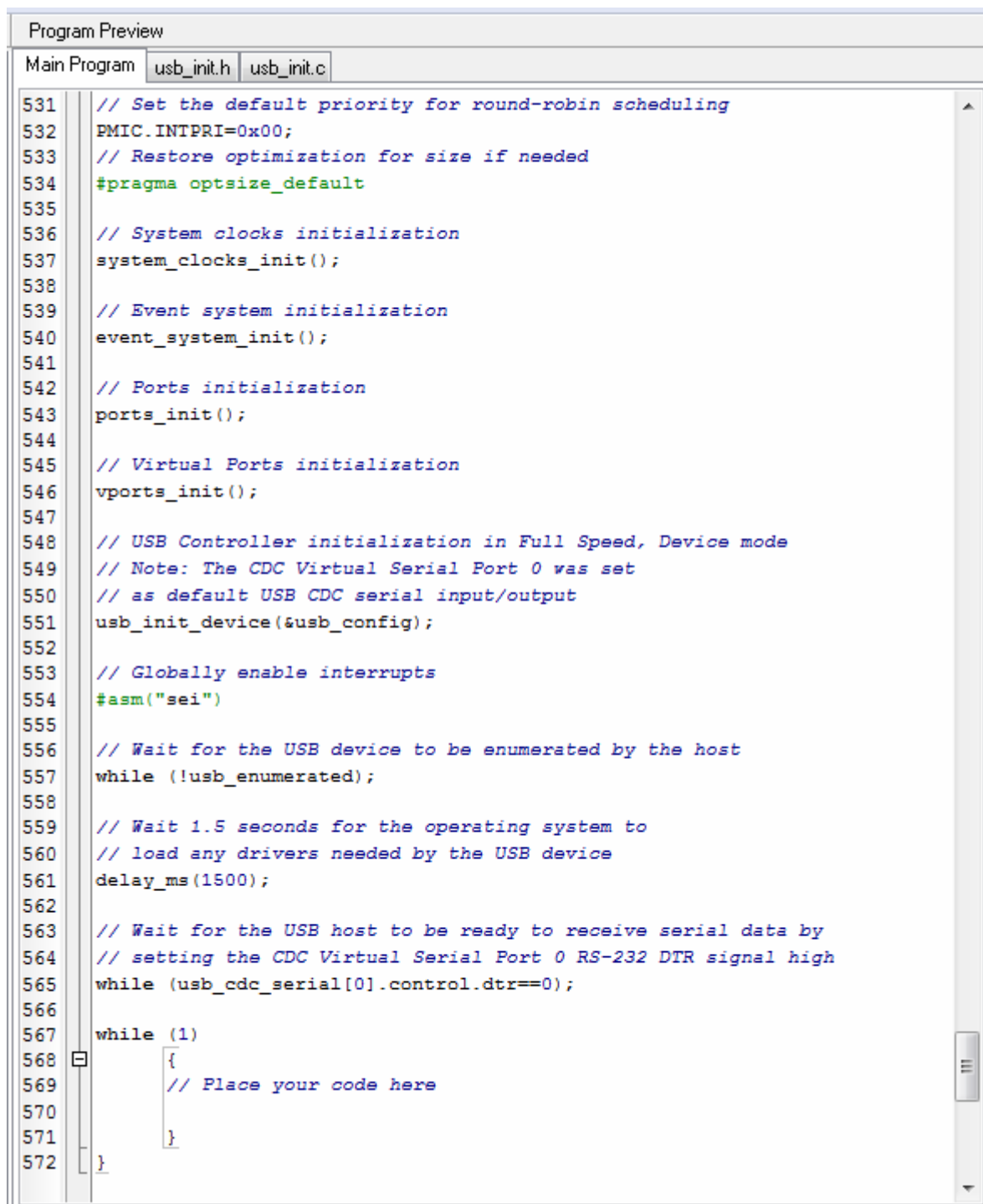
The service interval will be specified by the CodeWizardAVR in the endpoint descriptor.

After the **Program|Generate** menu command is executed, the wizard will create three source files:

- main program file
- usb_init.h
- usb_init.c.

CodeVisionAVR

The contents of each file can be viewed in the **Program Preview** window, by selecting the appropriate tab:



The screenshot shows the 'Program Preview' window with tabs for 'Main Program', 'usb_init.h', and 'usb_init.c'. The 'usb_init.c' tab is selected, displaying the following C code:

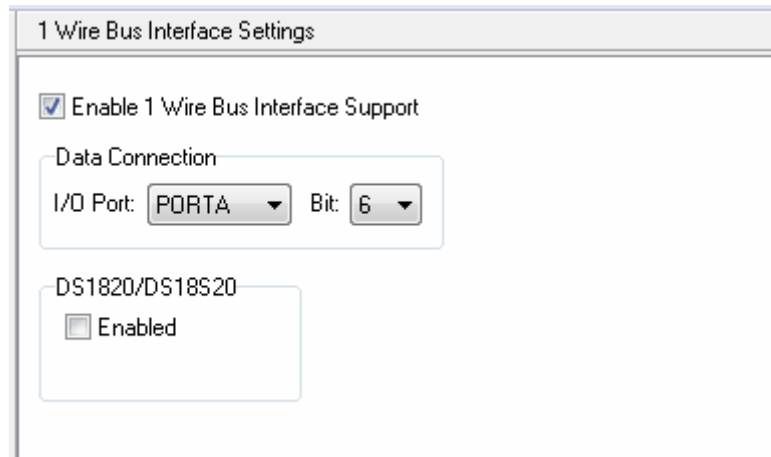
```
531 // Set the default priority for round-robin scheduling
532 PMIC.INTPRI=0x00;
533 // Restore optimization for size if needed
534 #pragma optsize_default
535
536 // System clocks initialization
537 system_clocks_init();
538
539 // Event system initialization
540 event_system_init();
541
542 // Ports initialization
543 ports_init();
544
545 // Virtual Ports initialization
546 vports_init();
547
548 // USB Controller initialization in Full Speed, Device mode
549 // Note: The CDC Virtual Serial Port 0 was set
550 // as default USB CDC serial input/output
551 usb_init_device(&usb_config);
552
553 // Globally enable interrupts
554 #asm("sei")
555
556 // Wait for the USB device to be enumerated by the host
557 while (!usb_enumerated);
558
559 // Wait 1.5 seconds for the operating system to
560 // load any drivers needed by the USB device
561 delay_ms(1500);
562
563 // Wait for the USB host to be ready to receive serial data by
564 // setting the CDC Virtual Serial Port 0 RS-232 DTR signal high
565 while (usb_cdc_serial[0].control.dtr==0);
566
567 while (1)
568 {
569     // Place your code here
570 }
571
572 }
```

When creating the new CodeVisionAVR project, the wizard will automatically set the correct options for USB library functions in the **Project|Configure|Libraries|USB** menu.

7.14 Setting the 1 Wire Bus

The 1 Wire Protocol Functions for the XMEGA chips can be configured by clicking on the **1 Wire**  node of the CodeWizardAVR selection tree.

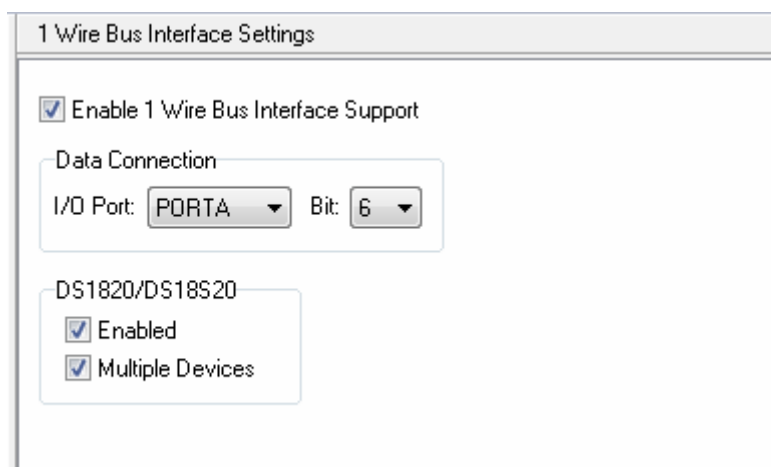
The following settings are available:



The dialog box titled "1 Wire Bus Interface Settings" contains the following options:

- ☒ Enable 1 Wire Bus Interface Support
- Data Connection**
 - I/O Port: PORTA
 - Bit: 6
- DS1820/DS18S20**
 - ☐ Enabled

- **Enable 1 Wire Bus Interface Support** allows the activation of the **1 Wire Protocol Functions**.
- **I/O Port** and **Bit** specify in **Data Connection**, the port and bit used for 1 Wire bus communication
- **DS1820/DS18S20 Enabled** check box activates the generation of support code for accessing the DS1820/DS18S20 temperature sensor devices:



The dialog box titled "1 Wire Bus Interface Settings" contains the following options:

- ☒ Enable 1 Wire Bus Interface Support
- Data Connection**
 - I/O Port: PORTA
 - Bit: 6
- DS1820/DS18S20**
 - ☒ Enabled
 - ☒ Multiple Devices

If several DS1820/DS18S20 devices are connected to the 1 Wire bus, the **Multiple Devices** option must be checked.

A maximum of 8 DS1820/DS18S20 devices can be connected to the bus.

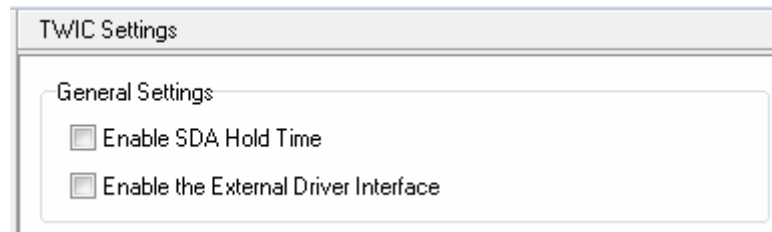
The ROM codes for these devices will be stored in the **ds1820_rom_codes** array.

The DS1820/DS18S20 devices can be accessed using the **Maxim DS1820/DS18S20 Temperature Sensors Functions**.

7.15 Setting the Two Wire Interfaces

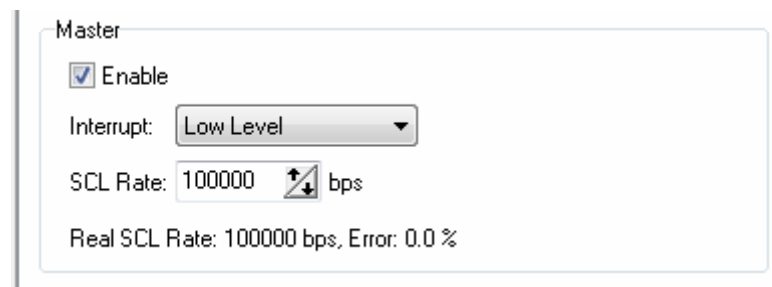
The XMEGA Two Wire Interfaces (TWI) can be configured by clicking on the **Two Wire Interfaces**  nodes of the CodeWizardAVR selection tree.

The following **General Settings** are available:



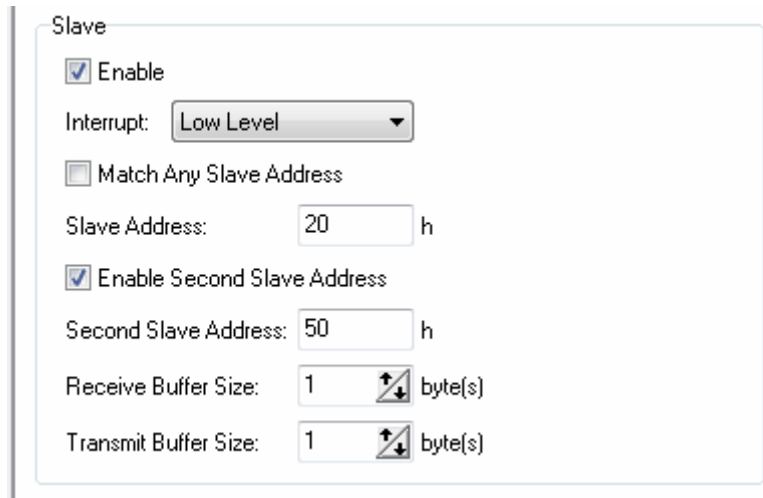
- **Enable SDA Hold Time** allows to add an internal hold time to the SDA signal with respect to the negative edge of SCL.
- **Enable the External Driver Interface** activates the usage of external TWI compliant tri-state drivers for the SDA and SCL signals. In this situation the internal TWI drivers with input filtering and slew rate control are bypassed. The normal I/O port pin function is used and the direction must be configured by the user software.

The following settings are available for operating the TWI module in **Master** mode:



- **Enable** activates the operation of the TWI module in master mode.
- **Interrupt** specifies the interrupt priority level used by the TWI module when operating in master mode.
- **SCL Rate** specifies the required TWI clock rate on the SCL pin. The **Real SCL Rate** is calculated and displayed based on the **System Clock** value.

The following settings are available for operating the TWI module in **Slave** mode:



Slave

☒ Enable

Interrupt: Low Level

☐ Match Any Slave Address

Slave Address: 20 h

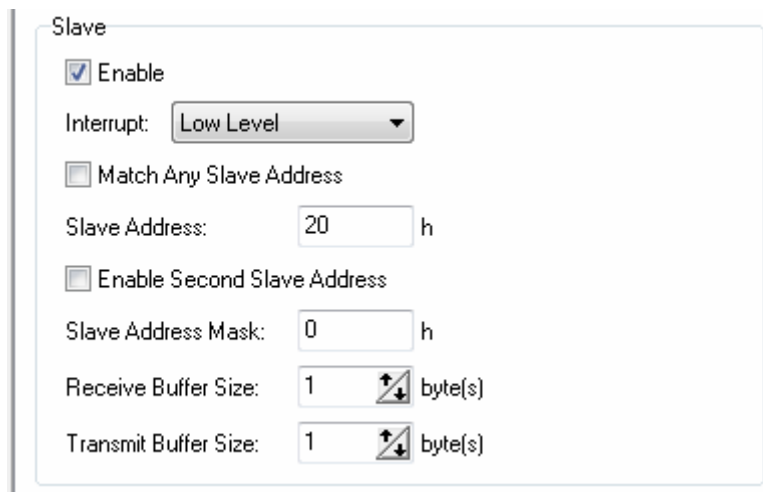
☒ Enable Second Slave Address

Second Slave Address: 50 h

Receive Buffer Size: 1 byte(s)

Transmit Buffer Size: 1 byte(s)

- **Enable** activates the operation of the TWI module in slave mode.
- **Interrupt** specifies the interrupt priority level used by the TWI module when operating in slave mode.
- **Match Any Slave Address** enables the TWI slave to respond to any slave address supplied by the master when starting a transaction.
- **Slave Address** represents the 7 bit slave address to which the slave will respond if the **Match Any Slave Address** option is **disabled**.
- **Enable Second Slave Address**, when **enabled**, allows to specify a **Second Slave Address** to which the slave should respond.
- **Slave Address Mask**, when the **Enable Second Slave Address** option is **disabled**, represents the 7 bit slave address bit mask applied to the **Slave Address**:



Slave

☒ Enable

Interrupt: Low Level

☐ Match Any Slave Address

Slave Address: 20 h

☐ Enable Second Slave Address

Slave Address Mask: 0 h

Receive Buffer Size: 1 byte(s)

Transmit Buffer Size: 1 byte(s)

If a bit in the **Slave Address Mask** is set to 1, the address match between the incoming address bit and the corresponding bit from the **Slave Address** is ignored, i.e. masked bits will always match.

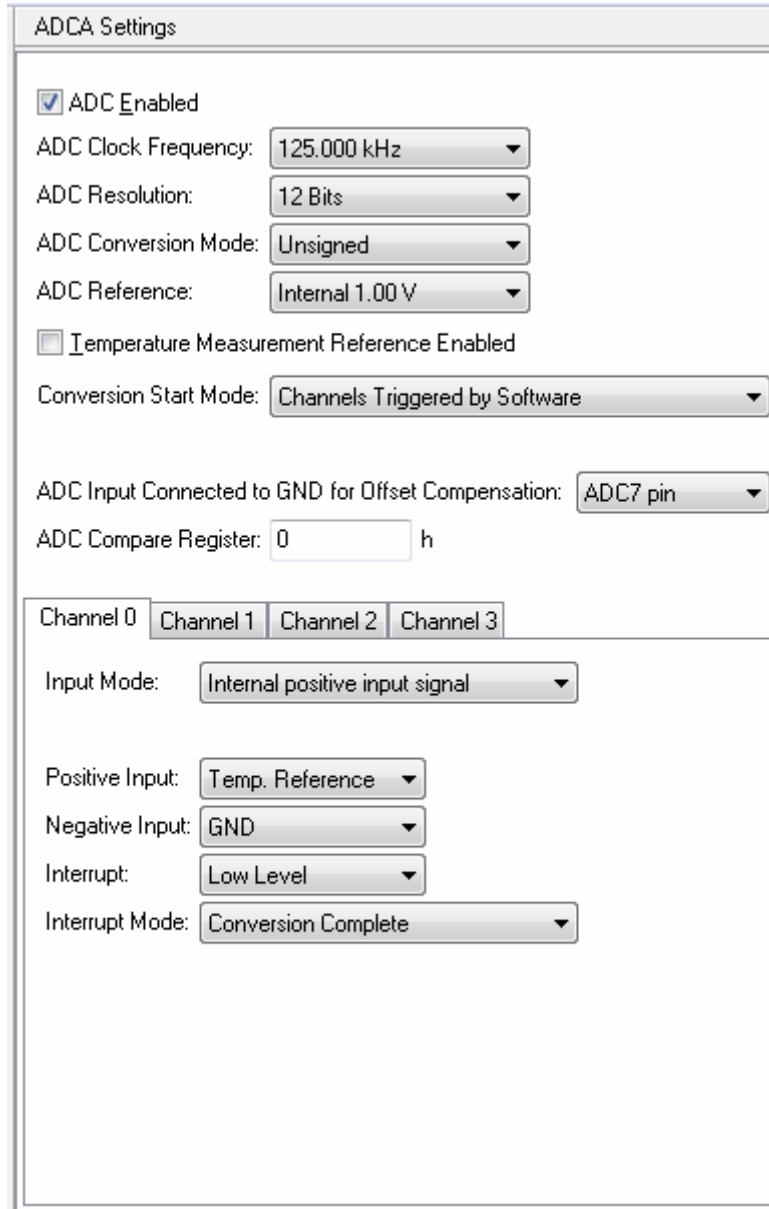
- **Receive Buffer Size** specifies the size of the receive buffer in bytes.
- **Transmit Buffer Size** specifies the size of the transmit buffer in bytes.

After the TWI is configured, the CodeWizardAVR will generate code that uses the **Two Wire Interface Functions for XMEGA Devices** library.

7.16 Setting the Analog to Digital Converters

The XMEGA Analog to Digital Converter(s) (ADC) can be configured by clicking on the **Analog to Digital Converters**  nodes of the CodeWizardAVR selection tree.

The following settings are available:



- **ADC Enabled** allows the activation of the selected ADC
- **ADC Clock Frequency** specifies the frequency of the clock signal used by the ADC
- **ADC Resolution** allows to select **8 Bit** or **12 Bit** analog to digital conversion resolution
- **ADC Conversion Mode** allows to select **Signed** or **Unsigned** analog to digital conversion
- **ADC Reference** allows to specify the voltage reference used by the ADC
- **Temperature Measurement Reference Enabled** activates the on-chip temperature sensor
- **Conversion Start Mode** allows to select how an analog to digital conversion is started for each ADC channel: **Triggered by Software**, **Free Running**, **Triggered by the Event System** and **Triggered by the Event System, Synchronized**

- **ADC Input Connected to GND for Offset Compensation** allows to specify which ADC input is connected to GND, in **Unsigned** conversion mode, so that the ADC offset voltage can be measured at start-up and subtracted from subsequent conversion results. For **Signed** conversion mode, there is no need to connect one of the ADC inputs to GND, because the offset is read using channel 0 in differential mode, with both + and - inputs connected internally together.
- **ADC Compare Register** allows to specify the initial value for the ADC **CMPL** and **CMPH** registers

For each ADC channel there is the possibility to specify the following options:

- **Input Mode** specifies which signals are applied to the ADC channel: **Internal positive input**, **Single-ended external positive input signal**, **Differential external input signal** and **Differential external input signal with gain**.

For the last input mode there is also the option to select the **Gain Factor**:

The screenshot shows the configuration window for Channel 0. At the top, there are four tabs: Channel 0, Channel 1, Channel 2, and Channel 3. Channel 0 is selected. Below the tabs, there are several configuration options, each with a dropdown menu:

- Input Mode: Differential input signal with gain
- Gain Factor: 1
- Positive Input: ADC0 pin
- Negative Input: ADC4 pin
- Interrupt: Low Level
- Interrupt Mode: Conversion Complete

Note: Differential input modes are available only for **Signed** ADC conversion mode.

- **Positive Input** allows to select which ADC pin will be used as channel's positive input for modes that use external input signals
- **Negative Input** allows to select which ADC pin will be used as channel's negative input for **Differential** input modes
- **Interrupt** allows to specify if an interrupt will be generated for the ADC channel, by one of the events specified in the **Interrupt Mode** option: **Conversion Complete**, **Compare Result Below Threshold** and **Compare Result Above Threshold**.

For the last two **Interrupt Modes**, the analog to digital conversion result is compared with the value of the **CMPL** and **CMPH** registers, an interrupt being generated if the specified condition is met.

In the **Free Running** conversion start mode, the ADC will continuously sweep the channels specified by the **Swept Channel(s)** list box:

ADCA Settings

☒ ADC Enabled

ADC Clock Frequency: 125.000 kHz

ADC Resolution: 12 Bits

ADC Conversion Mode: Unsigned

ADC Reference: Internal 1.00 V

☐ Temperature Measurement Reference Enabled

Conversion Start Mode: Free Running, Channels Swept Continuously

Swept Channel(s): 0, 1, 2, 3

ADC Input Connected to GND for Offset Compensation: ADC7 pin

ADC Compare Register: 0 h

Channel 0 Channel 1 Channel 2 Channel 3

Input Mode: Internal positive input signal

Positive Input: Temp. Reference

Negative Input: GND

Interrupt: Low Level

Interrupt Mode: Conversion Complete

In the above example figure, the ADC will continuously sweep the inputs of channels 0, 1, 2 and 3.

In the **Channels Triggered by the Event System** conversion start mode, each **Event Channel** will trigger the analog to digital conversion for the ADC channels specified by the **Trigger(s) Channel(s)** list box:

ADCA Settings

☒ ADC Enabled

ADC Clock Frequency: 125.000 kHz

ADC Resolution: 12 Bits

ADC Conversion Mode: Unsigned

ADC Reference: Internal 1.00 V

☐ Temperature Measurement Reference Enabled

Conversion Start Mode: Channels Triggered by the Event System

Event Channel(s): 0, 1, 2, 3 Trigger(s) Channel(s): 0, 1, 2, 3

ADC Input Connected to GND for Offset Compensation: ADC7 pin

ADC Compare Register: 0 h

Channel 0 Channel 1 Channel 2 Channel 3

Input Mode: Internal positive input signal

Positive Input: Temp. Reference

Negative Input: GND

Interrupt: Low Level

Interrupt Mode: Conversion Complete

In the above example figure, event channel 0 will trigger ADC channel 0, event channel 1 will trigger ADC channel 1, event channel 2 will trigger ADC channel 2 and event channel 3 will trigger ADC channel 3.

In the **Channels Swept by the Event System** and **Channels Swept by the Event System, Synchronized** conversion start modes, an event that occurs on **Event Channel** will trigger a sweep of all the ADC channels specified by the **Sweeps Channel(s)** list box:

ADCA Settings

☒ ADC Enabled

ADC Clock Frequency: 125.000 kHz

ADC Resolution: 12 Bits

ADC Conversion Mode: Unsigned

ADC Reference: Internal 1.00 V

☐ Temperature Measurement Reference Enabled

Conversion Start Mode: Channels Swept by the Event System

Event Channel: 0 Sweeps Channel(s): 0, 1, 2, 3

ADC Input Connected to GND for Offset Compensation: ADC7 pin

ADC Compare Register: 0 h

Channel 0 Channel 1 Channel 2 Channel 3

Input Mode: Internal positive input signal

Positive Input: Temp. Reference

Negative Input: GND

Interrupt: Low Level

Interrupt Mode: Conversion Complete

In the above example figure, an event that occurs on event channel 0 will start the sweep of ADC channels' 0, 1, 2 and 3 inputs.

The following functions are generated by the CodeWizardAVR:

void adc n _init(void)

This function will initialize the ADC n peripheral, where n is the name of the PORT where the ADC inputs are located.

The function will also perform the ADC calibration in 12 Bit mode (by reading the calibration value from the signature row), the measurement of its offset voltage and will store the offset value in the **adc n _offset** variable. This value will be later subtracted for offset compensation when performing analog to digital conversions.

void adc n _conv_start(unsigned char channel)

This function will start an analog to digital conversion for the specified **channel** of ADC n .

It is generated only in **Channels Triggered by Software** conversion start mode, if interrupts are enabled for at least one of the ADC n channels.

After the conversion is complete, its result can be read in the ADC n channel's interrupt service routine.

If software polling is used (interrupts are disabled for the ADC n channel) then the following functions can be used:

unsigned int adc n _read(unsigned char channel)

for **Unsigned** ADC conversion mode

int adc n _read(unsigned char channel)

for **Signed** ADC conversion mode.

When called, these functions will start an analog to digital conversion for the specified **channel** of ADC n , will wait for the conversion to complete, will compensate the ADC offset voltage and will return the conversion result.

Note: The analog to digital conversion will be started by the **adc n _read** functions only for **Channels Triggered by Software** conversion start mode. For the other start modes it will be automatically started by the ADC itself (**Free Running** mode) or by the **Event System**.

For the **Channels Triggered by Software**, **Channels Swept by the Event System** and **Channels Swept by the Event System, Synchronized** conversion start modes and if software polling is used (interrupts being disabled for at least one of the ADC n channels), the following functions are generated:

void adc n _sweep_read(unsigned int *pdata)

for **Unsigned** ADC conversion mode

void adc n _sweep_read(int *pdata)

for **Signed** ADC conversion mode.

When called, these functions will start analog to digital conversions for all the ADC n channels specified in the **Sweep** listbox, will wait for the conversions to complete, will compensate the ADC offset voltage and will store the conversion results in the array pointed by **pdata**.

Note: The analog to digital conversions will be started by the **adc n _sweep** functions only for **Channels Triggered by Software** conversion start mode. For the other start modes they will be automatically started by the **Event System**.

If interrupts are enabled for an ADC channel, then the corresponding interrupt service routine will be generated for it:

```
void adc $n$ _ch $m$ _isr(void)
```

where n is the name of the PORT where the ADC inputs are located and m is the number of the ADC n channel.

The interrupt service routine will contain code to read the conversion result from the **RESL** and **RESH** registers of ADC n channel m and compensate the ADC n offset voltage.

More details about ADC operation for the XMEGA chips can be found in the following Atmel documents:

- AVR1300: Using the XMEGA ADC
- XMEGA A Manual
- XMEGA D Manual.

7.17 Setting the Digital to Analog Converters

The XMEGA Digital to Analog Converter(s) (DAC) can be configured by clicking on the **Digital to Analog Converters**  nodes of the CodeWizardAVR selection tree.

The following settings are available:

- **DAC Enabled** allows the activation of the selected DAC
- **DAC Low Power Mode** allows the operation of the DAC in low power consumption mode
- **Internal Output Routed to the ADC and Analog Comparator MUX-es** allows to internally connect the DAC's output to the corresponding ADC and/or Analog Comparator multiplexers
- **Operating Mode** allows to select one of the two DAC operating modes: **Single Channel** (Ch0) or **Dual Channel** (Ch0 and Ch1).

In **Single Channel** operating mode, the DAC output is directly connected to the Channel 0 output, without using a sample and hold circuit.

This output can be activated using the **Channel 0 External Output Enabled** check box.

A Digital to Analog conversion can be triggered by:

- writing a new value to the **CH0DATAL** and **CH0DATAH** registers
- the **Event System**, if the **Channel 0 Triggered by the Event System** option is enabled.

In this later case, the **DAC Triggered by Event System Channel** option allows to select the channel on which an event will trigger a conversion.

The **DAC Voltage** reference option allows to select the reference used by the DAC:

- 1.0 V internal reference
- the AVCC pin
- the AREF pin on PORTA
- the AREF pin on PORTB.

The **Left Adjust Value** option, if enabled, allows to distribute the data bits 4..11 to the **CH0DATAH**, and data bits 0..3 to the bits 4..7 of the **CH0DATAL** registers.

This also allows for 8-bit Digital to Analog conversions if only the **CH0DATAH** register is written.

If the option is disabled, the data bits 0..7 are distributed to the **CH0DATAL**, and data bits 8..11 to the bits 8..11 of the **CH0DATAH** registers.

The **DAC Conversion Interval** specifies the time interval between a completed channel conversion until starting a new conversion.

Its minimal value depends of the **Peripheral Clock** value and can't be less than 1 us in **Single Channel** operating mode.

In **Dual Channel** operating mode the DAC output is fed into two different pins, using a sample and hold circuit.

In this operating mode the following additional options are available:

The screenshot shows a 'DAC Settings' dialog box with the following options:

- ☒ DAC Enabled
- ☐ DAC Low Power Mode
- ☐ Internal Output Routed to the ADC and Analog Compator MUX-es
- Operating Mode: Dual Channel (Sample/Hold for Ch0 & Ch1) ▼
- ☐ Channel 0 External Output Enabled
- ☐ Channel 1 External Output Enabled
- ☒ Channel 0 Triggered by the Event System
- ☒ Channel 1 Triggered by the Event System
- DAC Triggered by Event System Channel: 0 ▼
- DAC Voltage Reference: Internal 1.00 V ▼
- ☐ Left Adjust Value
- DAC Conversion Interval: 1.500 us ▼
- DAC Channel Refresh Timing: 8.000 us ▼

- **Channel 1 External Output Enabled** check box allows to activate the output of DAC Channel 1 on the corresponding port pin
- **Channel 1 Triggered by the Event System** check box allows to trigger a Digital To Analog conversion for Channel 1 too, when an event occurs on the **Event System Channel** selected by the corresponding option
- **DAC Channel Refresh Timing** allows to specify the time interval between each time a channel is updated. This interval can't exceed 30 us.

The following functions are generated by the CodeWizardAVR:

void dacn_init(void)

This function will initialize the DAC n peripheral, where n is the name of the PORT where the DAC outputs are located.

void dacn_write(unsigned char ch, unsigned int data)

This function will write the **data** value to the output of DAC n channel **ch**.

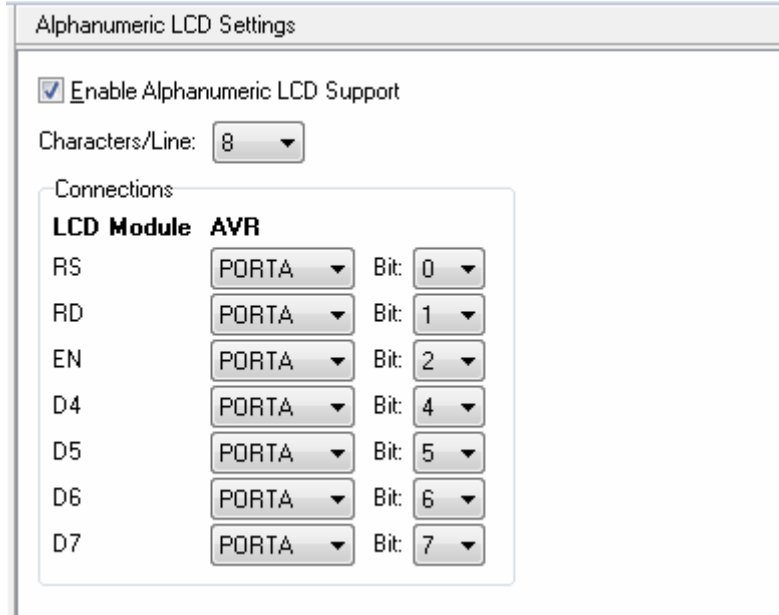
If triggering by the **Event System** is disabled for channel **ch**, the Digital to Analog conversion is automatically started by calling this function.

If triggering is enabled, the conversion will start only after the function is called *and* an event occurs on the corresponding **Event System** channel.

More details about DAC operation for the XMEGA chips can be found in the Atmel **XMEGA A Manual**.

7.18 Setting the Alphanumeric LCD

The I/O port allocation for the **LCD Functions for displays with up to 2x40 characters** can be configured by clicking on the **Alphanumeric LCD**  node of the CodeWizardAVR selection tree.



The dialog box titled "Alphanumeric LCD Settings" contains the following configuration options:

- ☒ **Enable Alphanumeric LCD Support**
- Characters/Line:** 8 (dropdown menu)
- Connections** group box:
 - LCD Module** | **AVR**
 - RS: PORTA | Bit: 0
 - RD: PORTA | Bit: 1
 - EN: PORTA | Bit: 2
 - D4: PORTA | Bit: 4
 - D5: PORTA | Bit: 5
 - D6: PORTA | Bit: 6
 - D7: PORTA | Bit: 7

The **Enable Alphanumeric LCD Support** check box activates the configuration specified for the *alcd.h* library functions.

The **Controller Type** option selects the alphanumeric LCD controller to be used:

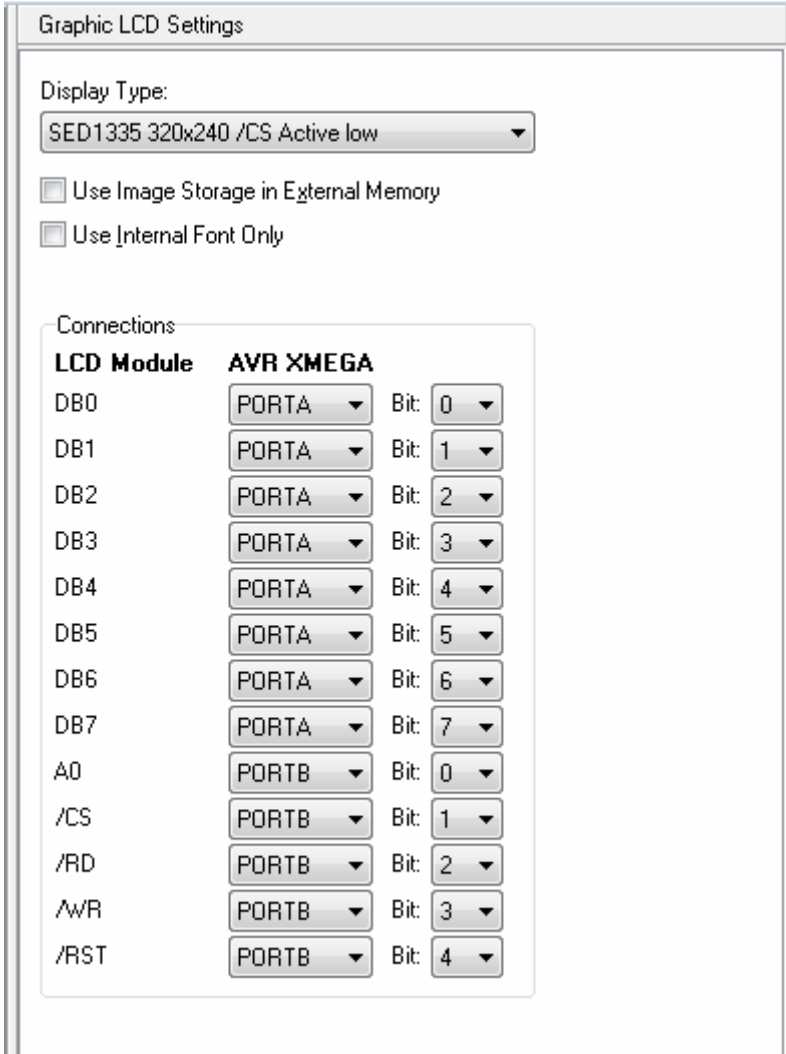
- Hitachi HD44780 or compatible
- Samsung KS0073
- Solomon Systech SSD1803, used in Electronic Assembly's (www.lcd-module.de) DIP203 display modules.

The **Characters/Line** list box allows to specify the number of characters per line supported by the LCD module.

The connections between the LCD module and the AVR I/O ports can be specified individually for each signal in the **Connections** group box.

7.19 Setting the Graphic Display

The I/O port allocation for the **Graphic Display Functions** can be configured by clicking on the **Graphic Display**  node of the CodeWizardAVR selection tree.



The dialog box titled "Graphic LCD Settings" contains the following configuration options:

- Display Type:** A dropdown menu showing "SED1335 320x240 /CS Active low".
- ☐ **Use Image Storage in External Memory**
- ☐ **Use Internal Font Only**
- Connections:** A table for mapping LCD signals to AVR XMEGA ports and bits.

LCD Module	AVR XMEGA
DB0	PORTA Bit: 0
DB1	PORTA Bit: 1
DB2	PORTA Bit: 2
DB3	PORTA Bit: 3
DB4	PORTA Bit: 4
DB5	PORTA Bit: 5
DB6	PORTA Bit: 6
DB7	PORTA Bit: 7
A0	PORTB Bit: 0
/CS	PORTB Bit: 1
/RD	PORTB Bit: 2
/WR	PORTB Bit: 3
/RST	PORTB Bit: 4

The **Display Type** list box allows to select the graphic controller type and display resolution.

The **Use Image Storage in External Memory** check box specifies if additional code will be generated for functions needed to read or write data from external memory, used for graphic image storage.

The **Use Internal Font Only** check box specifies for the `glcd_init` function, that only the internal character generator of the controller is used for displaying text.

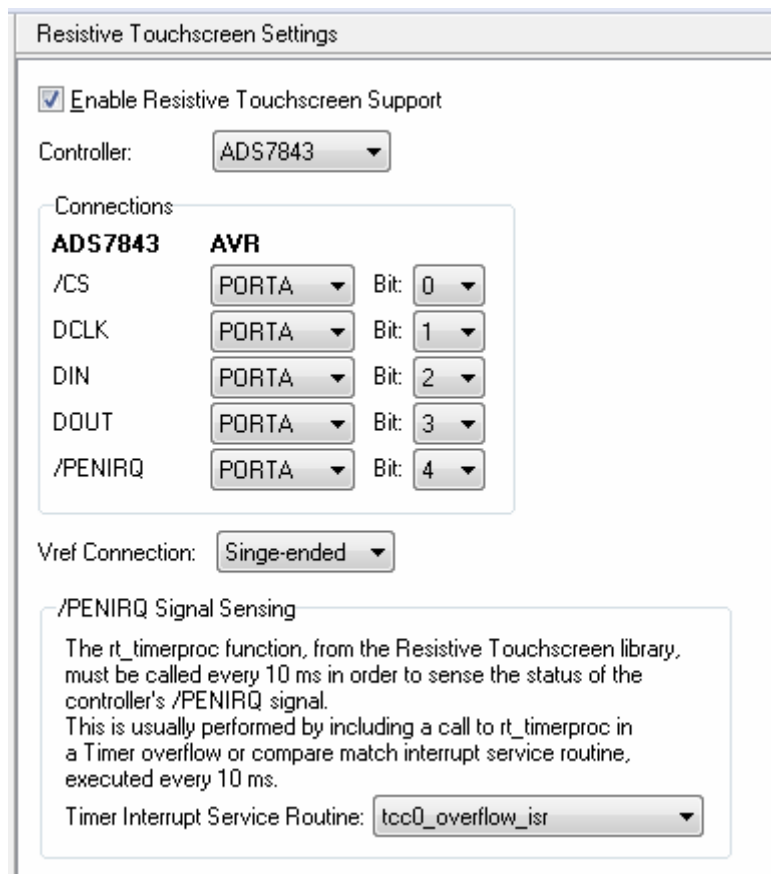
Note: This option is available only for graphic display controllers that have a built-in character generator.

The connections between the graphic LCD module and the AVR I/O ports can be specified individually for each signal in the **Connections** group box.

Note: In order to obtain maximum performance, it is advised to set the display controller's **data bus** bits to match the bits with the same numbers of the same AVR I/O port.

7.20 Setting the Resistive Touchscreen Controller

The Resistive Touchscreen Controller settings can be configured by clicking on the **Resistive Touchscreen** node of the CodeWizardAVR selection tree.



The dialog box titled "Resistive Touchscreen Settings" contains the following configuration options:

- ☒ **Enable Resistive Touchscreen Support**
- Controller:** ADS7843
- Connections:**

ADS7843	AVR	Bit
/CS	PORTA	0
DCLK	PORTA	1
DIN	PORTA	2
DOUT	PORTA	3
/PENIRQ	PORTA	4
- Vref Connection:** Single-ended
- /PENIRQ Signal Sensing:**

The `rt_timerproc` function, from the Resistive Touchscreen library, must be called every 10 ms in order to sense the status of the controller's /PENIRQ signal. This is usually performed by including a call to `rt_timerproc` in a Timer overflow or compare match interrupt service routine, executed every 10 ms.

Timer Interrupt Service Routine: tcc0_overflow_isr

The **Enable Resistive Touchscreen Support** check box activates the configuration specified for the *rtouch.h* library functions.

The **Controller** list box selects the type of the resistive touchscreen controller.

The **Connections** between the controller and the AVR I/O ports can be specified individually for each signal.

One of the two connection modes for the touchscreen controller's voltage reference can be selected using the **Vref Connection** list box:

- **Single-ended**
- **Differential.**

In order to sense the state of the /PENIRQ output of the touchscreen controller, the *rt_timerproc* (*rtouch.h*) function needs to be called every 10ms by a timer overflow or compare match interrupt service routine, which can be selected using the **Timer Interrupt Service Routine** list box.

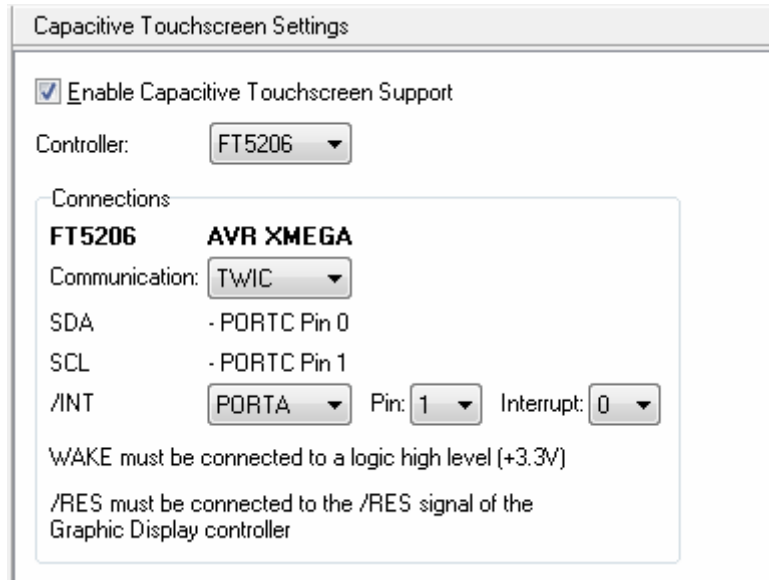
This list box is automatically updated by the CodeWizardAVR when the user enables or disables a timer interrupt.

If no interrupt service routine is selected, an error will be issued during code generation.

The user will be then prompted to go to the **Timer Settings** and configure one of the timers to generate an interrupt every 10 ms.

7.21 Setting the Capacitive Touchscreen Controller

The Capacitive Touchscreen Controller settings can be configured by clicking on the **Capacitive Touchscreen**  node of the CodeWizardAVR selection tree.



FT5206	AVR XMEGA
Communication:	TWIC
SDA	- PORTC Pin 0
SCL	- PORTC Pin 1
/INT	PORTA Pin: 1 Interrupt: 0

WAKE must be connected to a logic high level (+3.3V)

/RES must be connected to the /RES signal of the Graphic Display controller

The **Enable Capacitive Touchscreen Support** check box activates the generation of code for the *ft5x06.h* library functions.

The **Controller** list box selects the type of the capacitive touchscreen controller.

The **Connections** between the controller and the AVR I/O ports can be specified individually for each signal.

Communication with the capacitive touchscreen controller is performed using the hardware **TWI**.

The user has the choice of selecting the **TWI** peripheral to be used.

When detecting a touch, the controller produces a high to low transition of the **/INT** signal, which must be sensed by one of the I/O port input pins and produce an external interrupt.

This will be processed by the microcontroller, the corresponding interrupt service routine performing a call to the **ct_inthandler** function from the **Capacitive Touchscreen Functions** library, described in chapter 5.14.

The **WAKE** signal must be connected to a logic high level. Alternatively, it can be connected to an I/O port output pin and set to low level by the user's program, forcing the controller to enter low power consumption mode.

The **/RES** signal must be connected to the corresponding **/RES (/RESET)** reset signal of the graphic display controller.

7.22 Specifying the Project Information

The information placed in the comment header, located at the beginning of the C source file produced by CodeWizardAVR, can be specified by clicking on the **Project Information**  node of the selection tree.



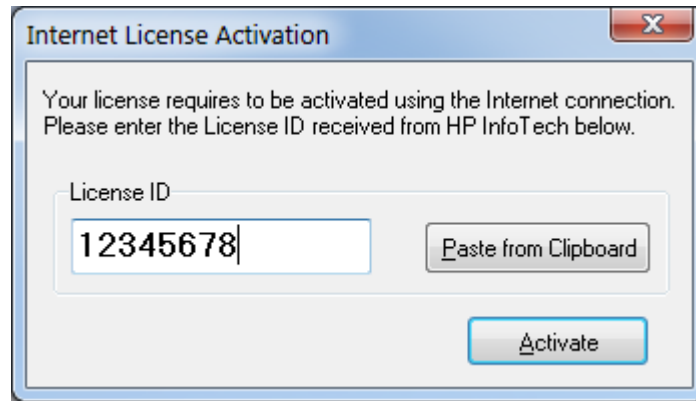
The screenshot shows a dialog box titled "Project Information". It contains several input fields: a text box for "Project Name:", two small text boxes for "Version:" and "Date:", a text box for "Author:", and a text box for "Company:". Below these is a large text area for "Comments:". The dialog box has a standard Windows-style border with a title bar.

You can specify the **Project Name**, **Date**, **Author**, **Company** and **Comments**.

8. Licensing System

8.1 Activating the License

The CodeVisionAVR license is locked to the hardware of the PC on which it is installed. If the license is not yet activated, the following dialog will be displayed at program startup:

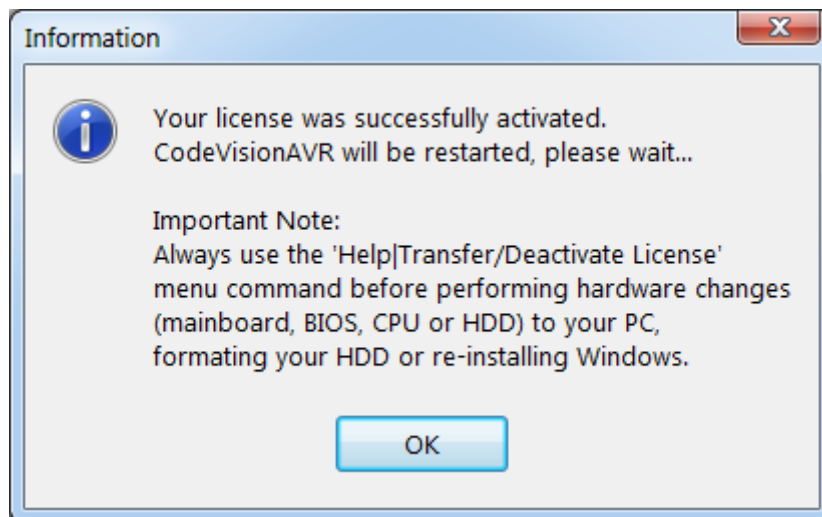


You must enter the **License ID** that was supplied by HP InfoTech when the license was initially purchased.

The **License ID** can be also pasted from the clipboard by pressing the **Paste from Clipboard** button. After that the license can be activated by pressing the **Activate** button.

CodeVisionAVR will contact the **Activation Server** using the Internet.

After several seconds, upon successful activation, the following confirmation message will be displayed:

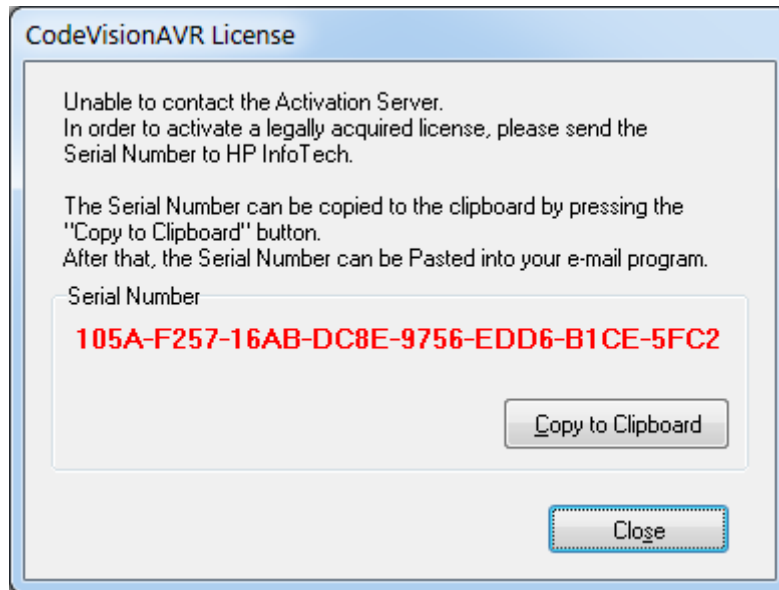


After pressing the **OK** button, CodeVisionAVR will be restarted and ready to use.

CodeVisionAVR

If there was an error contacting the **Activation Server**, the license needs to be activated manually by contacting HP InfoTech.

In this case the following message will be displayed with a **Serial Number** specific to the computer on which CodeVisionAVR is installed:



The **Serial Number** can be copied to the clipboard using the **Copy to Clipboard** button and then pasted from the clipboard in the e-mail program.

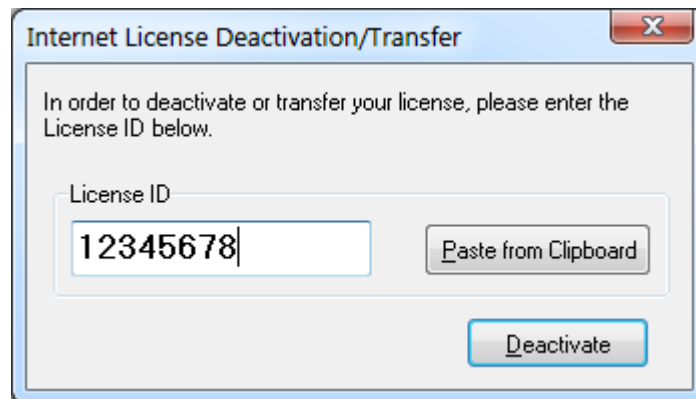
Note: If you experience problems contacting the **Activation Server**, please make sure that no firewall or antivirus program are blocking CodeVisionAVR to access the Internet.

8.2 Transferring or Deactivating the License

The CodeVisionAVR license is locked to the hardware of the PC on which the software is installed.

The **Help|Transfer/Deactivate License** menu command must be used in order to transfer the license to another computer.

The following dialog will be displayed:

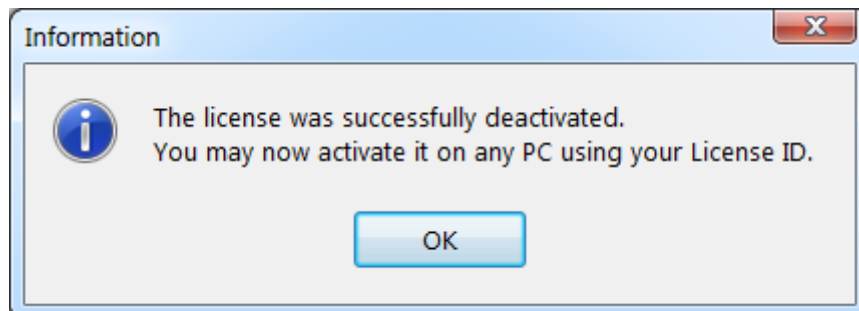


You must enter the **License ID** that was supplied by HP InfoTech when the license was initially purchased.

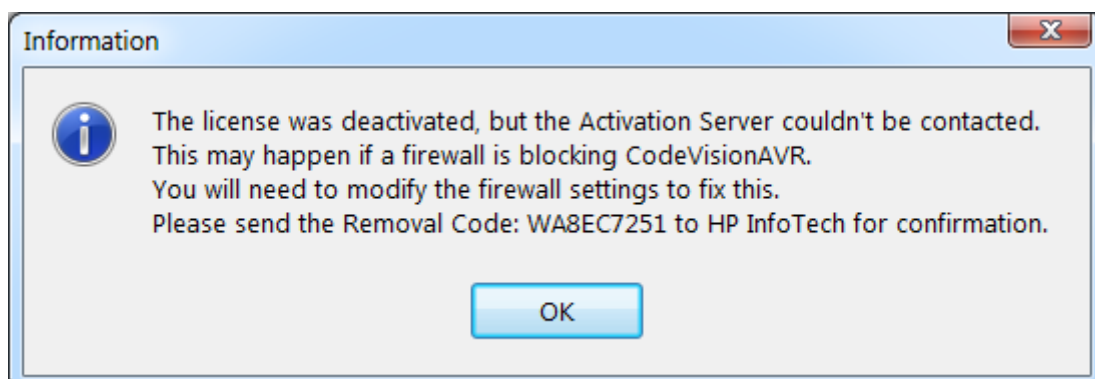
This is necessary in order to prevent accidental license deactivation by unauthorized persons. The **License ID** can be also pasted from the clipboard by pressing the **Paste from Clipboard** button. After that the license can be deactivated by pressing the **Deactivate** button.

CodeVisionAVR will contact the **Activation Server** using the Internet.

After several seconds, upon successful deactivation, the following confirmation message will be displayed:



If the **Activation Server** could not be contacted, the following message will be displayed:



CodeVisionAVR

The **Removal Code** must be sent by e-mail to HP InfoTech in order to confirm that the license was indeed deactivated.

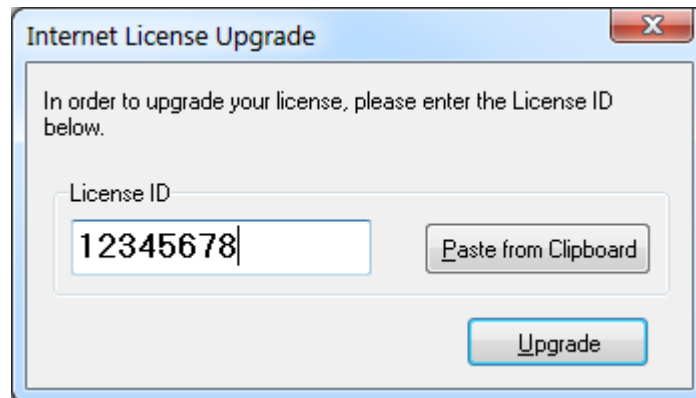
Note: If you experience problems contacting the **Activation Server**, please make sure that no firewall or antivirus program are blocking CodeVisionAVR to access the Internet.

If you wish to perform hardware changes to your computer (mainboard, BIOS or HDD) or format the HDD and reinstall Windows, you need to temporary deactivate the license using the above mentioned procedure, and once the changes are done, activate the license again as described in Chapter 7.1.

8.3 Upgrading the License

The **Help|Upgrade License** menu command must be used if you have purchased a license upgrade or update extension.

The following dialog will be displayed:



You must enter the **License ID** that was supplied by HP InfoTech when the license was initially purchased.

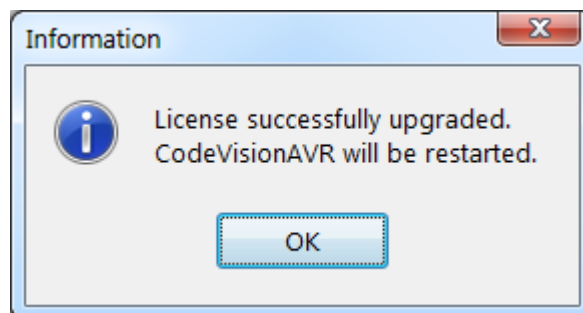
This is necessary in order to prevent accidental license upgrade by unauthorized persons.

The **License ID** can be also pasted from the clipboard by pressing the **Paste from Clipboard** button.

After that the license can be upgraded by pressing the **Upgrade** button.

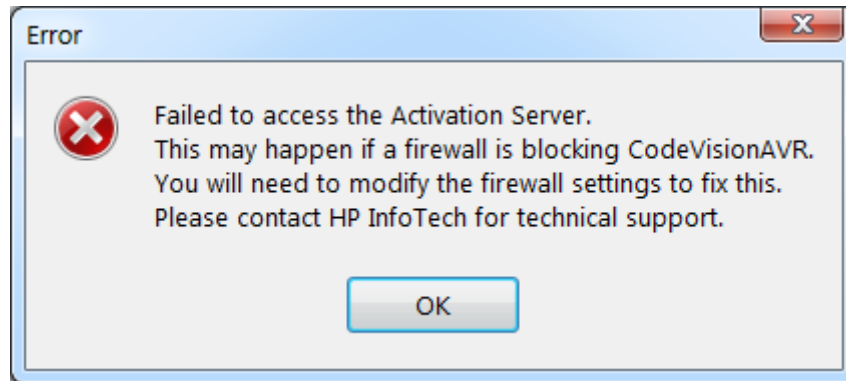
CodeVisionAVR will contact the **Activation Server** using the Internet.

After several seconds, upon successful upgrade, the following confirmation message will be displayed:



CodeVisionAVR

If there was an error contacting the **Activation Server**, the following error message will be displayed:



In this situation you will need to contact HP InfoTech in order to manually upgrade your license.

Note: If you experience problems contacting the **Activation Server**, please make sure that no firewall or antivirus program are blocking CodeVisionAVR to access the Internet.

9. License Agreement

9.1 Software License

The use of CodeVisionAVR indicates your understanding and acceptance of the following terms and conditions. This license shall supersede any verbal or prior verbal or written, statement or agreement to the contrary. If you do not understand or accept these terms, or your local regulations prohibit "after sale" license agreements or limited disclaimers, you must cease and desist using this product immediately.

This product is © Copyright 1998-2016 by Pavel Haiduc and HP InfoTech S.R.L., all rights reserved. International copyright laws, international treaties and all other applicable national or international laws protect this product. This software product and documentation may not, in whole or in part, be copied, photocopied, translated, or reduced to any electronic medium or machine readable form, without prior consent in writing, from HP InfoTech S.R.L. and according to all applicable laws. The sole owners of this product are Pavel Haiduc and HP InfoTech S.R.L.

9.2 Liability Disclaimer

This product and/or license is provided as is, without any representation or warranty of any kind, either express or implied, including without limitation any representations or endorsements regarding the use of, the results of, or performance of the product, its appropriateness, accuracy, reliability, or correctness.

The user and/or licensee assume the entire risk as to the use of this product.

Pavel Haiduc and HP InfoTech S.R.L. do not assume liability for the use of this program beyond the original purchase price of the software. In no event will Pavel Haiduc or HP InfoTech S.R.L. be liable for additional direct or indirect damages including any lost profits, lost savings, or other incidental or consequential damages arising from any defects, or the use or inability to use these programs, even if Pavel Haiduc or HP InfoTech S.R.L. have been advised of the possibility of such damages.

9.3 Restrictions

You may not use, copy, modify, translate, or transfer the programs, documentation, or any copy except as expressly defined in this agreement. You may not attempt to unlock or bypass any "copy-protection" or authentication algorithm utilized by the program. You may not remove or modify any copyright notice or the method by which it may be invoked.

9.4 Operating License

You have the non-exclusive right to use the program only by a single person, on a single computer at a time. You may physically transfer the program from one computer to another, provided that the program is used only by a single person, on a single computer at a time. In-group projects where multiple persons will use the program, you must purchase an individual license for each member of the group.

Use over a "local area network" (within the same locale) is permitted provided that only a single person, on a single computer uses the program at a time. Use over a "wide area network" (outside the same locale) is strictly prohibited under any and all circumstances.

9.5 Back-up and Transfer

You may make one copy of the program solely for "back-up" purposes, as prescribed by international copyright laws. You must reproduce and include the copyright notice on the back-up copy. You may transfer the product to another party only if the other party agrees to the terms and conditions of this agreement, and completes and returns registration information (name, address, etc.) to Pavel Haiduc and HP InfoTech S.R.L. within 30 days of the transfer. If you transfer the program you must at the same time transfer the documentation and back-up copy, or transfer the documentation and destroy the back-up copy. You may not retain any portion of the program, in any form, under any circumstance.

9.6 Terms

This license is effective until terminated. You may terminate it by destroying the program, the documentation and copies thereof. This license will also terminate if you fail to comply with any terms or conditions of this agreement. You agree upon such termination to destroy all copies of the program and of the documentation, or return them to Pavel Haiduc or HP InfoTech S.R.L. for disposal. Note that by registering this product you give Pavel Haiduc and HP InfoTech S.R.L. permission to reference your name in product advertisements.

9.7 Other Rights and Restrictions

All other rights and restrictions not specifically granted in this license are reserved by Pavel Haiduc and HP InfoTech S.R.L.

10. Technical Support and Updates

Registered users of commercial versions of CodeVisionAVR receive one-year of free updates and technical support starting from the date of license purchase.

The technical support is provided by e-mail in English or French languages.
The e-mail support address is: **office@hpinfotech.com**

11. Contact Information

HP InfoTech S.R.L. can be contacted at:

HP INFOTECH S.R.L.
BD. DECEBAL NR. 3
BL. S12B, SC. 2, AP. 29
SECTOR 3
BUCHAREST
ROMANIA

Phone: +(40)-723469754

Fax: +(40)-213261876

e-mail: office@hpinfotech.com

Internet: <http://www.hpinfotech.com>
<http://www.hpinfotech.biz>
<http://www.hpinfotech.ro>