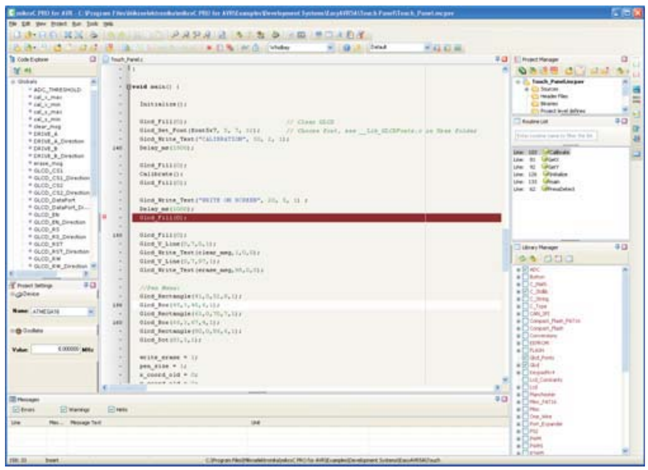
MikroElektronika

SOFTWARE AND HARDWARE SOLUTIONS FOR EMBEDDED WORLD ...making it simple

mikroC PRO for AVR



USER'S MANUAL

Develop your applications quickly and easily with the world's most intuitive mikroC PRO for AVR Microcontrollers.

Highly sophisticated IDE provides the power you need with the simplicity of a Windows based point-and-click environment.

With useful implemented tools, many practical code examples, broad set of built-in routines, and a comprehensive Help, mikroC PRO for AVR makes a fast and reliable tool, which can satisfy needs of experienced engineers and beginners alike.

December 2008.

Reader's note

DISCLAIMER:

HIGH RISK ACTIVITIES:

The mikroC PRO for AVR compiler is not fault-tolerant and is not designed, manufactured or intended for use or resale as on-line control equipment in hazardous environments requiring fail-safe performance, such as in the operation of nuclear facilities, aircraft navigation or communication systems, air traffic control, direct life support machines, or weapons systems, in which the failure of the Software could lead directly to death, personal injury, or severe physical or environmental damage ("High Risk Activities"). mikroElektronika and its suppliers specifically disclaim any express or implied warranty of fitness for High Risk Activities.

LICENSE AGREEMENT:

This manual covers mikroC PRO for AVR version 1.23 and the related topics. Newer versions may contain changes without prior notice.

COMPILER BUG REPORTS:

The compiler has been carefully tested and debugged. It is, however, not possible to guarantee a 100 % error free product. If you would like to report a bug, please contact us at the address office@mikroe.com. Please include next information in your bug report:

- Your operating system
- Version of mikroC PRO for AVR
- Code sample
- Description of a bug

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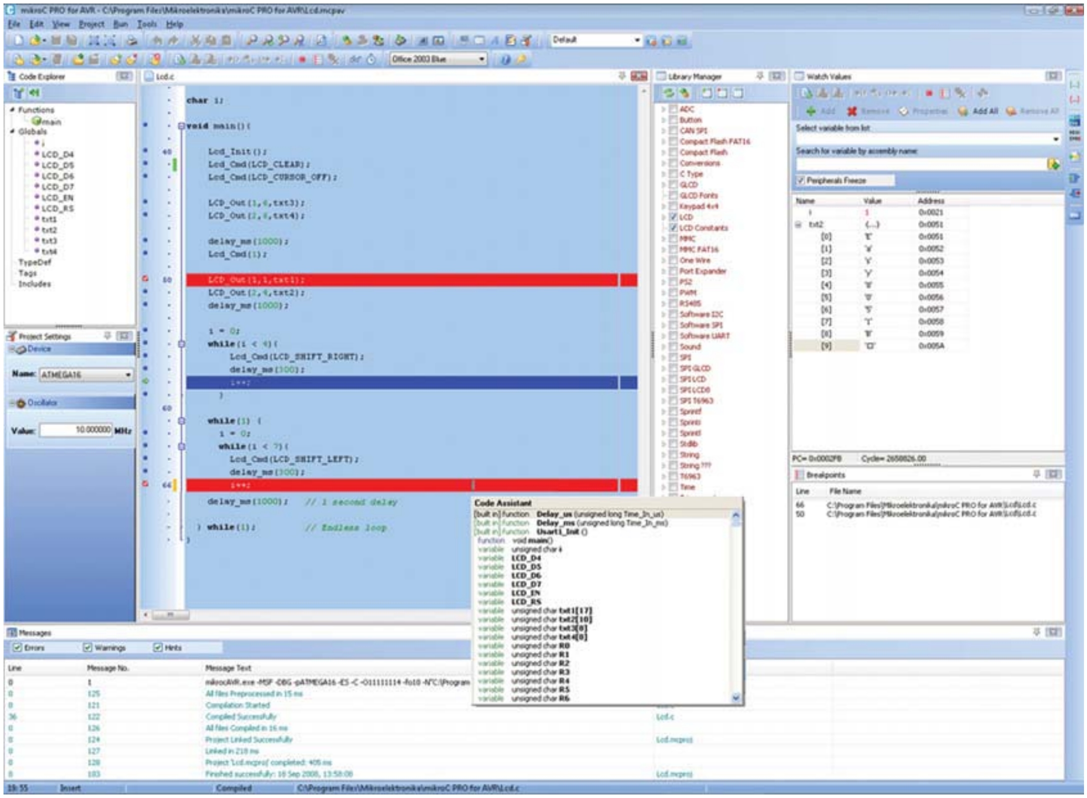
CHAPTER 1

Introduction to mikroC PRO for AVR

The mikroC PRO for AVR is a powerful, feature-rich development tool for AVR microcontrollers. It is designed to provide the programmer with the easiest possible solution to developing applications for embedded systems, without compromising performance or control.



mikroC PRO for AVR IDE

Features

mikroC PRO for AVR allows you to quickly develop and deploy complex applications:

- Write your C source code using the built-in Code Editor (Code and Parameter Assistants, Code Folding, Syntax Highlighting, Auto Correct, Code Templates, and more.)
- Use included mikroC PRO for AVR libraries to dramatically speed up the development: data acquisition, memory, displays, conversions, communication etc.
- Monitor your program structure, variables, and functions in the Code Explorer.
- Generate commented, human-readable assembly, and standard HEX compatible with all programmers.
- Inspect program flow and debug executable logic with the integrated Software Simulator.

- Get detailed reports and graphs: RAM and ROM map, code statistics, assembly listing, calling tree, and more.
- mikroC PRO for AVR provides plenty of examples to expand, develop, and use as building bricks in your projects. Copy them entirely if you deem fit – that's why we included them with the compiler.

Where to Start

- In case that you're a beginner in programming AVR microcontrollers, read carefully the AVR Specifics chapter. It might give you some useful pointers on AVR constraints, code portability, and good programming practices.

- If you are experienced in C programming, you will probably want to consult mikroC PRO for AVR Specifics first. For language issues, you can always refer to the comprehensive Language Reference. A complete list of included libraries is available at mikroC PRO for AVR Libraries.

- If you are not very experienced in C programming, don't panic! mikroC PRO for AVR provides plenty of examples making it easy for you to go quickly. We suggest that you first consult Projects and Source Files, and then start browsing the examples that you're the most interested in.

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TECHNICAL SUPPORT

In case you encounter any problem, you are welcome to our support forums at www.mikroe.com/forum/. Here, you may also find helpful information, hardware tips, and practical code snippets. Your comments and suggestions on future development of the mikroC PRO for AVR are always appreciated — feel free to drop a note or two on our Wishlist.

In our Knowledge Base www.mikroe.com/en/kb/ you can find the answers to Frequently Asked Questions and solutions to known problems. If you can not find the solution to your problem in Knowledge Base then report it to Support Desk www.mikroe.com/en/support/. In this way, we can record and track down bugs more efficiently, which is in our mutual interest. We respond to every bug report and question in a suitable manner, ever improving our technical support.

HOW TO REGISTER

The latest version of the mikroC PRO for AVR is always available for downloading from our website. It is a fully functional software libraries, examples, and comprehensive help included.

The only limitation of the free version is that it cannot generate hex output over 2 KB. Although it might sound restrictive, this margin allows you to develop practical, working applications with no thinking of demo limit. If you intend to develop really complex projects in the mikroC PRO for AVR, then you should consider the possibility of purchasing the license key.

Who Gets the License Key

Buyers of the mikroC PRO for AVR are entitled to the license key. After you have completed the payment procedure, you have an option of registering your mikroC PRO. In this way you can generate hex output without any limitations.

How to Get License Key

After you have completed the payment procedure, start the program. Select Help › How to Register from the drop-down menu or click the How To Register Icon . Fill out the registration form (figure below), select your distributor, and click the Send button.

This will start your e-mail client with message ready for sending. Review the information you have entered, and add the comment if you deem it necessary. Please, do not modify the subject line.

Upon receiving and verifying your request, we will send the license key to the e-mail address you specified in the form.

After Receving the License Key

The license key comes as a small autoextracting file – just start it anywhere on your computer in order to activate your copy of compiler and remove the demo limit. You do not need to restart your computer or install any additional components. Also, there is no need to run the mikroC PRO for AVR at the time of activation.

Notes:

- The license key is valid until you format your hard disk. In case you need to format the hard disk, you should request a new activation key.
- Please keep the activation program in a safe place. Every time you upgrade the compiler you should start this program again in order to reactivate the license.

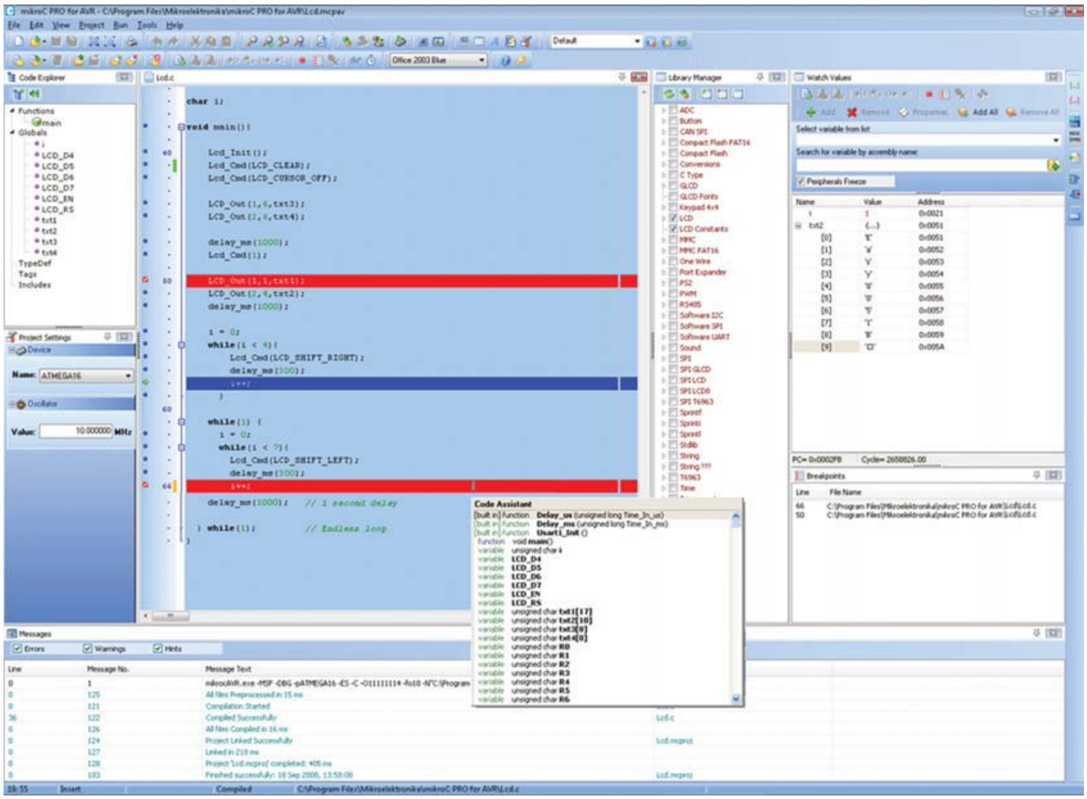
CHAPTER 2

mikroC PRO for AVR Environment

The mikroC PRO for AVR is an user-friendly and intuitive environment:

IDE OVERVIEW

The mikroC PRO for AVR is an user-friendly and intuitive environment:



- The Code Editor features adjustable Syntax Highlighting, Code Folding, Code Assistant, Parameters Assistant, Auto Correct for common typos and Code Templates (Auto Complete).
- The Code Explorer (with Keyboard shortcut browser and Quick Help browser) is at your disposal for easier project management.
- The Project Manager allows multiple project management
- General project settings can be made in the Project Settings window
- Library manager enables simple handling libraries being used in a project
- The Error Window displays all errors detected during compiling and linking.
- The source-level Software Simulator lets you debug executable logic step-by-step by watching the program flow.
- The New Project Wizard is a fast, reliable, and easy way to create a project.
- Help files are syntax and context sensitive.

- Like in any modern Windows application, you may customize the layout of mikroC PRO for AVR to suit your needs best.
- Spell checker underlines identifiers which are unknown to the project. In this way it helps the programmer to spot potential problems early, much before the project is compiled.

  Spell checker can be disabled by choosing the option in the Preferences dialog (F12).

MAIN MENU OPTIONS

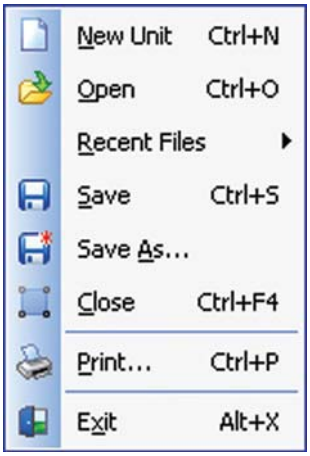
Available Main Menu options are:

- File
- Edit
- View
- Project
- Run
- Tools
- Help

Related topics: Keyboard shortcuts

FILE MENU OPTIONS

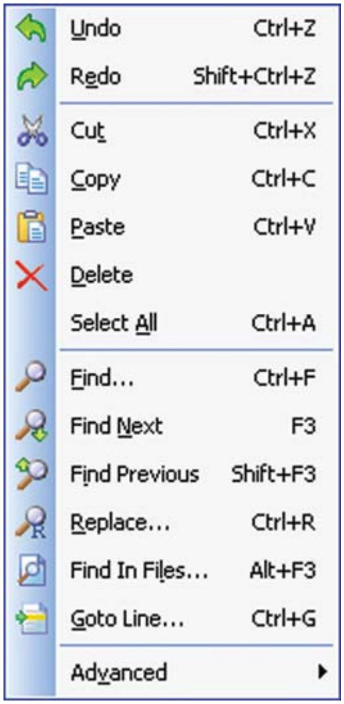
The File menu is the main entry point for manipulation with the source files.



File	Description
New Unit Ctrl+N	Open a new editor window.
Open Ctrl+O	Open source file for editing or image file for viewing.
Recent Files	Reopen recently used file.
Save Ctrl+S	Save changes for active editor.
Save As...	Save the active source file with the different name or change the file type.
Close Alt+F4	Close active source file.
Print... Ctrl+P	Print Preview.
Exit Alt+X	Exit IDE.

Related topics: Keyboard shortcuts, File Toolbar, Managing Source Files

EDIT MENU OPTIONS



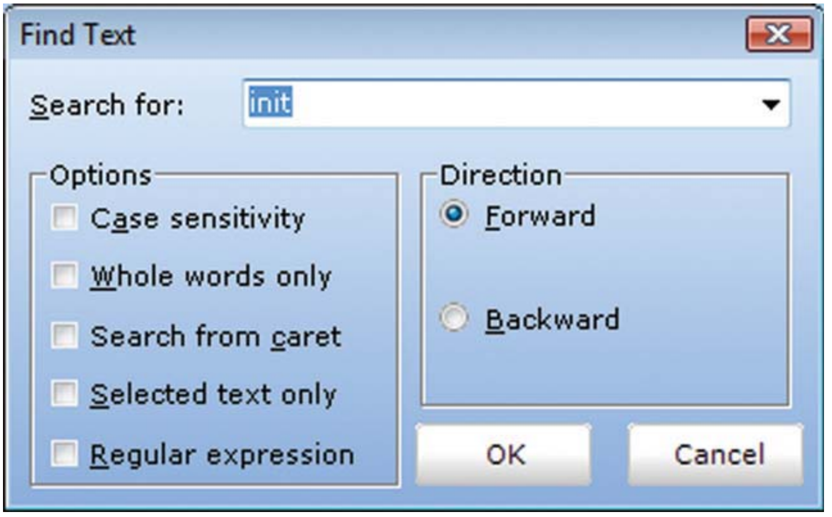
Edit	Description
Undo Ctrl+Z	Undo last change.
Redo Shift+Ctrl+Z	Redo last change.
Cut Ctrl+X	Cut selected text to clipboard.
Copy Ctrl+C	Copy selected text to clipboard.
Paste Ctrl+V	Paste text from clipboard.
Delete	Delete selected text.
Select All Ctrl+A	Select all text in active editor.
Find... Ctrl+F	Find text in active editor.

Find Next F3	Find next occurence of text in active editor.
Find Previous Shift+F3	Find previous occurence of text in active editor.
Replace... Ctrl+R	Replace text in active editor.
Find In Files... Alt+F3	Find text in current file, in all opened files, or in files from desired folder.
Goto Line... Ctrl+G	Goto to the desired line in active editor.
Advanced	Advanced Code Editor options

Advanced>>	**Description**
Comment Shift+Ctrl+.	Comment selected code or put single line comment if there is no selection.
Uncomment Shift+Ctrl+,	Uncomment selected code or remove single line comment if there is no selection.
Indent Shift+Ctrl+I	Indent selected code.
Outdent Shift+Ctrl+U	Outdent selected code.
Lowercase Ctrl+Alt+L	Changes selected text case to lowercase.
Uppercase Ctrl+Alt+U	Changes selected text case to uppercase.
Titlecase Ctrl+Alt+T	Changes selected text case to titlercase.

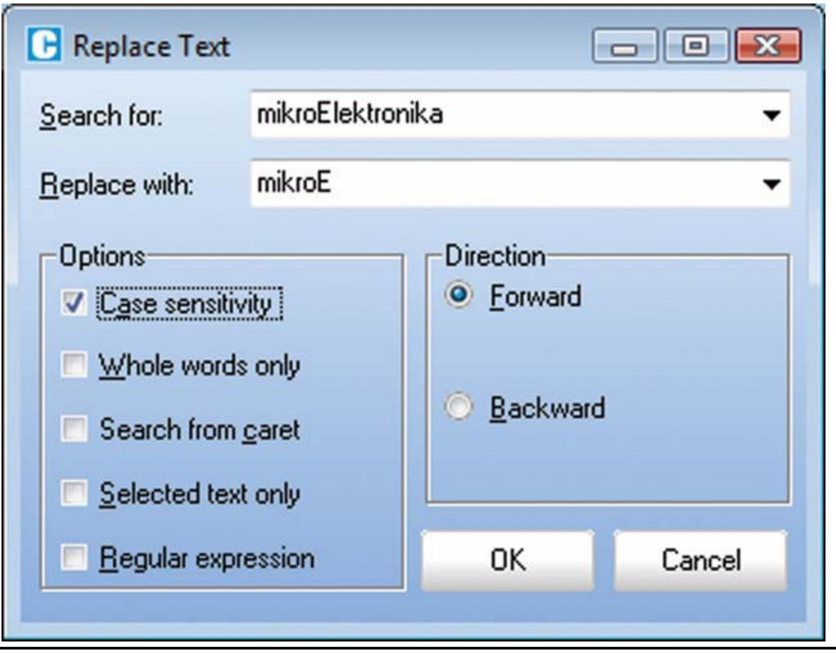
Find Text

Dialog box for searching the document for the specified text. The search is performed in the direction specified. If the string is not found a message is displayed.



Replace Text

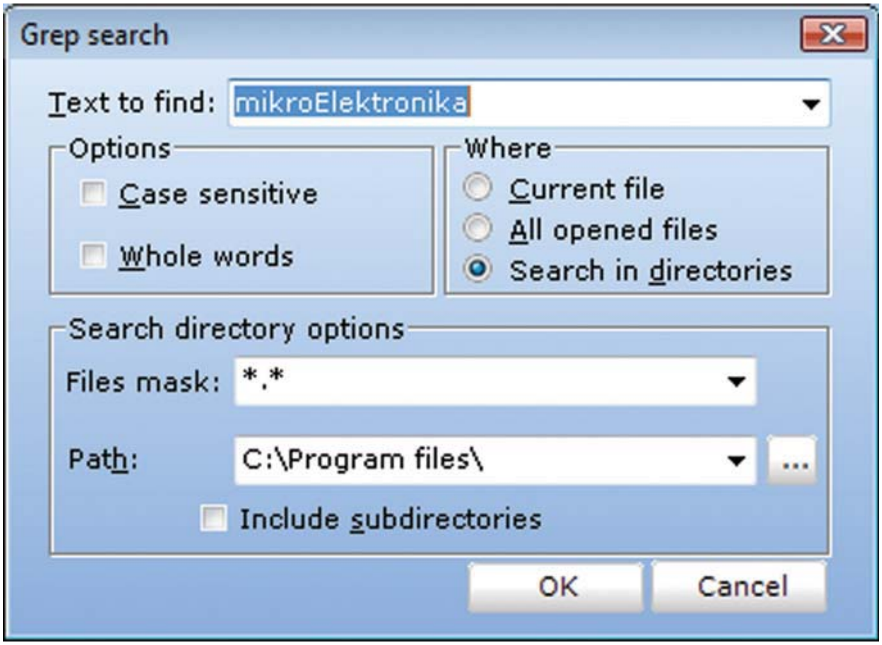
Dialog box for searching for a text string in file and replacing it with another text string.



Find In Files

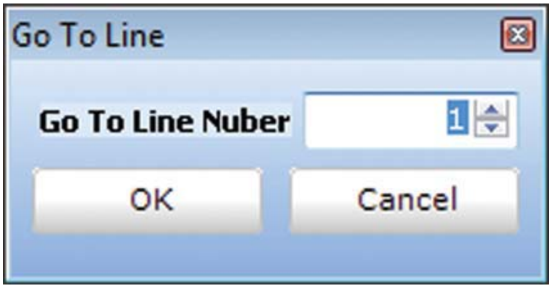
Dialog box for searching for a text string in current file, all opened files, or in files on a disk.

The string to search for is specified in the **Text to find** field. If Search in directories option is selected, The files to search are specified in the **Files mask** and **Path** fields.



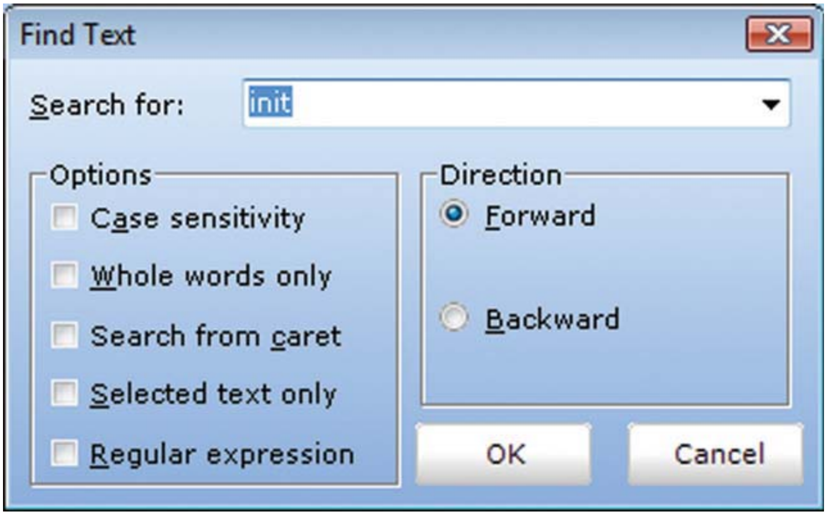
Go To Line

Dialog box that allows the user to specify the line number at which the cursor should be positioned.



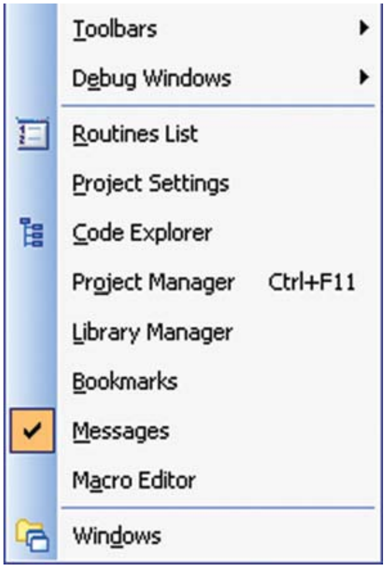
Regular expressions

By checking this box, you will be able to advance your search, through Regular expressions.



Related topics: Keyboard shortcuts, Edit Toolbar, Advanced Edit Toolbar

VIEW MENU OPTIONS

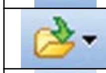
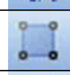


View	Description
Toolbars	Show/Hide toolbars.
Debug Windows	Show/Hide debug windows.
Routines List	Show/Hide Routine List in active editor.
Project Settings	Show/Hide Project Settings window.
Code Explorer	Show/Hide Code Explorer window.
Project Manager Shift+Ctrl+F11	Show/Hide Project Manager window.
Library Manager	Show/Hide Library Manager window.
Bookmarks	Show/Hide Bookmarks window.
Messages	Show/Hide Error Messages window.
Macro Editor	Show/Hide Macro Editor window.
Windows	Show Window List window.

TOOLBARS

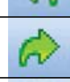
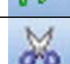
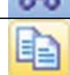
File Toolbar

File Toolbar is a standard toolbar with following options:

Icon	Description
	Opens a new editor window.
	Open source file for editing or image file for viewing.
	Save changes for active window.
	Save changes in all opened windows.
	Close current editor.
	Close all editors.
	Print Preview.

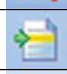
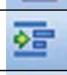
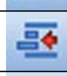
Edit Toolbar

Edit Toolbar is a standard toolbar with following options:

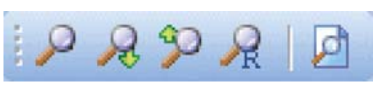
Icon	Description
	Undo last change.
	Redo last change.
	Cut selected text to clipboard.
	Copy selected text to clipboard.
	Paste text from clipboard.

Advanced Edit Toolbar

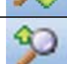
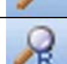
Advanced Edit Toolbar comes with following options:

Icon	Description
	Comment selected code or put single line comment if there is no selection
	Uncomment selected code or remove single line comment if there is no selection.
	Select text from starting delimiter to ending delimiter.
	Go to ending delimiter.
	Go to line.
	Indent selected code lines.
	Outdent selected code lines.
	Generate HTML code suitable for publishing current source code on the web.

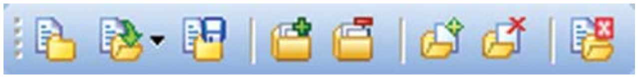
Find/Replace Toolbar



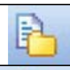
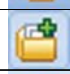
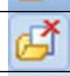
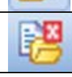
Find/Replace Toolbar is a standard toolbar with following options:

Icon	Description
	Find text in current editor.
	Find next occurence.
	Find previous occurence.
	Replace text.
	Find text in files.

Project Toolbar

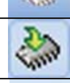
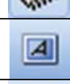


Project Toolbar comes with following options:

Icon	Description
	Open new project wizard. wizard.
	Open Project.
	Save Project.
	Add existing project to project group.
	Remove existing project from project group.
	Add File To Project.
	Remove File From Project.
	Close current project.

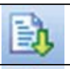
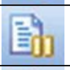
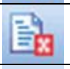
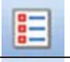
Build Toolbar

Build Toolbar comes with following options:

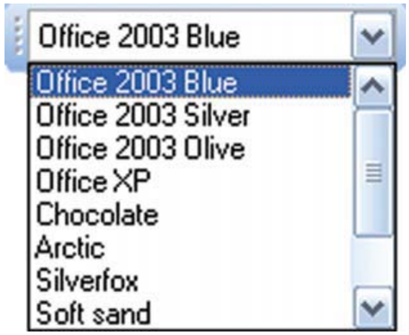
Icon	Description
	Build current project.
	Build all opened projects.
	Build and program active project.
	Start programmer and load current HEX file.
	Open assembly code in editor.
	View statistics for current project.

Debugger

Debugger Toolbar comes with following options:

Icon	Description
	Start Software Simulator.
	Run/Pause debugger.
	Stop debugger.
	Step into.
	Step over.
	Step out.
	Run to cursor.
	Toggle breakpoint.
	Toggle breakpoints.
	Clear breakpoints.
	View watch window
	View stopwatch window

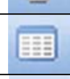
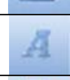
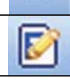
Styles Toolbar



Styles toolbar allows you to easily customize your workspace.

Tools Toolbar

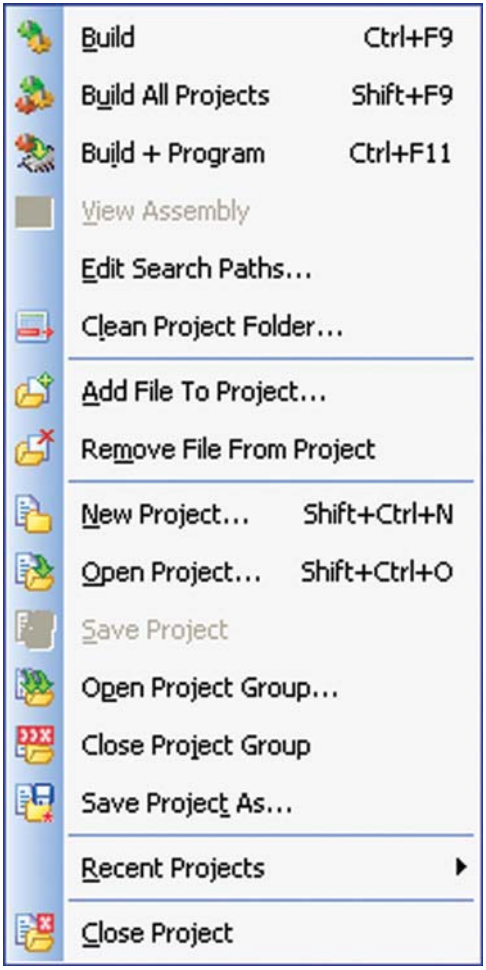
Tools Toolbar comes with following default options:

Icon	Description
	Run USART Terminal
	EEPROM
	ASCII Chart
	Seven segment decoder tool.

The Tools toolbar can easily be customized by adding new tools in Options(F12) window.

Related topics: Keyboard shortcuts, Integrated Tools, Debugger Windows

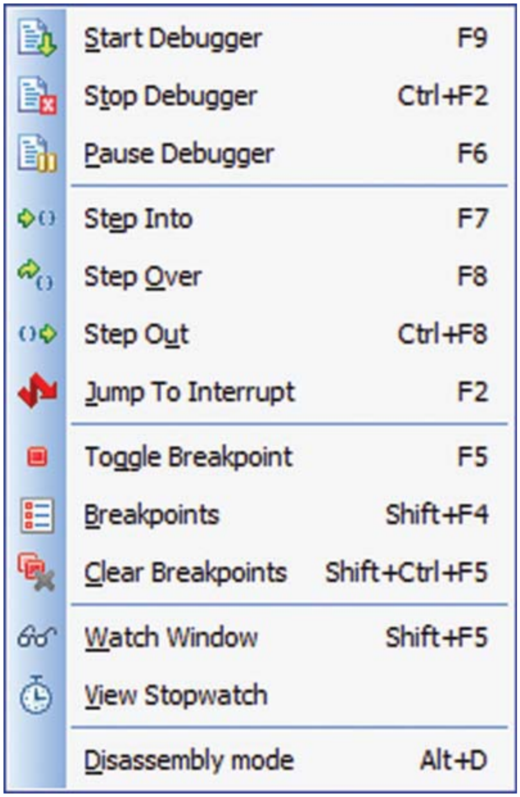
PROJECT MENU OPTIONS



Project	Description
Build Ctrl+F9	Build active project.
Build All Shift+F9	Build all projects.
Build + Program Ctrl+F11	Build and program active project.
View Assembly	View Assembly.
Edit Search Paths...	Edit search paths.
Clean Project Folder...	Clean Project Folder
Add File To Project...	Add file to project.
Remove File From Project	Remove file from project.
New Project...	Open New Project Wizard
Open Project... Shift+Ctrl+O	Open existing project.
Save Project	Save current project.
Open Project Group...	Open project group.
Close Project Group	Close project group.
Save Project As...	Save active project file with the different name.
Recent Projects	Open recently used project.
Close Project	Close active project.

Related topics: Keyboard shortcuts, Project Toolbar, Creating New Project, Project Manager, Project Settings

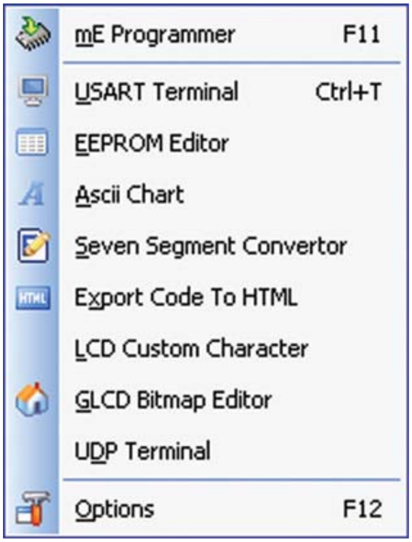
RUN MENU OPTIONS



Run	Description
Start Debugger F9	Start Software Simulator.
Stop Debugger Ctrl+F2	Stop debugger.
Pause Debugger F6	Pause Debugger.
Step Into F7	Step Into.
Step Over F8	Step Over.
Step Out Ctrl+F8	Step Out.
Jump To Interrupt F2	Jump to interrupt in current project.
Toggle Breakpoint F5	Toggle Breakpoint.
Show/Hide Breakpoints Shift+F4	Breakpoints.
Clear Breakpoints Shift+Ctrl+F5	Clear Breakpoints.
Watch Window Shift+F5	Show/Hide Watch Window
View Stopwatch	Show/Hide Stopwatch Window
Disassembly mode Ctrl+D	Toggle between C source and disassembly.

Related topics: Keyboard shortcuts, Debug Toolbar

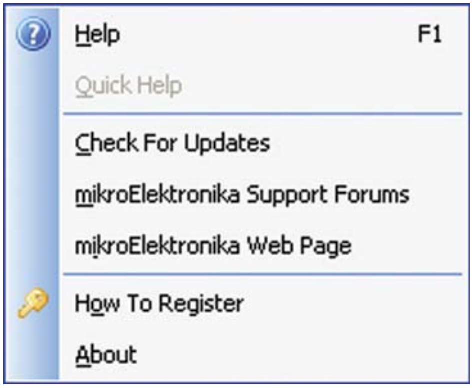
TOOLS MENU OPTIONS



Tools	Description
mE Programmer F11	Run mikroElektronika Programmer
USART Terminal Ctrl+T	Run USART Terminal
EEPROM Editor	Run EEPROM Editor
Ascii Chart	Run ASCII Chart
Seven Segment Convertor	Run 7 Segment Display Decoder
Export Code To HTML	Generate HTML code suitable for publishing source code on the web.
LCD Custom Character	Generate your own custom LCD characters
GLCD Bitmap Editor	Generate bitmap pictures for GLCD
UDP Terminal	UDP communication terminal.
Options F12	Open Options window

Related topics: Keyboard shortcuts, Tools Toolbar

HELP MENU OPTIONS



Help	Description
Help	Îpen Help File.
Quick Help	Quick Help.
Check For Updates	Check if new compiler version is available.
mikroElektronika Support Forums	Open mikroElektronika Support Forums in a default browser.
mikroElektronika Web Page	Open mikroElektronika Web Page in a default browser.
How To Register	Information on how to register.
About	Open About window.

Related topics: Keyboard shortcuts

KEYBOARD SHORTCUTS

Below is a complete list of keyboard shortcuts available in mikroC PRO for AVR IDE. You can also view keyboard shortcuts in the Code Explorer window, tab Keyboard.

IDE Shortcuts	
F1	Help
Ctrl+N	New Unit
Ctrl+O	Open
Ctrl+Shift+O	Open Project
Ctrl+Shift+N	Open New Project
Ctrl+K	Close Project
Ctrl+F9	Compile
Shift+F9	Compile All
Ctrl+F11	Compile and Program
Shift+F4	View breakpoints
Ctrl+Shift+F5	Clear breakpoints
F11	Start AVRFlash Programmer
F12	Preferences
Basic Editor Shortcuts	
F3	Find, Find Next
Shift+F3	Find Previous
Alt+F3	Grep Search, Find in Files
Ctrl+A	Grep Search, Find in Files
Ctrl+C	Copy
Ctrl+F	Find
Ctrl+R	Replace
Ctrl+P	Print
Ctrl+S	Save unit
Ctrl+Shift+S	Save All
Ctrl+V	Paste

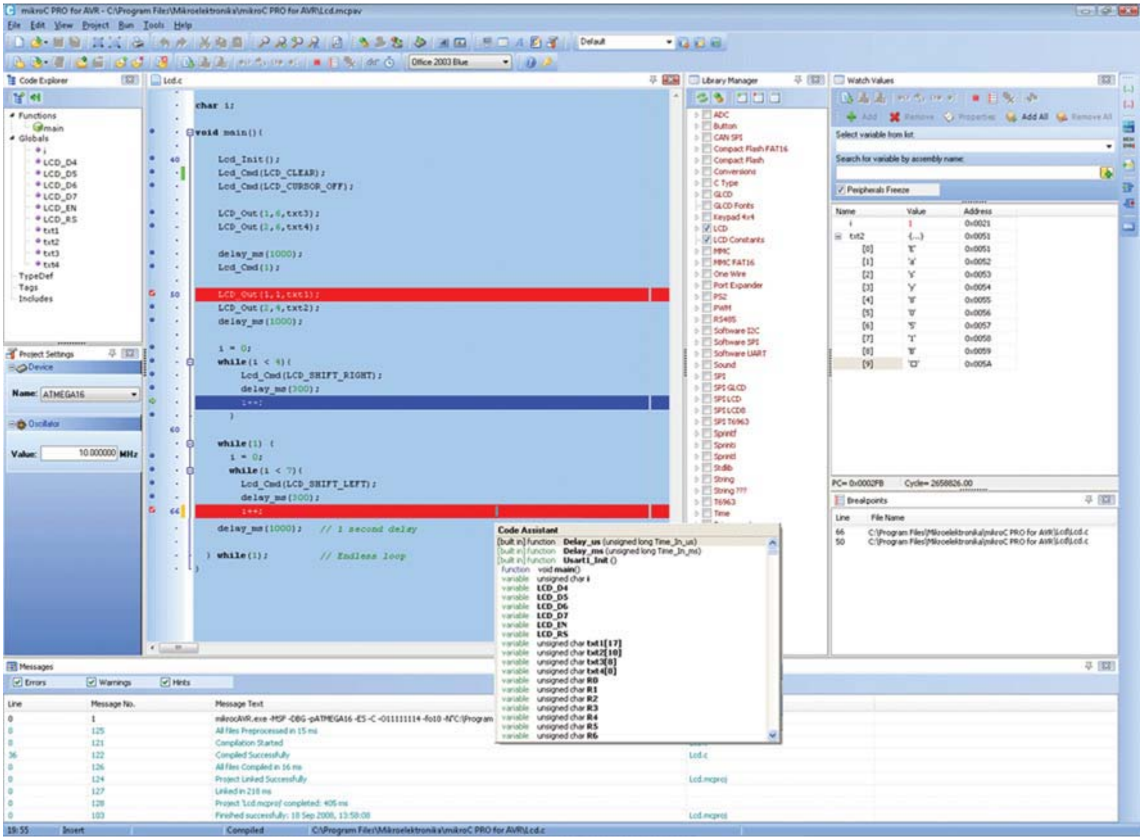
Ctrl+X	Cut
Ctrl+Y	Delete entire line
Ctrl+Z	Undo
Ctrl+Shift+Z	Redo
Advanced Editor Shortcuts	
Ctrl+Space	Code Assistant
Ctrl+Shift+Space	Parameters Assistant
Ctrl+D	Find declaration
Ctrl+E	Incremental Search
Ctrl+L	Routine List
Ctrl+G	Goto line
Ctrl+J	Insert Code Template
Ctrl+Shift+.	Comment Code
Ctrl+Shift+,	Uncomment Code
Ctrl+*number*	Goto bookmark
Ctrl+Shift+*number*	Set bookmark
Ctrl+Shift+I	Indent selection
Ctrl+Shift+U	Unindent selection
TAB	Indent selection
Shift+TAB	Unindent selection
Alt+Select	Select columns
Ctrl+Alt+Select	Select columns
Ctrl+Alt+L	Convert selection to lowercase
Ctrl+Alt+U	Convert selection to uppercase
Ctrl+Alt+T	Convert to Titlecase

Software Simulator Shortcuts	
F2	Jump To Interrupt
F4	Run to Cursor
F5	Toggle Breakpoint
F6	Run/Pause Debugger
F7	Step into
F8	Step over
F9	Debug
Ctrl+F2	Reset
Ctrl+F5	Add to Watch List
Ctrl+F8	Step out
Alt+D	Dissasembly view
Shift+F5	Open Watch Window

MIKROC PRO FOR AVR IDE

IDE Overview

The mikroC PRO for AVR is an user-friendly and intuitive environment:



- The Code Editor features adjustable Syntax Highlighting, Code Folding, Code Assistant, Parameters Assistant, Auto Correct for common typos and Code Templates (Auto Complete).
- The Code Explorer (with Keyboard shortcut browser and Quick Help browser) is at your disposal for easier project management.
- The Project Manager alows multiple project management.
- General project settings can be made in the Project Settings window.
- Library manager enables simple handling libraries being used in a project.
- The Error Window displays all errors detected during compiling and linking.
- The source-level Software Simulator lets you debug executable logic step-by-step by watching the program flow.

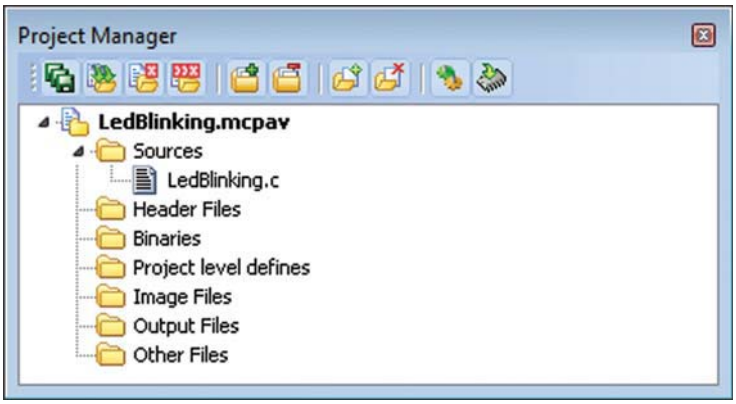
- The New Project Wizard is a fast, reliable, and easy way to create a project.
- Help files are syntax and context sensitive.
- Like in any modern Windows application, you may customize the layout of mikroC PRO for AVR to suit your needs best.
- Spell checker underlines identifiers which are unknown to the project. In this way it helps the programmer to spot potential problems early, much before the project is compiled.
  Spell checker can be disabled by choosing the option in the Preferences dialog (F12).

CUSTOMIZING IDE LAYOUT

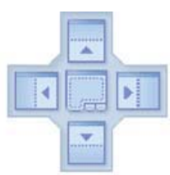
Docking Windows

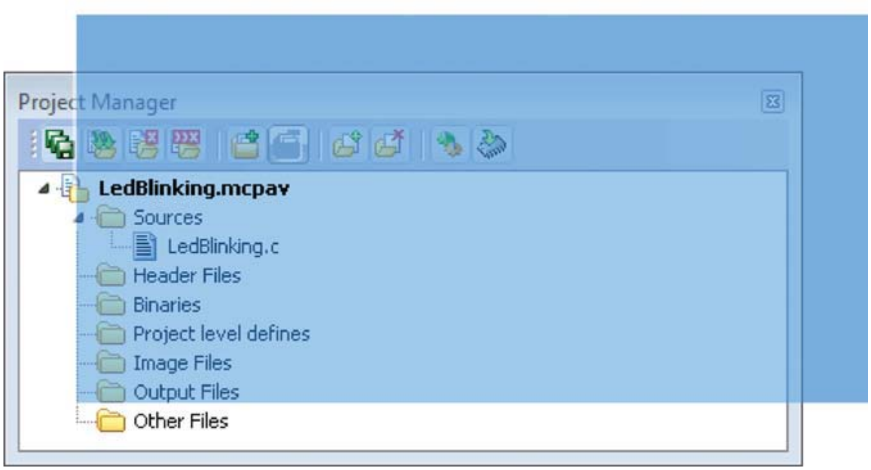
You can increase the viewing and editing space for code, depending on how you arrange the windows in the IDE.

Step 1: Click the window you want to dock, to give it focus.

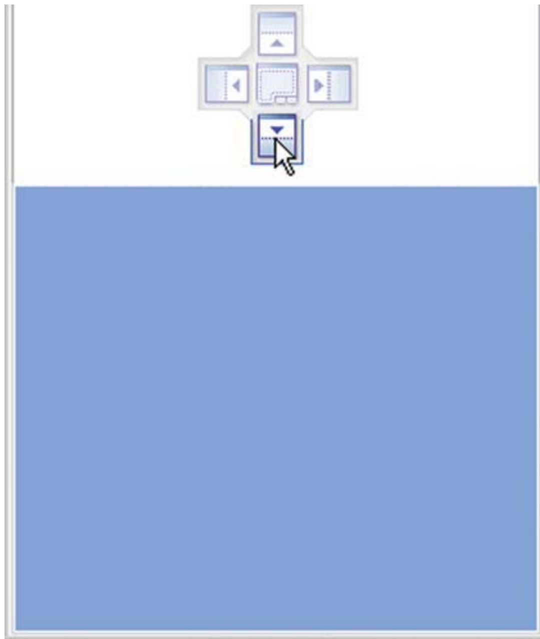


Step 2: Drag the tool window from its current location. A guide diamond appears. The four arrows of the diamond point towards the four edges of the IDE.





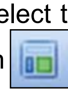
Step 3: Move the pointer over the corresponding portion of the guide diamond. An outline of the window appears in the designated area.

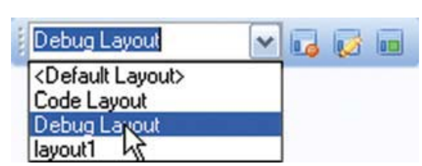


Step 4: To dock the window in the position indicated, release the mouse button.

Tip: To move a dockable window without snapping it into place, press CTRL while dragging it.

Saving Layout

Once you have a window layout that you like, you can save the layout by typing the name for the layout and pressing the Save Layout Icon  .
To set the layout select the desired layout from the layout drop-down list and click the Set Layout Icon  .
To remove the layout from the drop-down list, select the desired layout from the list and click the Delete Layout Icon  .

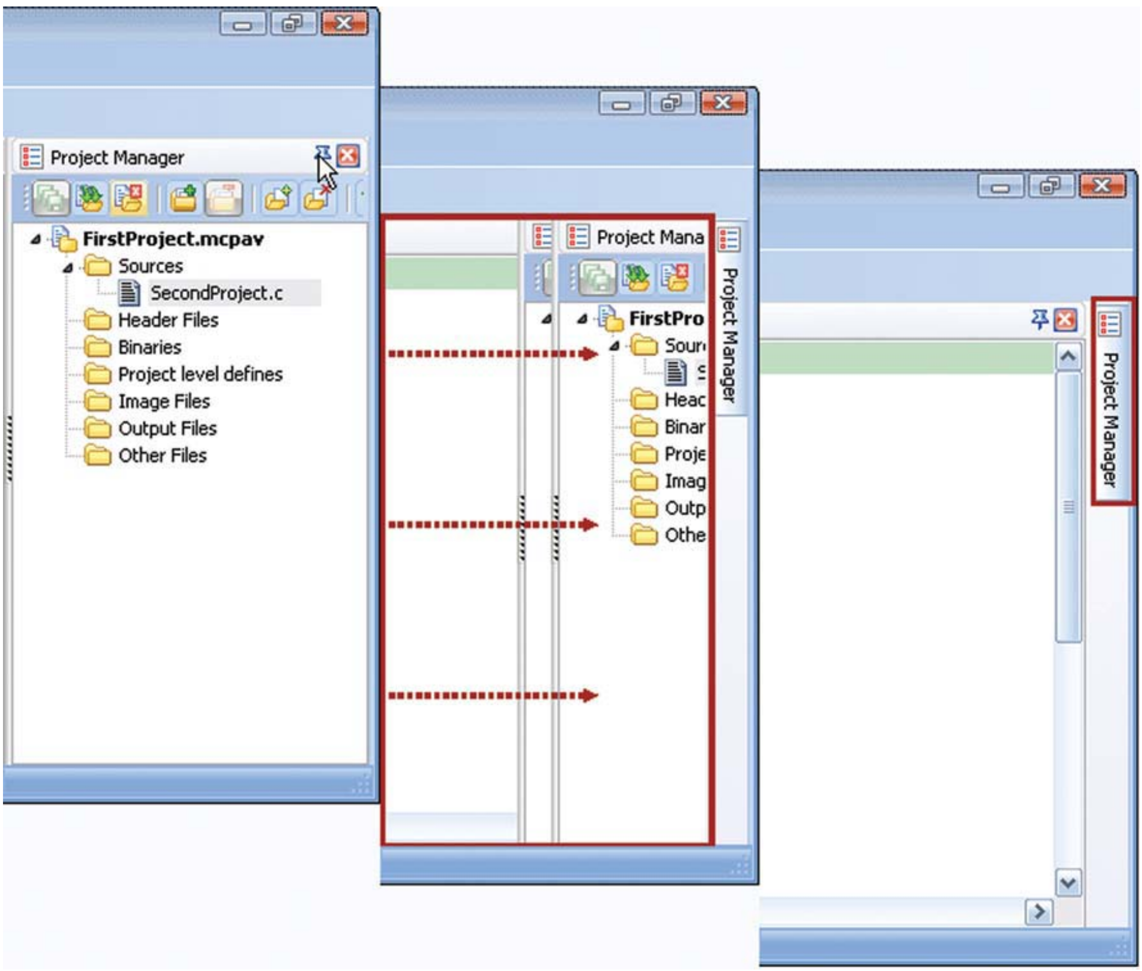


Auto Hide

Auto Hide enables you to see more of your code at one time by minimizing tool windows along the edges of the IDE when not in use.

-Click the window you want to keep visible to give it focus.

-Click the Pushpin Icon  on the title bar of the window.



When an auto-hidden window loses focus, it automatically slides back to its tab on the edge of the IDE. While a window is auto-hidden, its name and icon are visible on a tab at the edge of the IDE. To display an auto-hidden window, move your pointer over the tab. The window slides back into view and is ready for use.

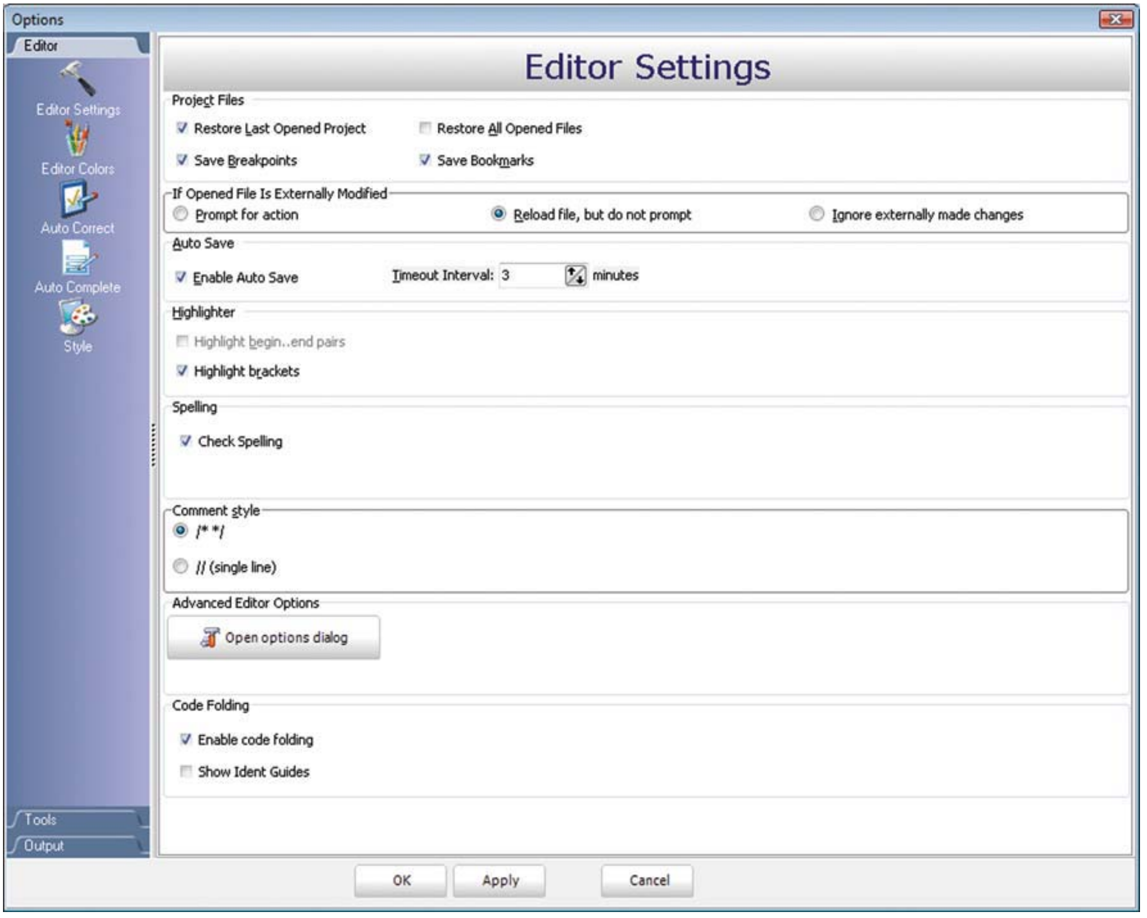
ADVANCED CODE EDITOR

The Code Editor is advanced text editor fashioned to satisfy needs of professionals. General code editing is the same as working with any standard text-editor, including familiar Copy, Paste and Undo actions, common for Windows environment.

Advanced Editor Features

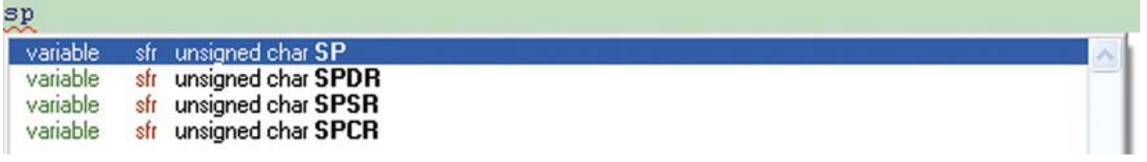
- Adjustable Syntax Highlighting
- Code Assistant
- Code Folding
- Parameter Assistant
- Code Templates (Auto Complete)
- Auto Correct for common typos
- Spell Checker
- Bookmarks and Goto Line
- Comment / Uncomment

You can configure the Syntax Highlighting, Code Templates and Auto Correct from the Editor Settings dialog. To access the Settings, click Tools › Options from the drop-down menu, click the Show Options Icon  or press F12 key.



Code Assistant

If you type the first few letters of a word and then press *Ctrl+Space*, all valid identifiers matching the letters you have typed will be prompted in a floating panel (see the image below). Now you can keep typing to narrow the choice, or you can select one from the list using the keyboard arrows and *Enter*.



Code Folding

Code folding is IDE feature which allows users to selectively hide and display sections of a source file. In this way it is easier to manage large regions of code within one window, while still viewing only those subsections of the code that are relevant during a particular editing session.

While typing, the code folding symbols (⊟ and ⊞) appear automatically. Use the folding symbols to hide/unhide the code subsections.

```
void main(){

        PORTA = 0;
        PORTB = 0;
        Lcd_Init();
        LCD_Out(1,1,txt[0]);
        LCD_Out(2,1,txt[1]);
        delay_ms(1000);
        Lcd_Cmd(1);

        LCD_Out(1,1,txt[1]);
        LCD_Out(2,4,txt[2]);
        delay_ms(500);
   }
```

```
void main(){ ...
```

If you place a mouse cursor over the tooltip box, the collapsed text will be shown in a tooltip style box.

```
void main(){ ...
void main(){

        PORTA = 0;
        PORTB = 0;
        Lcd_Init();
        LCD_Out(1,1,txt[0]);
        LCD_Out(2,1,txt[1]);
        delay_ms(1000);
        Lcd_Cmd(1);

        LCD_Out(1,1,txt[1]);
        LCD_Out(2,4,txt[2]);
        delay_ms(500);
   }
```

Parameter Assistant

The Parameter Assistant will be automatically invoked when you open parenthesis "(" or press *Shift+Ctrl+Space*. If the name of a valid function precedes the parenthesis, then the expected parameters will be displayed in a floating panel. As you type the actual parameter, the next expected parameter will become bold.

Code Templates (Auto Complete)

You can insert the Code Template by typing the name of the template (for instance, whiles), then press *Ctrl+J* and the Code Editor will automatically generate a code.

You can add your own templates to the list. Select **Tools › Options** from the drop-down  menu, or click the Show Options Icon and then select the Auto Complete Tab. Here you can enter the appropriate keyword, description and code of your template.

Autocomplete macros can retreive system and project information:

- `%DATE%` - current system date
- `%TIME%` - current system time
- `%DEVICE%` - device(MCU) name as specified in project settings
- `%DEVICE_CLOCK%` - clock as specified in project settings
- `%COMPILER%` - current compiler version

These macros can be used in template code, see template `ptemplate` provided with mikroC PRO for AVR installation.

Auto Correct

The Auto Correct feature corrects common typing mistakes. To access the list of rec-  ognized typos, select **Tools › Options** from the drop-down menu, or click the Show Options Icon and then select the Auto Correct Tab. You can also add your own preferences to the list.

Also, the Code Editor has a feature to comment or uncomment the selected code by simple click of a mouse, using the Comment Icon  and Uncomment Icon  from the Code Toolbar.

Spell Checker

The Spell Checker underlines unknown objects in the code, so they can be easily noticed and corrected before compiling your project.

Select **Tools › Options** from the drop-down menu, or click the Show Options Icon  and then select the Spell Checker Tab.

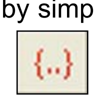
Bookmarks

Bookmarks make navigation through a large code easier. To set a bookmark, use *Ctrl+Shift+number*. To jump to a bookmark, use *Ctrl+number*.

Goto Line

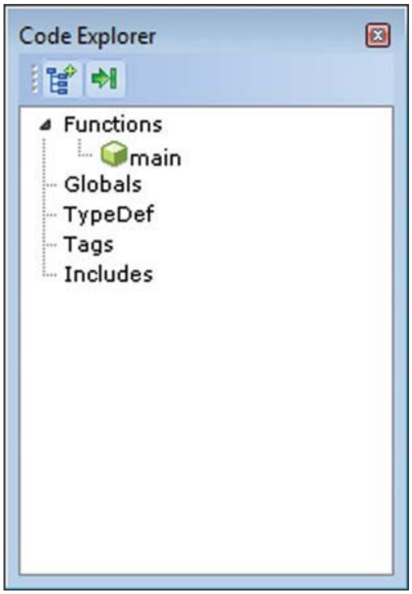
The Goto Line option makes navigation through a large code easier. Use the shortcut *Ctrl+G* to activate this option.

Comment / Uncomment

Also, the Code Editor has a feature to comment or uncomment the selected code by simple click of a mouse, using the Comment Icon  and Uncomment Icon  from the Code Toolbar.

CODE EXPLORER

The Code Explorer gives clear view of each item declared inside the source code. You can jump to a declaration of any item by right clicking it. Also, besides the list of defined and declared objects, code explorer displays message about first error and it's location in code.



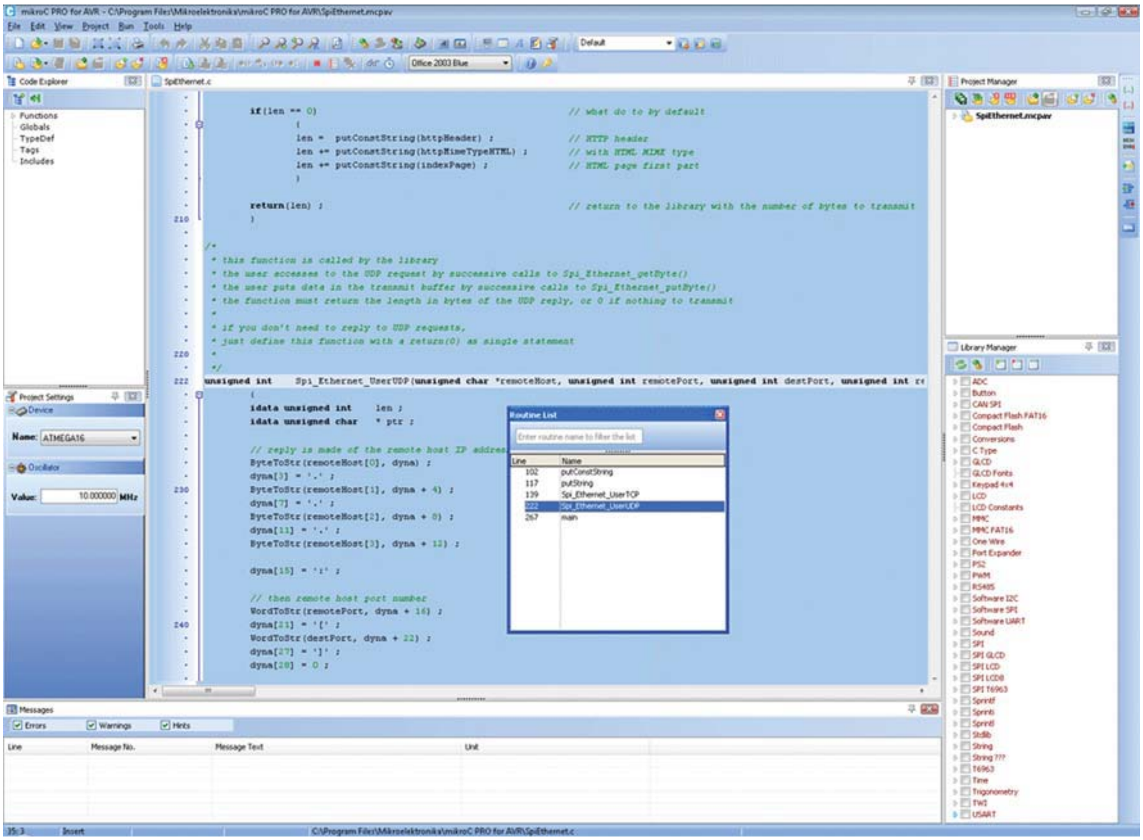
Following options are available in the Code Explorer:

Icon	Description
	Expand/Collapse all nodes in tree.
	Locate declaration in code.

ROUTINE LIST

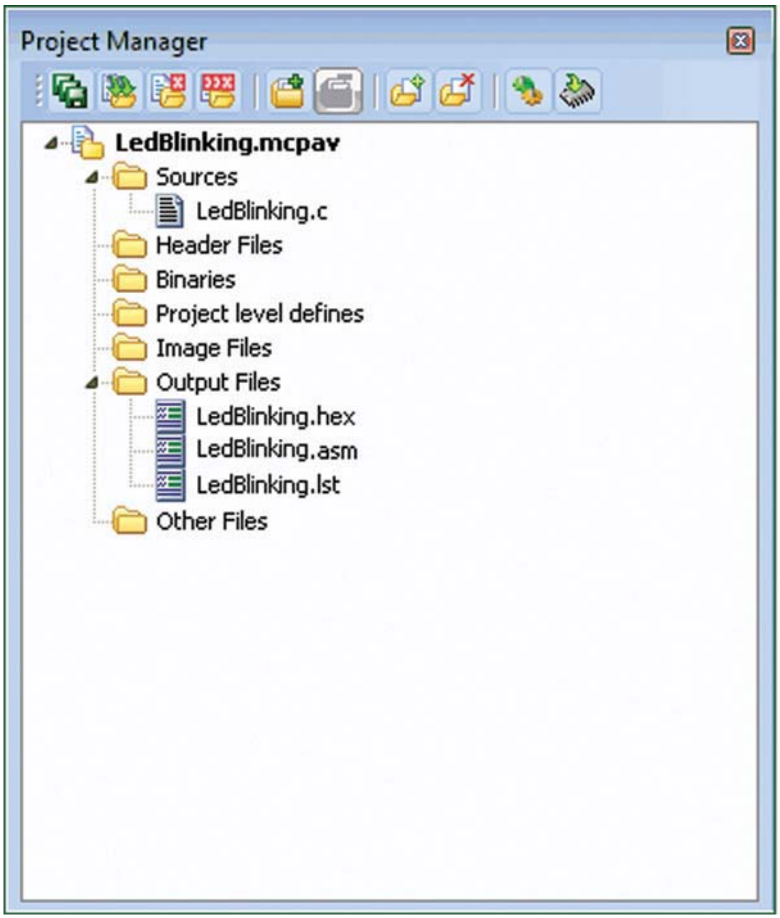
Routine list diplays list of routines, and enables filtering routines by name. Routine list window can be accessed by pressing *Ctrl+L*.

You can jump to a desired routine by double clicking on it.

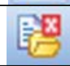
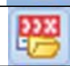
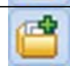
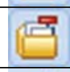


PROJECT MANAGER

Project Manager is IDE feature which allows users to manage multiple projects. Several projects which together make project group may be open at the same time. Only one of them may be active at the moment.
Setting project in **active** mode is performed by **double click** on the desired project in the Project Manager.



Following options are available in the Project Manager:

Icon	Description
	Save project Group.
	Open project group.
	Close the active project.
	Close project group.
	Add project to the project group.
	Remove project from the project group.
	Add file to the active project.
	Remove selected file from the project.
	Build the active project.
	Run mikroElektronika's Flash programmer.

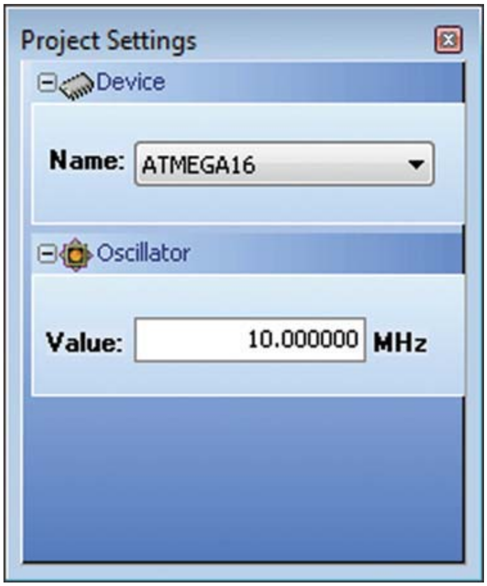
For details about adding and removing files from project see Add/Remove Files from Project.

Related topics: Project Settings, Project Menu Options, File Menu Options, Project Toolbar, Build Toolbar, Add/Remove Files from Project

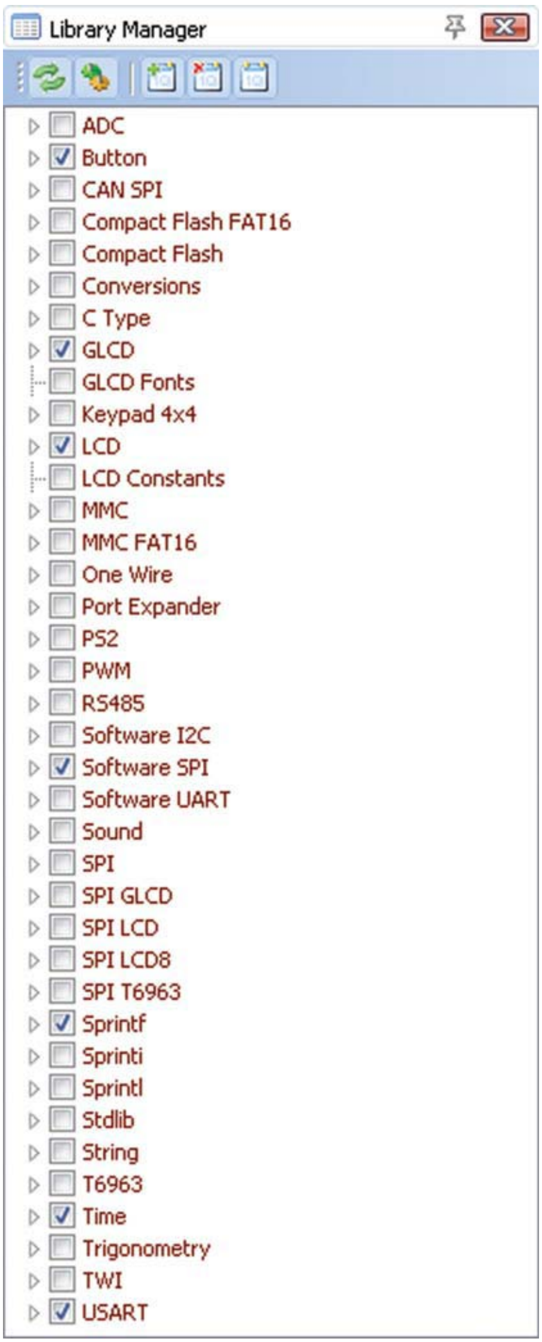
PROJECT SETTINGS WINDOW

Following options are available in the Project Settings Window:

- Device - select the appropriate device from the device drop-down list.
- Oscillator - enter the oscillator frequency value.



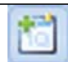
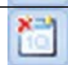
LIBRARY MANAGER



Library Manager enables simple handling libraries being used in a project. Library Manager window lists all libraries (extencion .mcl) which are instantly stored in the compiler Uses folder. The desirable library is added to the project by selecting check box next to the library name.

In order to have all library functions accessible, simply press the button **Check All**  and all libraries will be selected. In case none library is needed in a project, press the button **Clear All**  and all libraries will be cleared from the project.

Only the selected libraries will be linked.

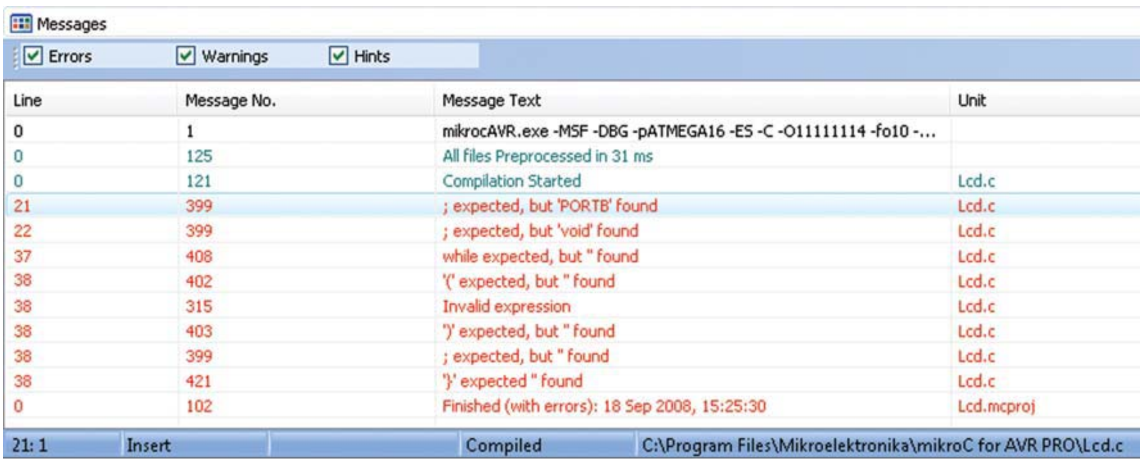
Icon	Description
	Refresh Library by scanning files in "Uses" folder.Useful when new libraries are added by copying files to "Uses" folder.
	Rebuild all available libraries. Useful when library sources are available and need refreshing.
	Include all available libraries in current project.
	No libraries from the list will be included in current project.
	Restore library to the state just before last project saving.

Related topics: mikroC PRO for AVR Libraries, Creating New Library

ERROR WINDOW

In case that errors were encountered during compiling, the compiler will report them and won't generate a hex file. The Error Window will be prompted at the bottom of the main window by default.

The Error Window is located under message tab, and displays location and type of errors the compiler has encountered. The compiler also reports warnings, but these do not affect the output; only errors can interefere with the generation of hex.



Double click the message line in the Error Window to highlight the line where the error was encountered.

Related topics: Error Messages

STATISTICS

After successful compilation, you can review statistics of your code. Click the Statistics Icon  .

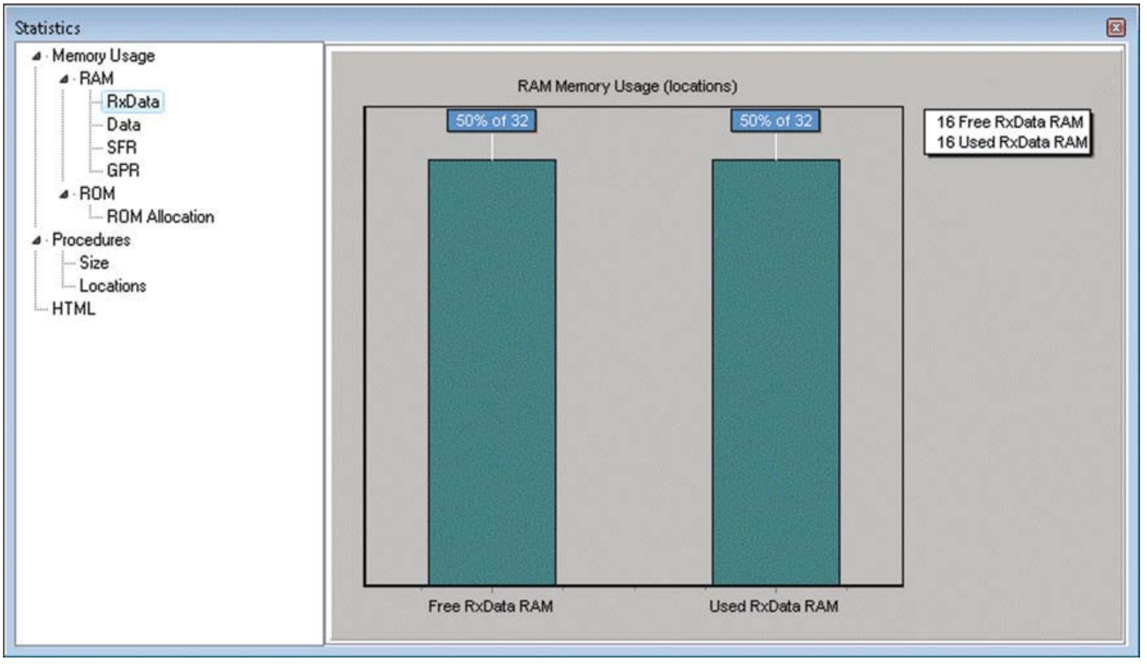
Memory Usage Windows

Provides overview of RAM and ROM usage in the form of histogram.

RAM Memory

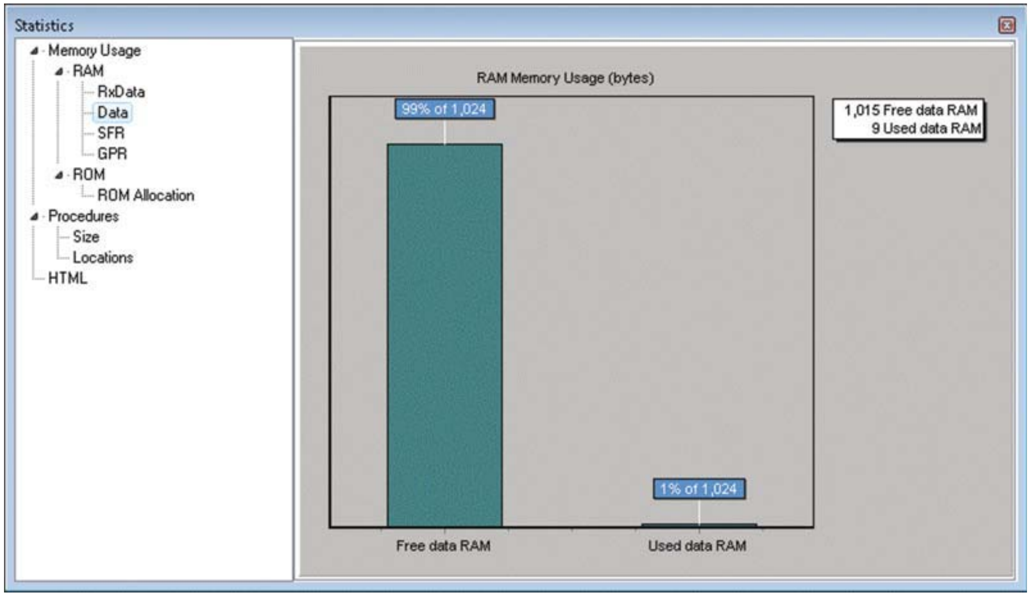
Rx Memory Space

Displays Rx memory space usage in form of histogram.



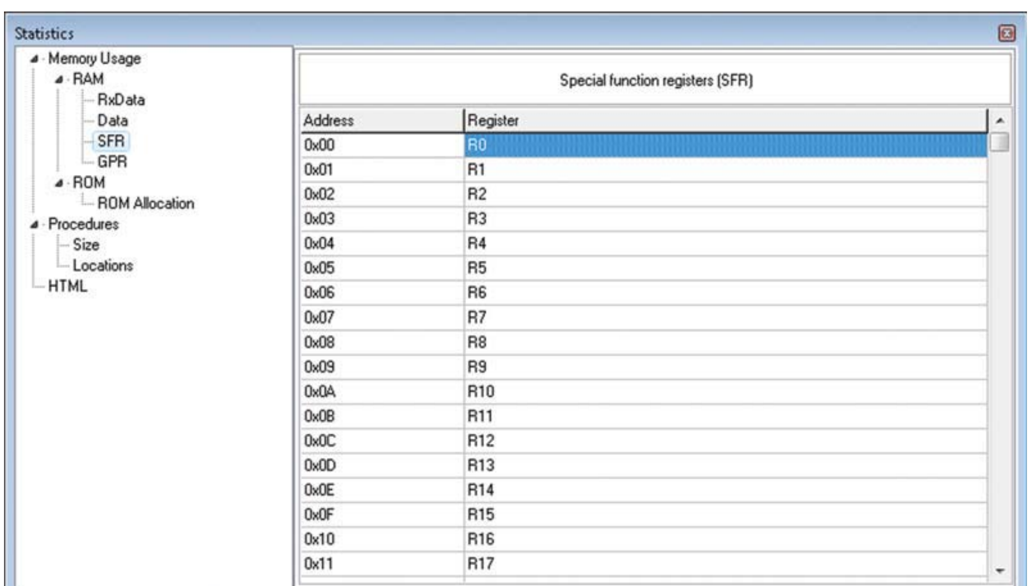
Data Memory Space

Displays Data memory space usage in form of histogram.



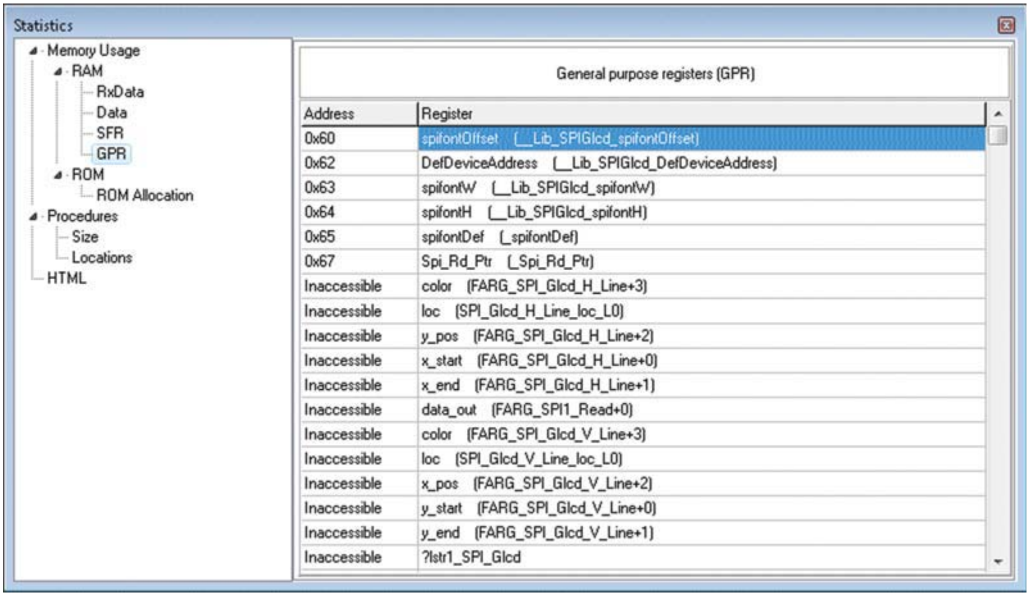
Special Function Registers

Summarizes all Special Function Registers and their addresses.



General Purpose Registers

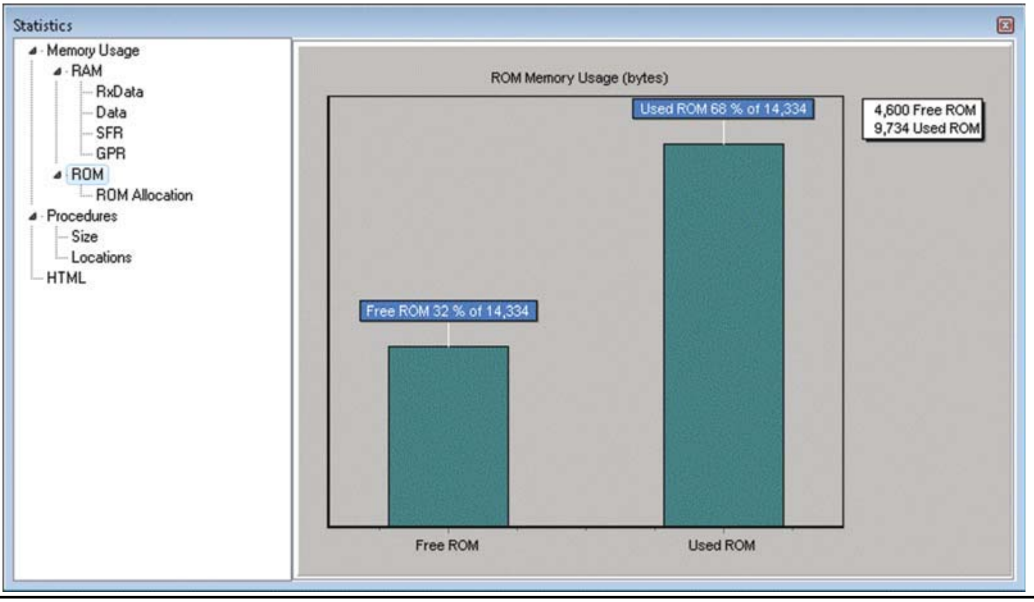
Summarizes all General Purpose Registers and their addresses. Also displays symbolic names of variables and their addresses.



ROM Memory

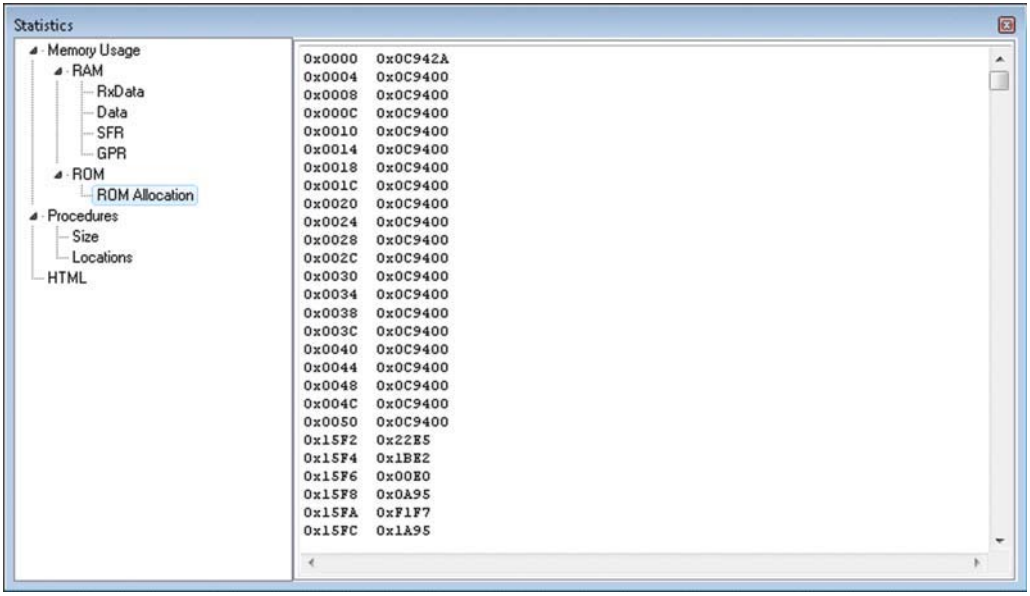
ROM Memory Usage

Displays ROM memory usage in form of histogram.



ROM Memory Allocation

Displays ROM memory allocation.

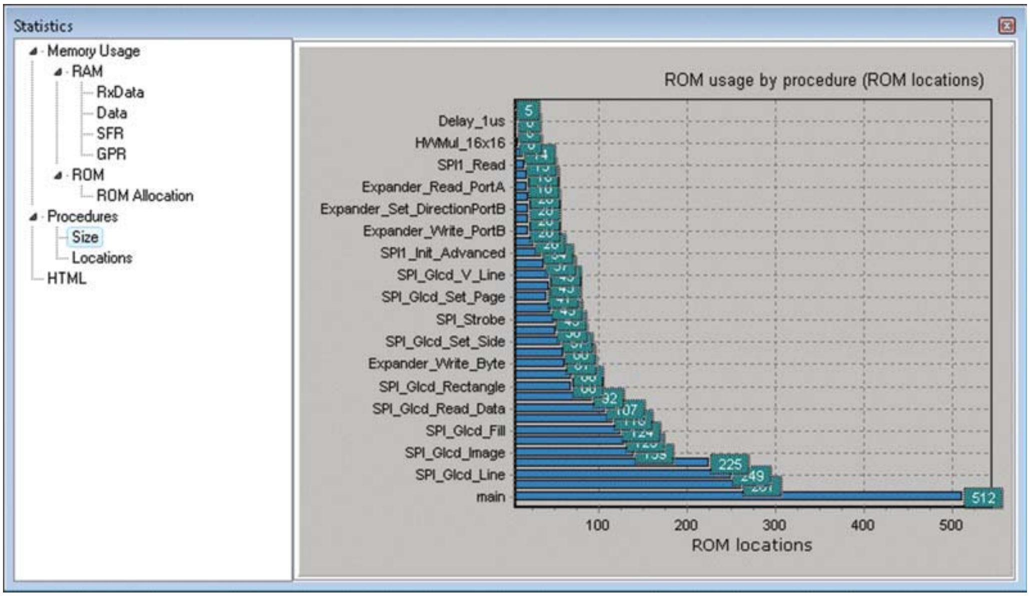


Procedures Windows

Provides overview procedures locations and sizes.

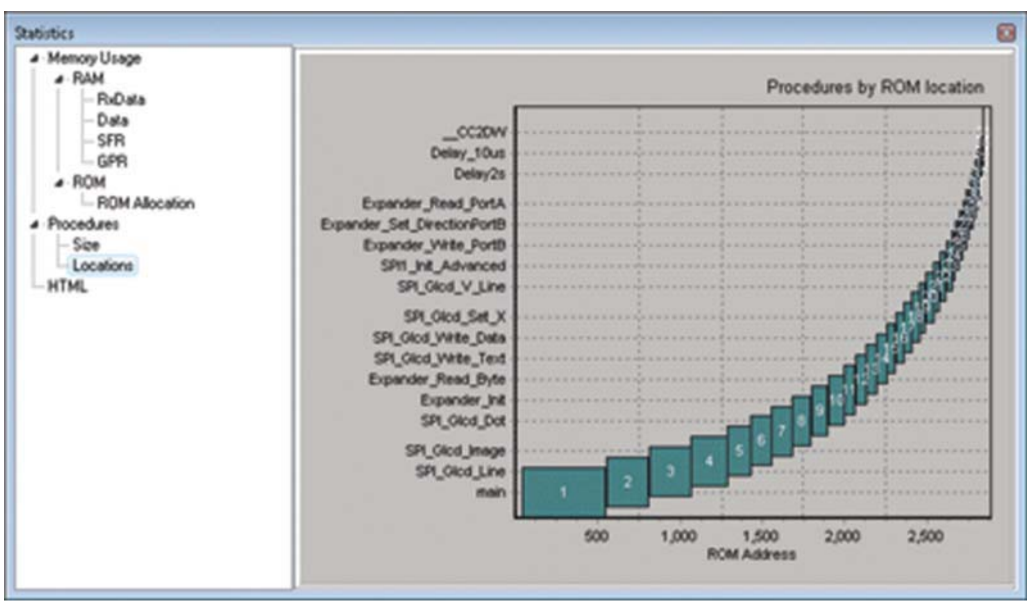
Procedures Size Window

Displays size of each procedure.



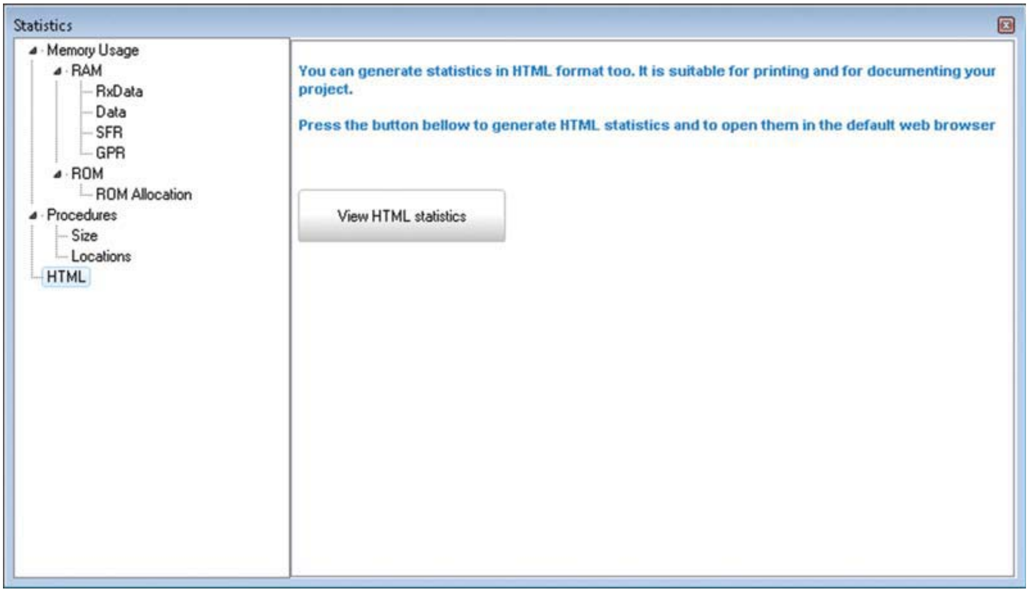
Procedures Locations Window

Displays how functions are distributed in microcontroller's memory.



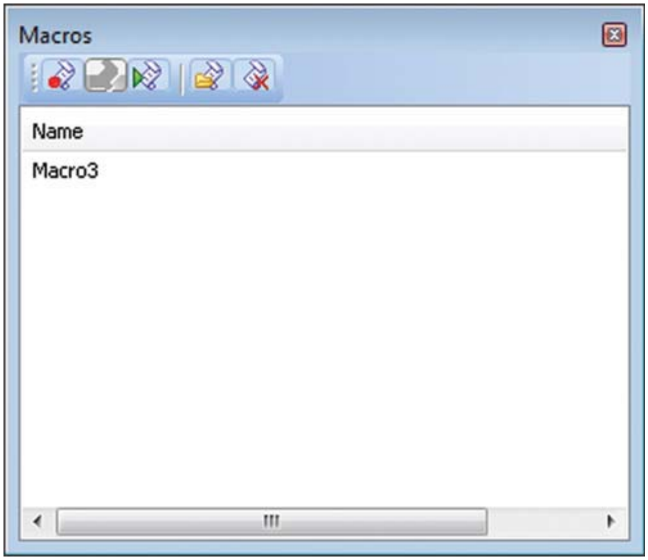
HTML Window

Display statistics in default web browser.

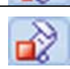


MACRO EDITOR

A macro is a series of keystrokes that have been 'recorded' in the order performed. A macro allows you to 'record' a series of keystrokes and then 'playback', or repeat, the recorded keystrokes.



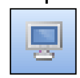
The Macro offers the following commands:

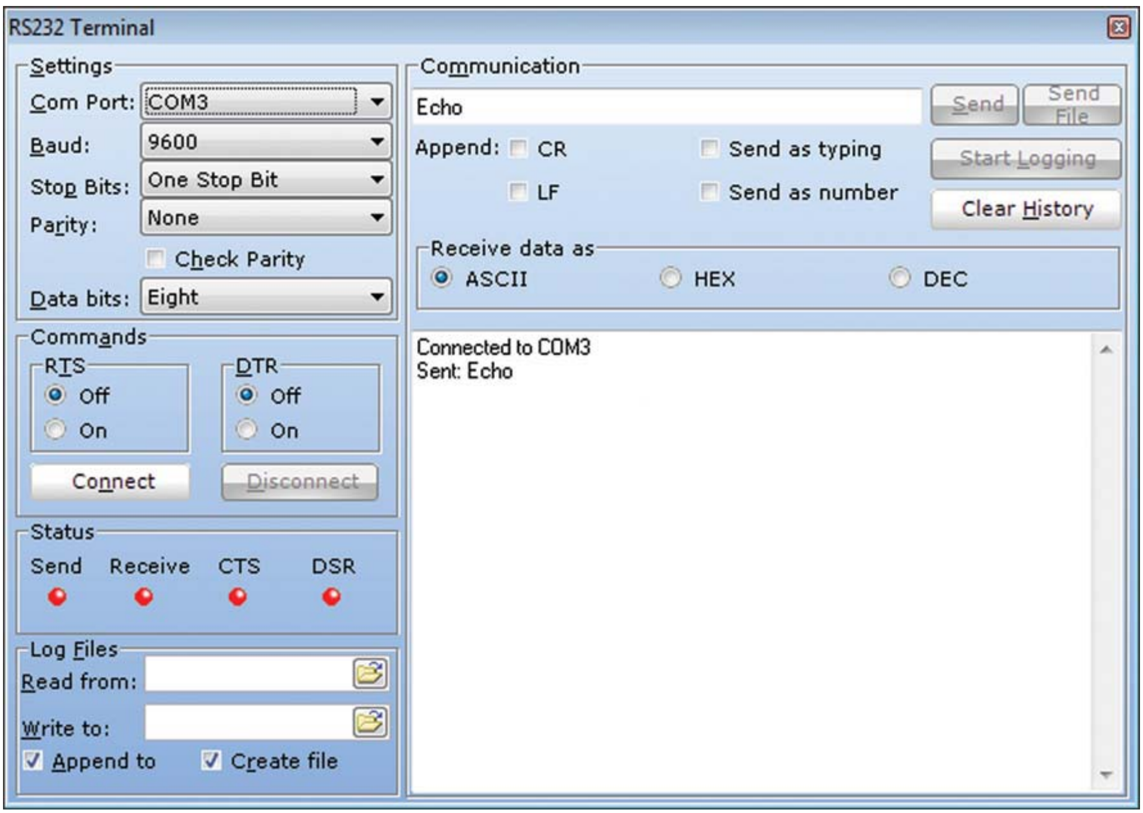
Icon	Description
	Starts 'recording' keystrokes for later playback.
	Stops capturing keystrokesthat was started when the Start Recordig command was selected.
	Allows a macro that has been recorded to be replayed.
	New macro.
	Delete macro.

Related topics: Advanced Code Editor, Code Templates

INTEGRATED TOOLS

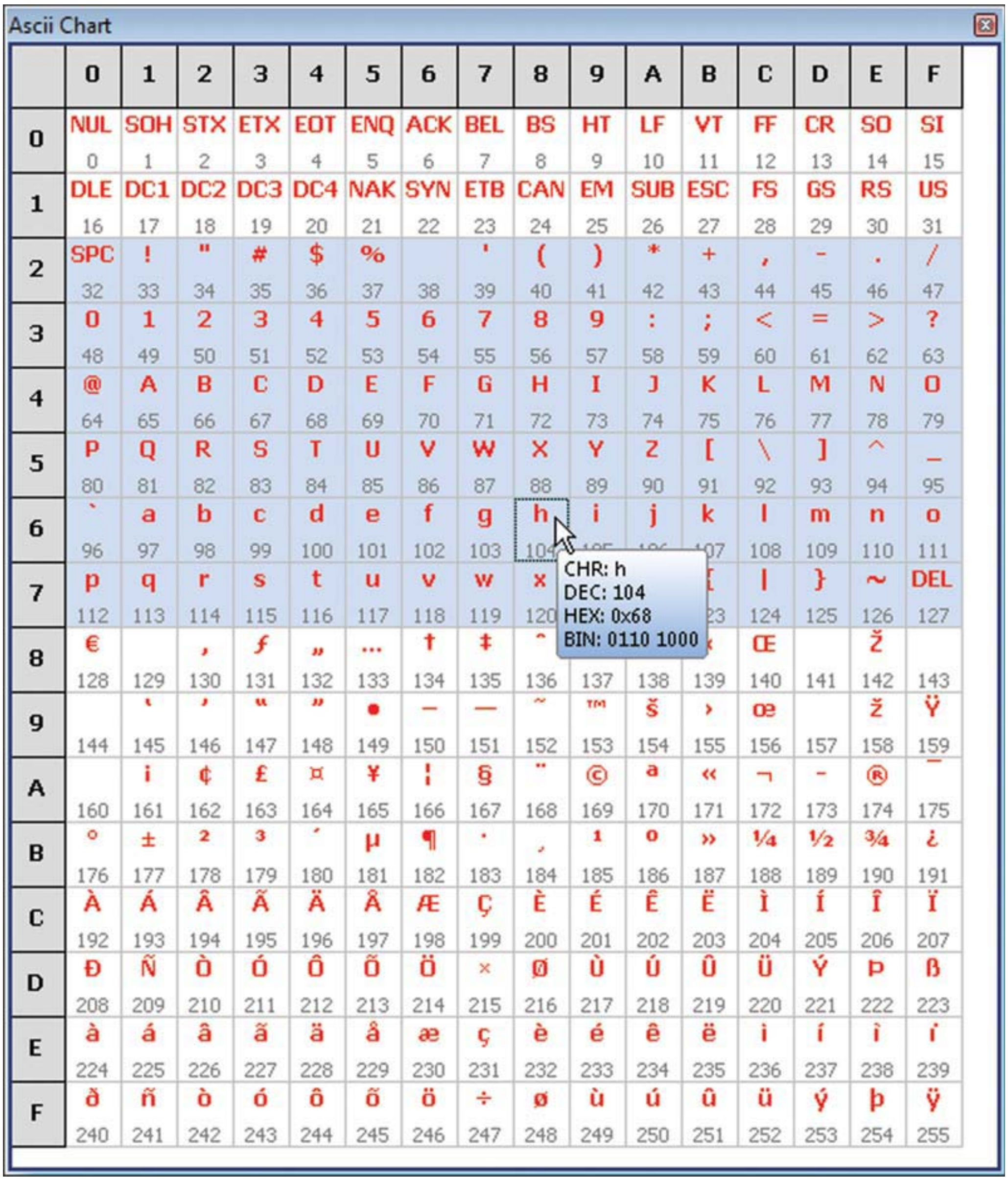
USART Terminal

The mikroC PRO for AVR includes the USART communication terminal for RS232 communication. You can launch it from the drop-down menu Tools › USART Terminal or by clicking the USART Terminal Icon  from Tools toolbar.



ASCII Chart

The ASCII Chart is a handy tool, particularly useful when working with LCD display. You can launch it from the drop-down menu **Tools › ASCII chart** or by clicking the View ASCII Chart Icon from Tools toolbar.

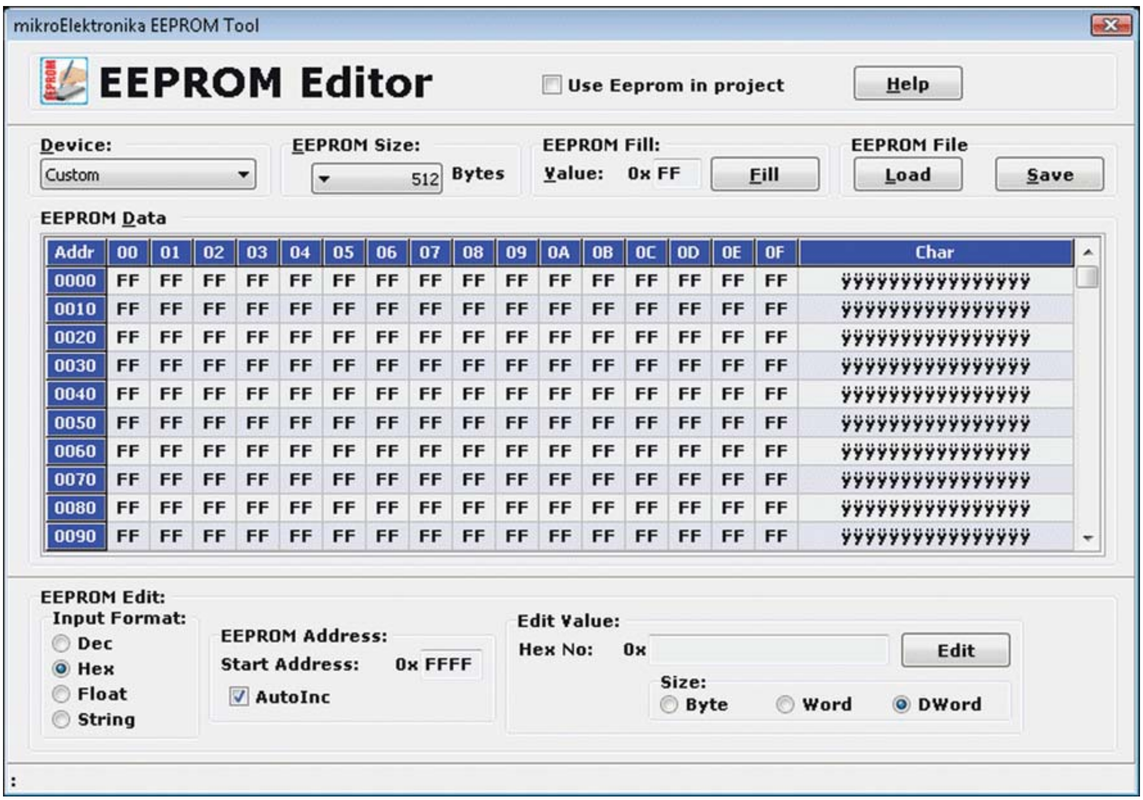


	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NUL 0	SOH 1	STX 2	ETX 3	EOT 4	ENQ 5	ACK 6	BEL 7	BS 8	HT 9	LF 10	VT 11	FF 12	CR 13	SO 14	SI 15
1	DLE 16	DC1 17	DC2 18	DC3 19	DC4 20	NAK 21	SYN 22	ETB 23	CAN 24	EM 25	SUB 26	ESC 27	FS 28	GS 29	RS 30	US 31
2	SPC 32	! 33	" 34	# 35	$ 36	% 37	38	' 39	(40	) 41	* 42	+ 43	, 44	- 45	. 46	/ 47
3	0 48	1 49	2 50	3 51	4 52	5 53	6 54	7 55	8 56	9 57	: 58	; 59	< 60	= 61	> 62	? 63
4	@ 64	A 65	B 66	C 67	D 68	E 69	F 70	G 71	H 72	I 73	J 74	K 75	L 76	M 77	N 78	O 79
5	P 80	Q 81	R 82	S 83	T 84	U 85	V 86	W 87	X 88	Y 89	Z 90	[91	\ 92	] 93	^ 94	_ 95
6	` 96	a 97	b 98	c 99	d 100	e 101	f 102	g 103	h 104	i	j	k	l 108	m 109	n 110	o 111
7	p 112	q 113	r 114	s 115	t 116	u 117	v 118	w 119	x 120				| 124	} 125	~ 126	DEL 127
8	€ 128	129	‚ 130	ƒ 131	„ 132	… 133	† 134	‡ 135	ˆ 136	137	138	139	Œ 140	141	Ž 142	143
9	144	‘ 145	’ 146	“ 147	” 148	• 149	– 150	— 151	˜ 152	™ 153	š 154	› 155	œ 156	157	ž 158	Ÿ 159
A	160	¡ 161	¢ 162	£ 163	¤ 164	¥ 165	¦ 166	§ 167	¨ 168	© 169	ª 170	« 171	¬ 172	- 173	® 174	¯ 175
B	° 176	± 177	² 178	³ 179	´ 180	µ 181	¶ 182	· 183	¸ 184	¹ 185	º 186	» 187	¼ 188	½ 189	¾ 190	¿ 191
C	À 192	Á 193	Â 194	Ã 195	Ä 196	Å 197	Æ 198	Ç 199	È 200	É 201	Ê 202	Ë 203	Ì 204	Í 205	Î 206	Ï 207
D	Ð 208	Ñ 209	Ò 210	Ó 211	Ô 212	Õ 213	Ö 214	× 215	Ø 216	Ù 217	Ú 218	Û 219	Ü 220	Ý 221	Þ 222	ß 223
E	à 224	á 225	â 226	ã 227	ä 228	å 229	æ 230	ç 231	è 232	é 233	ê 234	ë 235	ì 236	í 237	î 238	ï 239
F	ð 240	ñ 241	ò 242	ó 243	ô 244	õ 245	ö 246	÷ 247	ø 248	ù 249	ú 250	û 251	ü 252	ý 253	þ 254	ÿ 255

EEPROM Editor

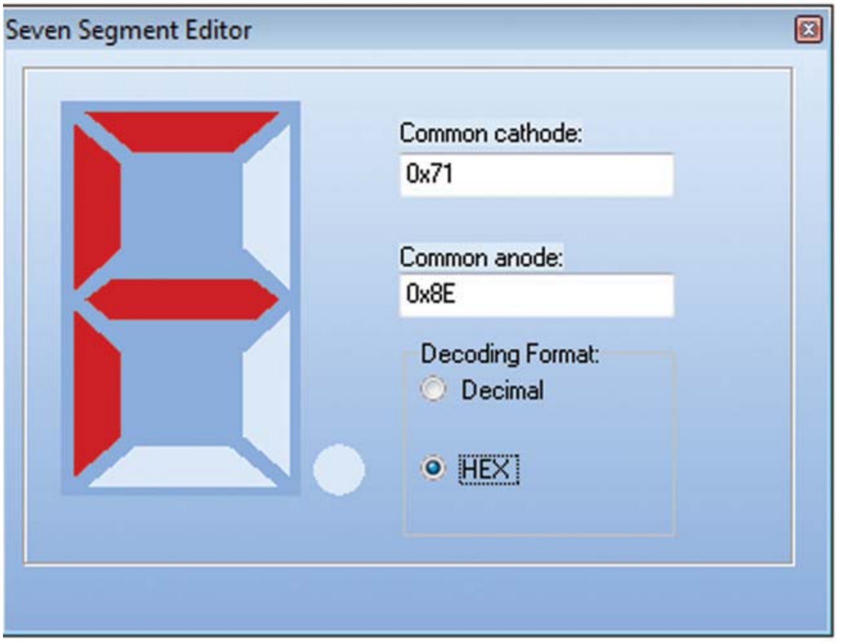
The EEPROM Editor is used for manipulating MCU's EEPROM memory. You can launch it from the drop-down menu **Tools › EEPROM Editor**. When Use this EEPROM definition is checked compiler will generate Intel hex file `project_name.ihex` that contains data from EEPROM editor.

When you run mikroElektronika programmer software from mikroC PRO for AVR IDE - `project_name.hex` file will be loaded automatically while `ihex` file must be loaded manually.



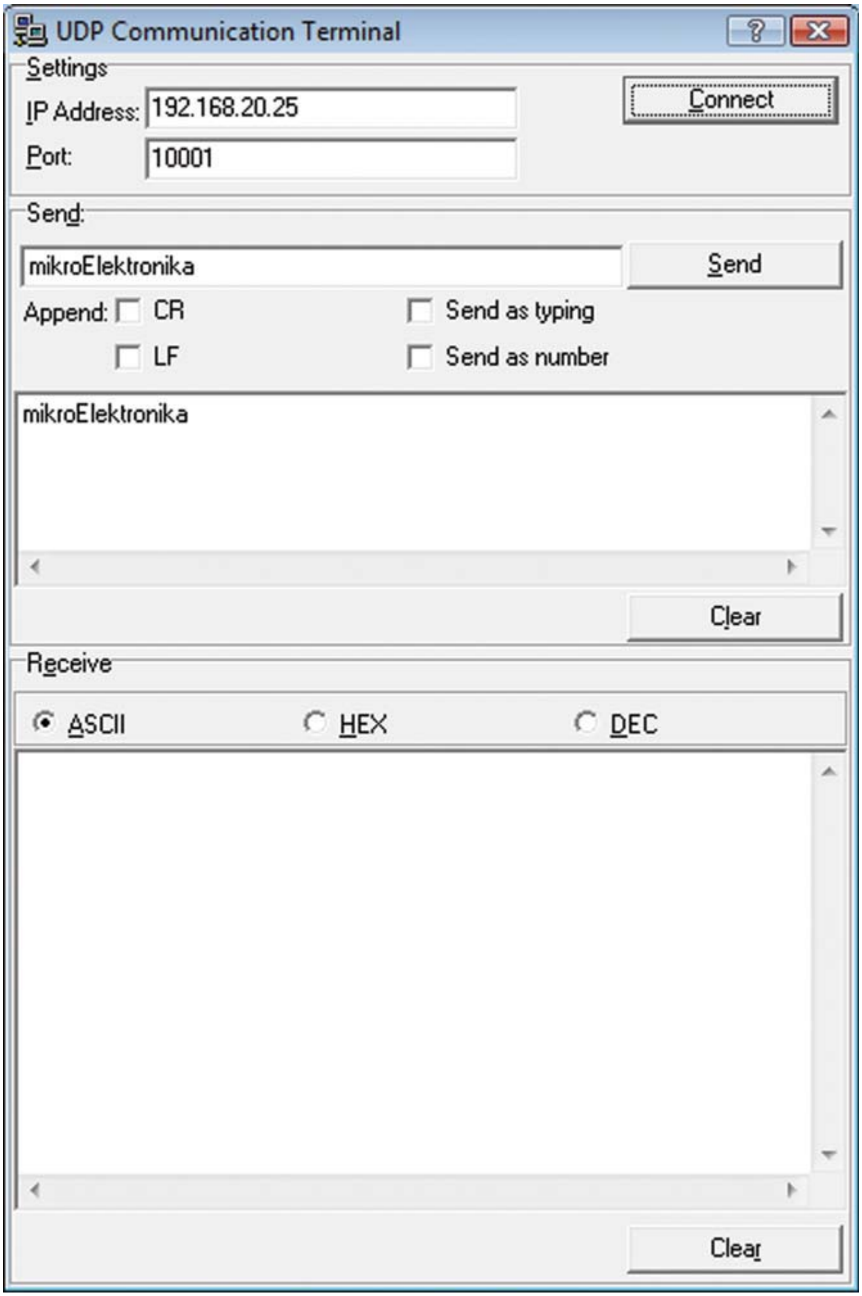
7 Segment Display Decoder

The 7 Segment Display Decoder is a convenient visual panel which returns decimal/hex value for any viable combination you would like to display on 7seg. Click on the parts of 7 segment image to get the requested value in the edit boxes. You can launch it from the drop-down menu **Tools › 7 Segment Decoderor** by clicking the Seven Segment Icon  from Tools toolbar.



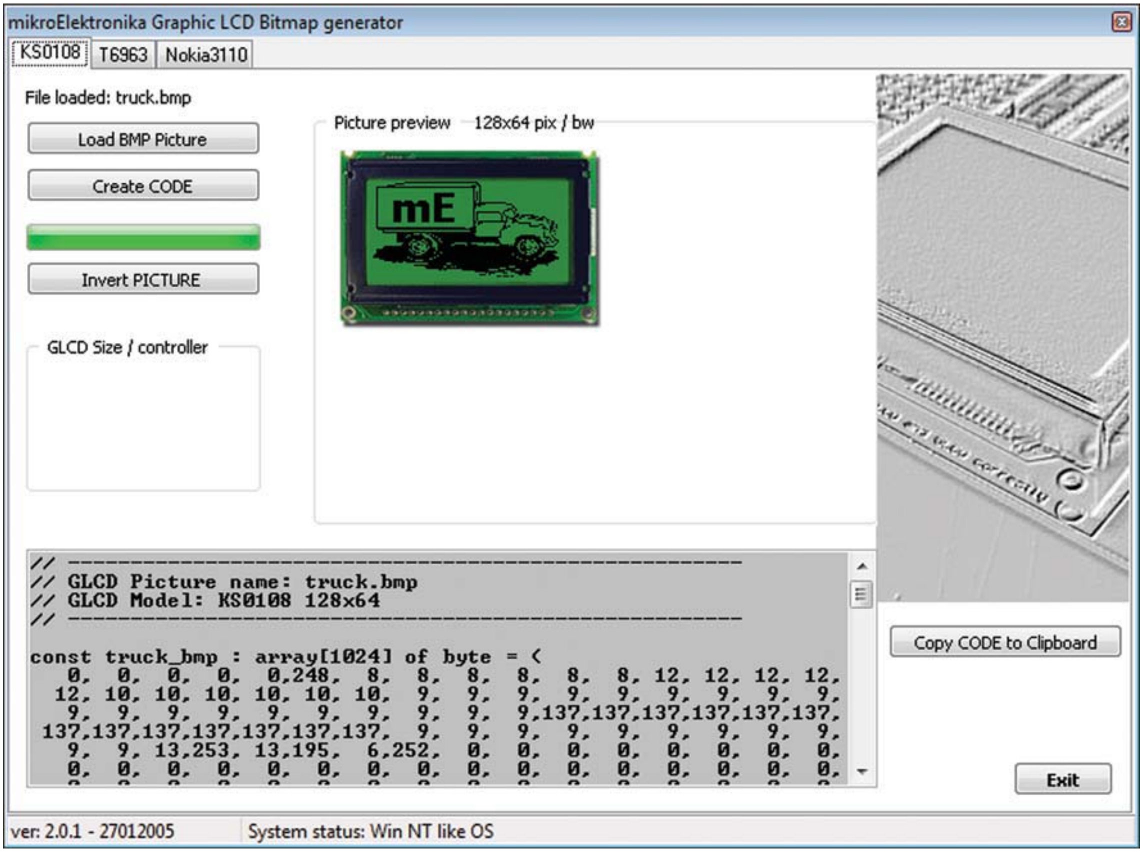
UDP Terminal

The mikroC PRO for AVR includes the UDP Terminal. You can launch it from the drop-down menu **Tools › UDP Terminal**.



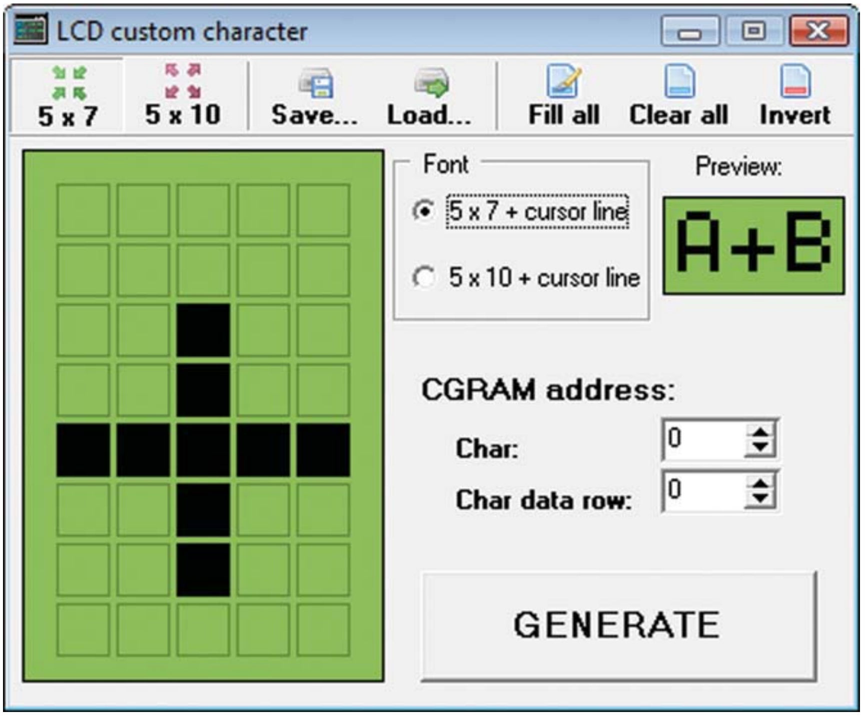
Graphic LCD Bitmap Editor

The mikroC PRO for AVR includes the Graphic LCD Bitmap Editor. Output is the mikroC PRO for AVR compatible code. You can launch it from the drop-down menu **Tools › GLCD Bitmap Editor**.



LCD Custom Character

mikroC PRO for AVR includes the LCD Custom Character. Output is mikroC PRO for AVR compatible code. You can launch it from the drop-down menu **Tools › LCD Custom Character**.



OPTIONS

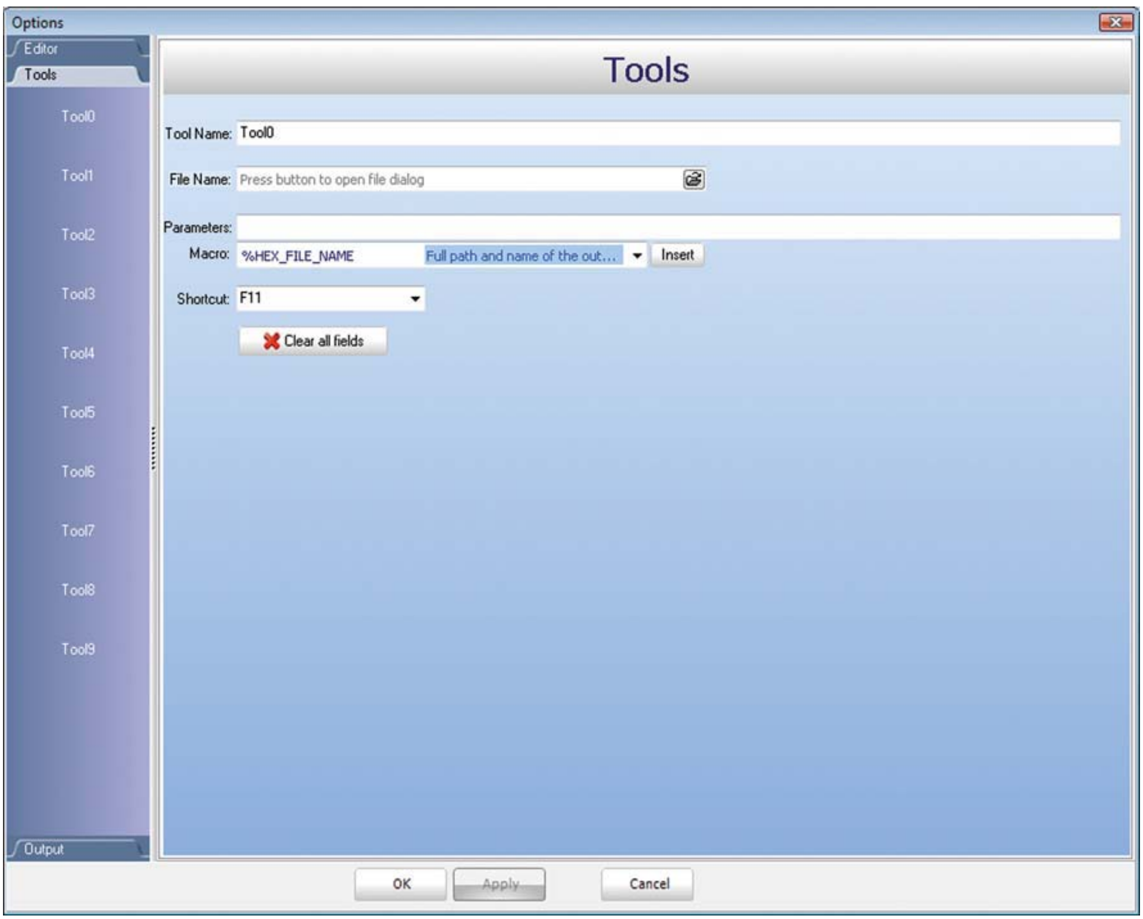
Options menu consists of three tabs: Code Editor, Tools and Output settings

Code editor

The Code Editor is advanced text editor fashioned to satisfy needs of professionals.

Tools

The mikroC PRO for AVR includes the Tools tab, which enables the use of shortcuts to external programs, like Calculator or Notepad.
You can set up to 10 different shortcuts, by editing Tool0 - Tool9.

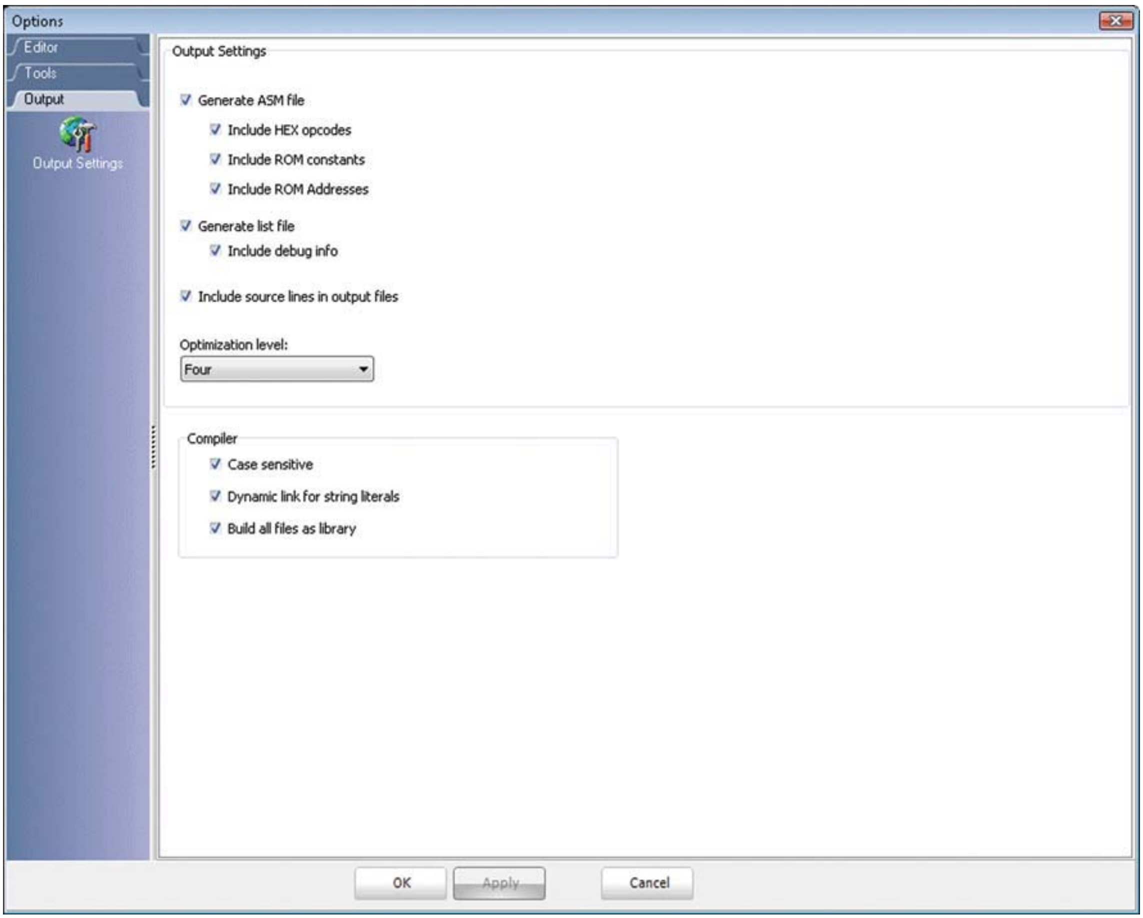


Output settings

By modifying Output Settings, user can configure the content of the output files. You can enable or disable, for example, generation of ASM and List file.

Also, user can choose optimization level, and compiler specific settings, which include case sensitivity, dynamic link for string literals setting (described in mikroC PRO for AVR specifics).

Build all files as library enables user to use compiled library (*.mcl) on any AVR MCU.



REGULAR EXPRESSIONS

Introduction

Regular Expressions are a widely-used method of specifying patterns of text to search for. Special metacharacters allow you to specify, for instance, that a particular string you are looking for, occurs at the beginning, or end of a line, or contains n recurrences of a certain character.

Simple matches

Any single character matches itself, unless it is a metacharacter with a special meaning described below. A series of characters matches that series of characters in the target string, so the pattern "`short`" would match "`short`" in the target string. You can cause characters that normally function as metacharacters or escape sequences to be interpreted by preceding them with a backslash "`\`".
For instance, metacharacter "`^`" matches beginning of string, but "`\^`" matches character "`^`", and "`\\`" matches "`\`", etc.

Examples :

`unsigned` matches string `'unsigned'`
`\^unsigned` matches string `'^unsigned'`

Escape sequences

Characters may be specified using a escape sequences: "`\n`" matches a newline, "`\t`" a tab, etc. More generally, `\xnn,` where `nn` is a string of hexadecimal digits, matches the character whose ASCII value is `nn`.
If you need wide(Unicode)character code, you can use '`\x{nnnn}`', where '`nnnn`' - one or more hexadecimal digits.

`\xnn` - char with hex code `nn`
`\x{nnnn)` - char with hex code nnnn (one byte for plain text and two bytes for Unicode)
`\t` - tab (HT/TAB), same as `\x09`
`\n` - newline (NL), same as `\x0a`
`\r` - car.return (CR), same as `\x0d`
`\f` - form feed (FF), same as `\x0c`
`\a` - alarm (bell) (BEL), same as `\x07`
`\e` - escape (ESC) , same as `\x1b`

Examples:

`unsigned\x20int` matches '`unsigned int`' (note space in the middle)
`\tunsigned` matches '`unsigned`' (predecessed by tab)

Character classes

You can specify a character class, by enclosing a list of characters in `[]`, which will match any of the characters from the list. If the first character after the "`[`" is "`^`", the class matches any character not in the list.

Examples:

`count[aeiou]r` finds strings '`countar`', '`counter`', etc. but not '`countbr`', '`countcr`', etc.
`count[^aeiou]r` finds strings '`countbr`', '`countcr`', etc. but not '`countar`', '`counter`', etc.

Within a list, the "`-`" character is used to specify a range, so that a-z represents all characters between "`a`" and "`z`", inclusive.

If you want "`-`" itself to be a member of a class, put it at the start or end of the list, or escape it with a backslash.
If you want '`]`', you may place it at the start of list or escape it with a backslash.

Examples:

`[-az]` matches '`a`', '`z`' and '`-`'
`[az-]` matches '`a`', '`z`' and '`-`'
`[a\-z]` matches '`a`', '`z`' and '`-`'
`[a-z]` matches all twenty six small characters from '`a`' to '`z`'
`[\n-\x0D]` matches any of `#10,#11,#12,#13`.
`[\d-t]` matches any digit, '`-`' or '`t`'.
`[]-a]` matches any char from '`]`'..'`a`'.

Metacharacters

Metacharacters are special characters which are the essence of regular expressions.There are different types of metacharacters, described below.

Metacharacters - Line separators

`^` - start of line
`$` - end of line
`\A` - start of text
`\Z` - end of text
`.` - any character in line

Examples:

`^PORTA` - matches string ' `PORTA` ' only if it's at the beginning of line
`PORTA$` - matches string ' `PORTA` ' only if it's at the end of line
`^PORTA$` - matches string ' `PORTA` ' only if it's the only string in line
`PORT.r` - matches strings like '`PORTA`', '`PORTB`', '`PORT1`' and so on

The "`^`" metacharacter by default is only guaranteed to match beginning of the input string/text, and the "`$`" metacharacter only at the end. Embedded line separators will not be matched by "`^`" or "`$`".
You may, however, wish to treat a string as a multi-line buffer, such that the "`^`" will match after any line separator within the string, and "`$`" will match before any line separator.
Regular expressons works with line separators as recommended at www.unicode.org (http://www.unicode.org/unicode/reports/tr18/):

Metacharacters - Predefined classes

`\w` - an alphanumeric character (including "`_`")
`\W` - a nonalphanumeric
`\d` - a numeric character
`\D` - a non-numeric
`\s` - any space (same as `[\t\n\r\f]`)
`\S` - a non space

You may use \w, \d and \s within custom character classes.

Example:

`routi\de` - matches strings like '`routi1e`', '`routi6e`' and so on, but not '`routine`', '`routime`' and so on.

Metacharacters - Word boundaries

A word boundary ("\b") is a spot between two characters that has a "\w" on one side of it and a "\W" on the other side of it (in either order), counting the imaginary characters off the beginning and end of the string as matching a "\W".

\b - match a word boundary)
\B - match a non-(word boundary)

Metacharacters - Iterators

Any item of a regular expression may be followed by another type of metacharacters - iterators. Using this metacharacters,you can specify number of occurences of previous character, metacharacter or subexpression.

* - zero or more ("greedy"), similar to {0,}
+ - one or more ("greedy"), similar to {1,}
? - zero or one ("greedy"), similar to {0,1}
{n} - exactly n times ("greedy")
{n,} - at least n times ("greedy")
{n,m} - at least n but not more than m times ("greedy")
*? - zero or more ("non-greedy"), similar to {0,}?
+? - one or more ("non-greedy"), similar to {1,}?
?? - zero or one ("non-greedy"), similar to {0,1}?
{n}? - exactly n times ("non-greedy")
{n,}? - at least n times ("non-greedy")
{n,m}? - at least n but not more than m times ("non-greedy")

So, digits in curly brackets of the form, {n,m} , specify the minimum number of times to match the item n and the maximum m. The form {n} is equivalent to {n,n} and matches exactly n times. The form {n,} matches n or more times. There is no limit to the size of n or m, but large numbers will chew up more memory and slow down execution.

If a curly bracket occurs in any other context, it is treated as a regular character.

Examples:

count.*r ß- matches strings like 'counter', 'countelkjdflkj9r' and 'countr'
count.+r - matches strings like 'counter', 'countelkjdflkj9r' but not 'countr'
count.?r - matches strings like 'counter', 'countar' and 'countr' but not 'countelkj9r'

`counte{2}r` - matches string `'counteer'`
`counte{2,}r` - matches strings like `'counteer'`, `'counteeer'`, `'counteeer'` etc.
`counte{2,3}r` - matches strings like `'counteer'`, or `'counteeer'` but not `'counteeeer'`

A little explanation about "greediness". "Greedy" takes as many as possible, "non-greedy" takes as few as possible.
For example, `'b+'` and `'b*'` applied to string `'abbbbc'` return `'bbbb'`, `'b+?'` returns `'b'`, `'b*?'` returns empty string, `'b{2,3}?'` returns `'bb'`, `'b{2,3}'` returns `'bbb'`.

Metacharacters - Alternatives

You can specify a series of alternatives for a pattern using "`|`" to separate them, so that `fee|fie|foe` will match any of "`fee`", "`fie`", or "`foe`" in the target string (as would `f(e|i|o)e)`). The first alternative includes everything from the last pattern delimiter `("(", "[",` or the beginning of the pattern) up to the first "`|`", and the last alternative contains everything from the last "`|`" to the next pattern delimiter. For this reason, it's common practice to include alternatives in parentheses, to minimize confusion about where they start and end.

Alternatives are tried from left to right, so the first alternative found for which the entire expression matches, is the one that is chosen. This means that alternatives are not necessarily greedy. For example: when matching `rou|rout` against "`rou-tine`", only the "`rou`" part will match, as that is the first alternative tried, and it successfully matches the target string (this might not seem important, but it is important when you are capturing matched text using parentheses.) Also remember that "`|`" is interpreted as a literal within square brackets, so if you write `[fee|fie|foe]` You're really only matching `[feio|]`.

Examples:

`rou(tine|te)` - matches strings `'routine'` or `'route'`.

Metacharacters - Subexpressions

The bracketing construct `( ... )` may also be used for define regular subexpressions. Subexpressions are numbered based on the left to right order of their opening parenthesis. First subexpression has number `'1'`

Examples:

`(int){8,10}` matches strings which contain 8, 9 or 10 instances of the `'int'`
`routi([0-9]|a+)e` matches `'routi0e'`, `'routi1e'` , `'routine'`, `'routinne'`, `'routinnne'` etc.

Metacharacters - Backreferences

Metacharacters `\1` through `\9` are interpreted as backreferences. `\` matches previously matched subexpression `#`.

Examples:

`(.)\1+` matches `'aaaa'` and `'cc'`.
`(.+)\1+` matches `'abab'` and `'123123'`
`(['"]?)(\d+)\1` matches "`13`" (in double quotes), or '`4`' (in single quotes) or `77` (without quotes) etc

MIKROC PRO FOR AVR COMMAND LINE OPTIONS

Usage: `mikroCAvr.exe [-<opts> [-<opts>]] [<infile> [-<opts>]] [-<opts>]]`
Infile can be of `*.c` and `*.pld` type.

The following parameters and some more (see manual) are valid:

`-P` : MCU for which compilation will be done.
`-FO` : Set oscillator [in MHz].
`-SP` : Add directory to the search path list.
`-IP` : Add directory to the #include search list.
`-N` : Output files generated to file path specified by filename.
`-B` : Save compiled binary files (`*.mcl`) to 'directory'.
`-O` : Miscellaneous output options.
`-DBG` : Generate debug info.
`-L` : Check and rebuild new libraries.
`-DL` : Build all files as libraries.
`-Y` : Dynamic link for string literals.
`-C` : Turn on case sensitivity.

Example:

```
mikrocAvr.exe -MSF -DBG -pATMEGA16 -ES -C -O11111114 -fo8 -N"C:\Lcd\Lcd.mcpav" -SP"C:\Program Files\Mikroelektronika\mikroC PRO for AVR\Defs\"
-SP"C:\Program Files\Mikroelektronika\mikroC PRO for AVR\Uses\LTE64KW\" -SP"C:\Lcd\" "Lcd.c" "__Lib_Math.mcl" "__Lib_MathDouble.mcl" "__Lib_System.mcl" "__Lib_Delays.mcl" "__Lib_LcdConsts.mcl" "__Lib_Lcd.mcl"
```

Parameters used in the example:

`-MSF` : Short Message Format; used for internal purposes by IDE.
`-DBG` : Generate debug info.
`-pATMEGA16` : MCU pATMEGA16 selected.
`-C` : Turn on case sensitivity.
`-O11111114` : Miscellaneous output options.
`-fo8` : Set oscillator frequency [in MHz].
`-N"C:\Lcd\Lcd.mcpav"-SP"C:\Program Files\Mikroelektronika\mikroC PRO for AVR\defs\"` : Output files generated to file path specified by filename.
`-SP"C:\Program Files\Mikroelektronika\mikroC PRO for AVR\defs\"` : Add directory to the search path list.
`-SP"C:\Program Files\Mikroelektronika\mikroC PRO for AVR\uses\"` : Add directory to the search path list.
`-SP"C:\Lcd\"` : Add directory to the search path list.
`Lcd.c" "__Lib_Math.mcl" "__Lib_MathDouble.mcl" "__Lib_System.mcl" "__Lib_Delays.mcl" "__Lib_LcdConsts.mcl" "__Lib_Lcd.mcl"` : Specify input files.

TUTORIALS

Projects

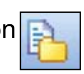
The mikroC PRO for AVR organizes applications into projects, consisting of a single project file (extension .mcpav) and one or more source files (extension). mikroC PRO for AVR IDE allows you to manage multiple projects (see Project Manager). Source files can be compiled only if they are part of a project.

The project file contains the following information:

- project name and optional description,
- target device,
- device flags (config word),
- device clock,
- list of the project source files with paths,
- header files (*.h),
- binary files (*.mcl),
- image files,
- other files.

Note that the project does not include files in the same way as preprocessor does, see Add/Remove Files from Project.

New Project

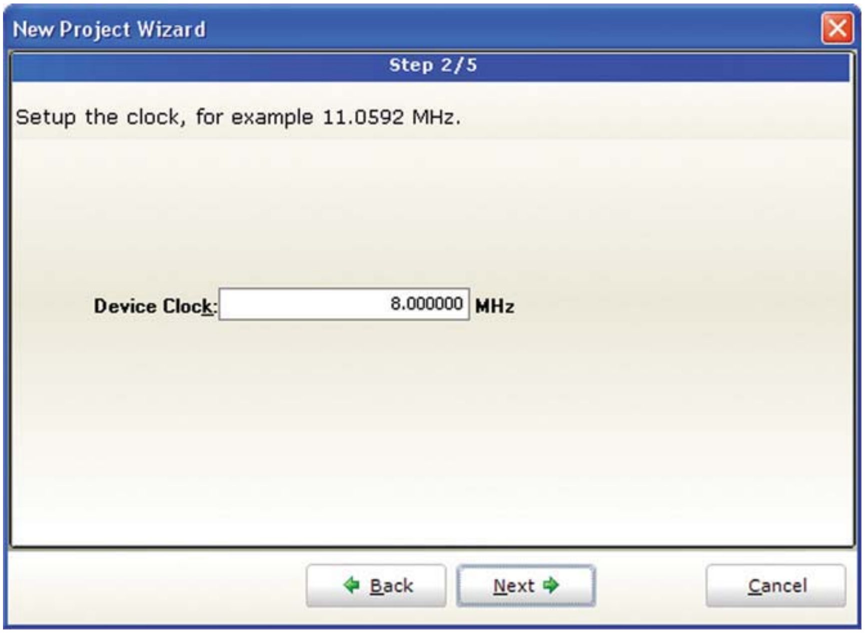
The easiest way to create a project is by means of the New Project Wizard, drop-down menu Project › New Project or by clicking the New Project Icon  from Project Toolbar.

New Project Wizard Steps

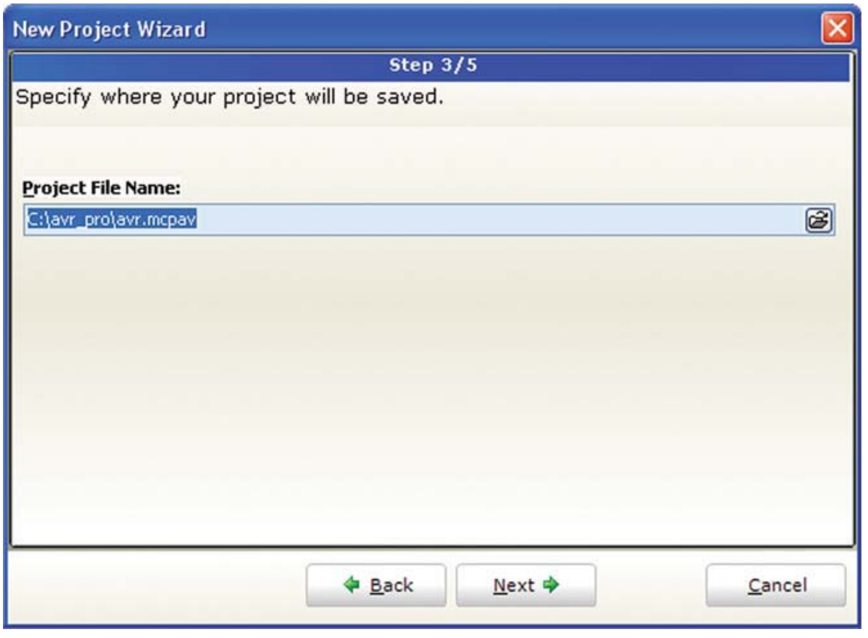
Start creating your New project, by clicking Next button:

Step One - Select the device from the device drop-down list.

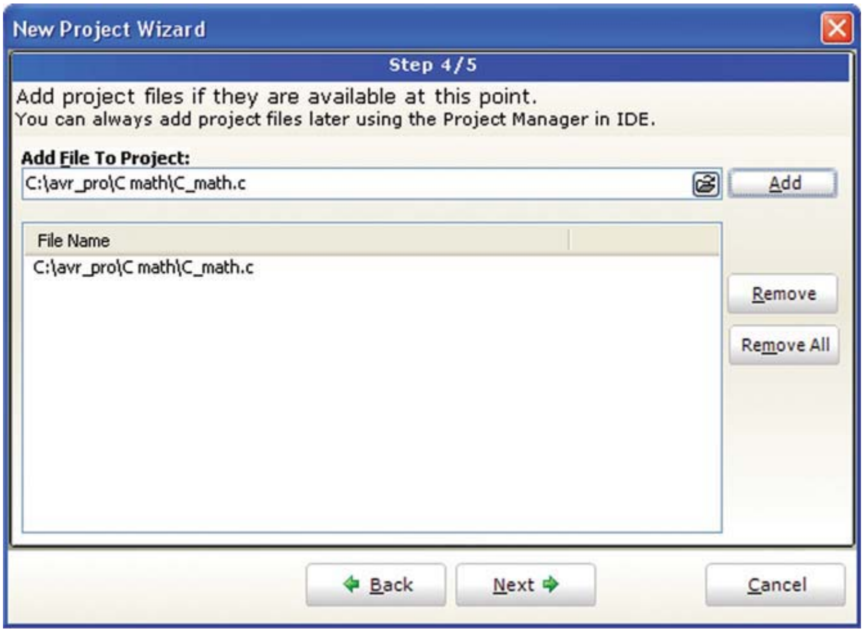
Step Two - Enter the oscillator frequency value.



Step Three - Specify the location where your project will be saved.



Step Four - Add project file to the project if they are avaiable at this point. You can always add project files later using Project Manager.



Step Five - Click Finish button to create your New Project:

Related topics: Project Manager, Project Settings

CUSTOMIZING PROJECTS

Edit Project

You can change basic project settings in the Project Settings window. You can change chip, and oscillator frequency. Any change in the Project Setting Window affects currently active project only, so in case more than one project is open, you have to ensure that exactly the desired project is set as active one in the Project Manager.

Managing Project Group

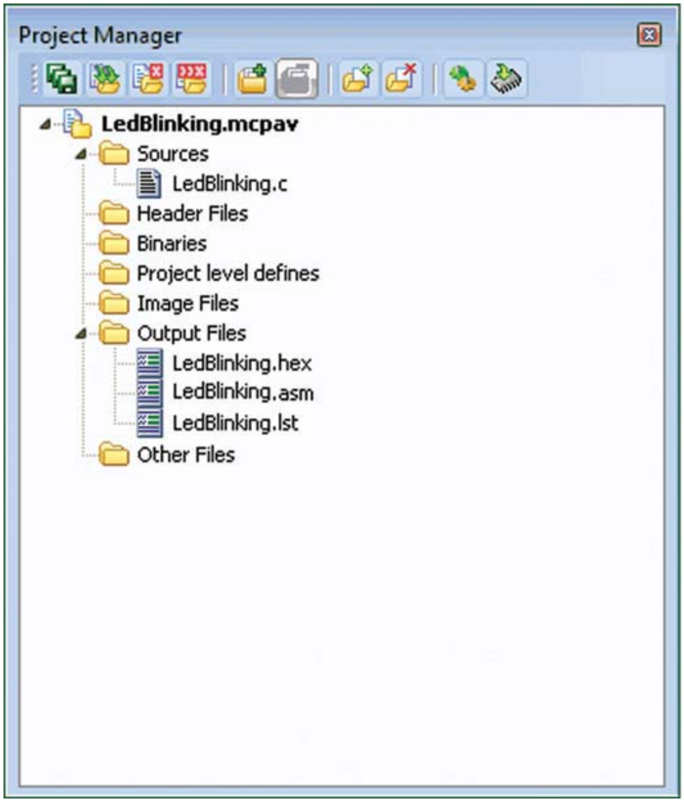
mikroC PRO for AVR IDE provides covenient option which enables several projects to be open simultaneously. If you have several projects being connected in some way, you can create a project group.

The project group may be saved by clicking the Save Project Group Icon  from the Project Manager window. The project group may be reopend by clicking the Open Project Group Icon  . All relevant data about the project group is stored in the project group file (extension .mpgroup)

Add/Remove Files from Project

The project can contain the following file types:

- source files
- `.h` header files
- `.mcl` binary files
- `.pld` project level defines files
- image files
- `.hex, .asm` and `.lst` files, see output files. These files can not be added or removed from project.
- other files



The list of relevant source files is stored in the project file (extension `.mcpav`).

To add source file to the project, click the Add File to Project Icon . Each added source file must be self-contained, i.e. it must have all necessary definitions after preprocessing.

To remove file(s) from the project, click the Remove File from Project Icon  .

Project Level Defines:

Project Level Defines(`.pld`) files can also be added to project. Project level define files enable you to have defines that are visible in all source files in the project. A file must contain one definition per line in the following form:

```
<symbol>[ =[ <value>]]
<symbol  (a,b)>[ =[ <value>]]
```

Define a macro named symbol. To specify a value, use `=<value>`. If `=<value>` is omitted, 1 is assumed. Do not enter white-space characters immediately before the "`=`". If a white-space character is entered immediately after the "`=`", the macro is defined as zero token. This option can be specified repeatedly. Each appearance of symbol will be replaced by the value before compilation.
There are two predefined project level defines see predefined project level defines

Note: For inclusion of the header files (extension .h), use the preprocessor directive `#include`. See File Inclusion for more information.

Related topics: Project Manager, Project Settings

SOURCE FILES

Source files containing C code should have the extension . The list of source files relevant to the application is stored in project file with extension `.mcpav`, along with other project information. You can compile source files only if they are part of the project.

Use the preprocessor directive `#include` to include header files with the extension `.h`. Do not rely on the preprocessor to include source files other than headers — see Add/Remove Files from Project for more information.

Managing Source Files

Creating new source file

To create a new source file, do the following:

1. Select **File › New Unit** from the drop-down menu, or press Ctrl+N, or click the New File Icon  from the File Toolbar.
2. A new tab will be opened. This is a new source file. Select **File › Save** from the drop-down menu, or press Ctrl+S, or click the Save File Icon  from the File Toolbar and name it as you want.

If you use the New Project Wizard, an empty source file, named after the project with extension , will be created automatically. The mikroC PRO for AVR does not require you to have a source file named the same as the project, it's just a matter of convenience.

Opening an existing file

1. Select **File › Open** from the drop-down menu, or press Ctrl+O, or click the Open File Icon  from the File Toolbar. In Open Dialog browse to the location of the file that you want to open, select it and click the Open button.
2. The selected file is displayed in its own tab. If the selected file is already open, its current Editor tab will become active.
   Printing an open file

Printing an open file

1. Make sure that the window containing the file that you want to print is the active window.
2. Select **File › Print** from the drop-down menu, or press Ctrl+P.
3. In the Print Preview Window, set a desired layout of the document and click the OK button. The file will be printed on the selected printer.

Saving file

1. Make sure that the window containing the file that you want to save is the active window.
2. Select **File › Save** from the drop-down menu, or press Ctrl+S, or click the Save File Icon  from the File Toolbar.

Saving file under a different name

1. Make sure that the window containing the file that you want to save is the active window.
2. Select **File › Save As** from the drop-down menu. The New File Name dialog will be displayed.
3. In the dialog, browse to the folder where you want to save the file.
4. In the File Name field, modify the name of the file you want to save.
5. Click the Save button.

Closing file

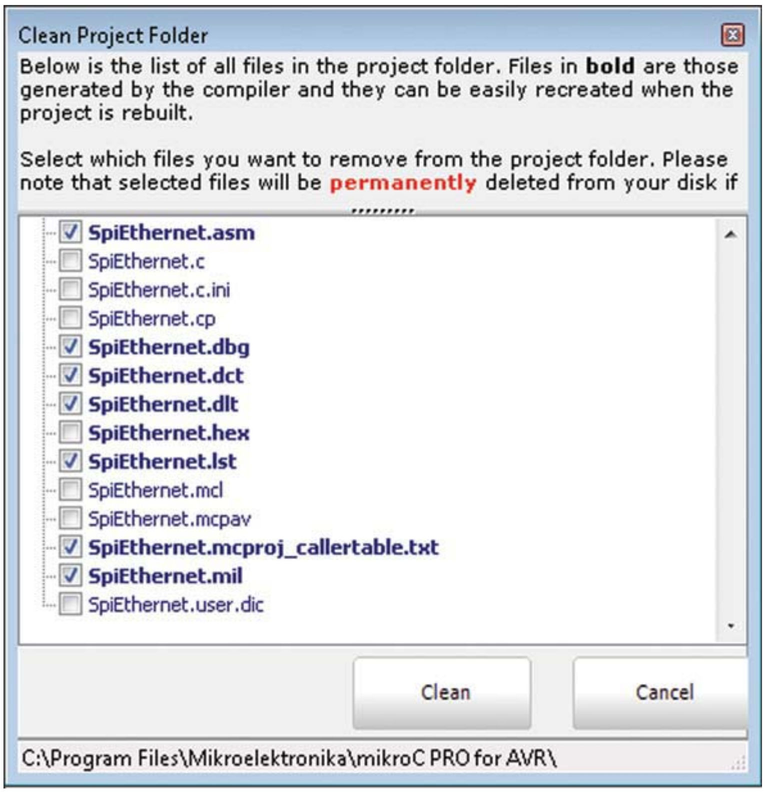
1. Make sure that the tab containing the file that you want to close is the active tab.
2. Select **File › Close** from the drop-down menu, or right click the tab of the file that you want to close and select **Close** option from the context menu.
3. If the file has been changed since it was last saved, you will be prompted to save your changes.

Related topics:File Menu, File Toolbar, Project Manager, Project Settings,

CLEAN PROJECT FOLDER

Clean Project Folder

This menu gives you option to choose which files from your current project you want to delete.



COMPILATION

When you have created the project and written the source code, it's time to compile it. Select **Project › Build** from the drop-down menu, or click the Build Icon  from the Project Toolbar. If more more than one project is open you can compile all open projects by selecting **Project › Build All** from the drop-down menu, or click the Build All Icon  from the Project Toolbar.

Progress bar will appear to inform you about the status of compiling. If there are some errors, you will be notified in the Error Window. If no errors are encountered, the mikroC PRO for AVR will generate output files.

Output Files

Upon successful compilation, the mikroC PRO for AVR will generate output files in the project folder (folder which contains the project file `.mcpav`). Output files are summarized in the table below:

Format	Description	File Type
Intel HEX	Intel style hex records. Use this file to program AVR MCU.	`.hex`
Binary	mikro Compiled Library. Binary distribution of application that can be included in other projects.	`.mcl`
List File	Overview of AVR memory allotment: instruction addresses, registers, routines and labels.	`.lst`
Assembler File	Human readable assembly with symbolic names, extracted from the List File.	`.asm`

Assembly View

After compiling the program in the mikroC PRO for AVR, you can click the View Assembly icon  or select **Project › View Assembly** from the drop-down menu to review the generated assembly code (.asm file) in a new tab window. Assembly is human-readable with symbolic names.

Related topics:Project Menu, Project Toolbar, Error Window, Project Manager, Project Settings

ERROR MESSAGES

Compiler Error Messages

- Syntax Error: [%s] expected, but [%s] found
- Array element cannot be function
- Function cannot return array
- Inconsistent storage class
- Inconsistent type
- [%s] tag redefined [%s]
- Illegal typecast [%s] [%s]
- [%s] is not valid identifier
- Invalid statement
- Constant expression required
- Internal error [%s]
- Too many actual parameters
- Not enough parameters
- Invalid expression
- Identifier expected, but [%s] found
- Operator [%s] is not applicable to these operands [%s]
- Assigning to non-lvalue [%s]
- Cannot cast [%s] to [%s]
- Cannot assign [%s] to [%s]
- Lvalue required
- Pointer required
- Argument is out of range
- Undeclared identifier [%s] in expression
- Too many initializers
- Cannot establish this baud rate at [%s] MHz clock
- Stack overflow
- Invalid operator [%s]
- Expected variable, but constant [%s] found
- Expected constant, but [%s] found
- [%s] cannot be used outside a loop
- Unknown type [%s]
- Variable [%s] is redeclared
- Undeclared identifier [%s]
- Output limit has raised 2K words
- [%s] has already been declared [%s]
- Type mismatch: expected [%s] , but [%s] found
- File [%s] not found [%s]
- There is not enough RAM space for all variables
- There is not enough ROM space
- Invalid type in Array

- Division by zero
- Incompatible types: [%s] [%s]
- Too many characters.
- Assembler instruction [%s] was not found.
- project name must be specified
- Unknown command line Option: [%s]
- File extension missing: [%s]
- Bad FO argument: [%s]
- Preprocessor exited with error code [%s]
- Bad absolute address [%s]
- Recursion or cross-calling of [%s]
- no files specified
- Device parameter missing (for example -PATMEGA...)
- Invalid parameter string
- Project name must be set
- Specifier needed
- [%s] not found %s
- Index out of bounds
- Array dimension must be greater than 0
- Const expression expected
- Integer const expected
- Recursion in definition
- Array corrupted
- Arguments cannot be of void type
- Arguments cannot have explicit memory specificator
- Bad storage class
- Pointer to function required
- Function required
- Illegal pointer conversion to double
- Integer type needed
- Members cannot have memory specifier
- Members cannot be of bit or sbit type
- Too many initializers
- Too many initializers of subaggregate
- Already used [%s]
- Illegal expression with void
- Address must be greater than 0
- Address must be greater than 0
- [%s] Identifier redefined
- User abort
- Exp. must be greater than 0
- Invalid declarator expected '(' or identifier
- typdef name redefined: [%s]
- Declarator error
- Specifer/qualifier list expected

- [%s] already used
- ILevel can be used only with interrupt service routines
- ; expected, but [%s] found
- Expected "{"
- [%s] Identifier redefined
- '(' expected, but [%s] found
- ')' expected, but [%s] found
- 'case' out of switch
- ':' expected, but [%s] found
- 'default' label out of switch
- switch expression must evaluate to integral type
- while expected, but [%s] found
- void func cannot return values
- 'continue' outside of loop
- Unreachable code
- Label redefined
- void type in expression
- Too many chars
- Unresolved type
- Arrays of objects containing zero-size arrays are illegal
- Invalid enumerator
- ILevel can be used only with interrupt service routines
- ILevel value must be integral constant
- ILevel out of range "0..4"
- '}' expected [%s] found
- ')' expected, but [%s] found
- 'break' outside of loop or switch
- Empty char
- Nonexistent field [%s]
- Illegal char representation: [%s]
- Initializer syntax error: multidimensional array missing subscript
- Too many initializers of subaggregate
- At least one Search Path must be specified
- Not enough RAM for call stack
- Demo Limit
- Parameter [%s] must not be of bit or sbit type
- Function must not have return value of bit or sbit type

Compiler Warning Messages

- Bad or missing fosc parameter. Default value 8MHz used
- Specified search path does not exist: [%s]
- Specified include path does not exist: [%s]
- Result is not defined in function: [%s]
- Initialization of extern object [%s]
- Suspicious pointer conversion
- Implicit conversion of pointer to int
- Unknown pragma line ignored: [%s]
- Implicit conversion of int to ptr
- Generated baud rate is [%s] bps (error = [%s] percent)
- Illegal file type: [%s]

Linker Error Messages

- Redefinition of [%s] already defined in [%s]
- main function is not defined
- System routine is not found for initialization of: [%s]
- Bad agregate definition [%s]
- Unresolved extern [%s]
- Bad function absolute address [%s]
- Not enough RAM [%s]

SOFTWARE SIMULATOR OVERVIEW

The Source-level Software Simulator is an integral component of the mikroC PRO for AVR environment. It is designed to simulate operations of the AVR MCUs and assist the users in debugging C code written for these devices.

After you have successfully compiled your project, you can run the Software Simulator by selecting **Run › Start Debugger** from the drop-down menu, or by clicking the Start Debugger Icon from the Debugger Toolbar. Starting the Software Simulator makes more options available: Step Into, Step Over, Step Out, Run to Cursor, etc. Line that is to be executed is color highlighted (blue by default).

Note: The Software Simulator simulates the program flow and execution of instruction lines, but it cannot fully emulate AVR device behavior, i.e. it doesn't update timers, interrupt flags, etc.

Watch Window

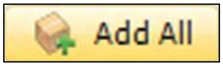
The Software Simulator Watch Window is the main Software Simulator window which allows you to monitor program items while simulating your program. To show the Watch Window, select **View › Debug Windows › Watch** from the drop-down menu.

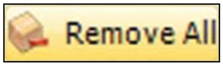
The Watch Window displays variables and registers of the MCU, along with their addresses and values.

There are two ways of adding variable/register to the watch list:

- by its real name (variable's name in "C" code). Just select desired variable/register from **Select variable from list** drop-down menu and click the Add Button Add .
- by its name ID (assembly variable name). Simply type name ID of the variable/register you want to display into **Search the variable by assemby name** box and click the Add Button Add .

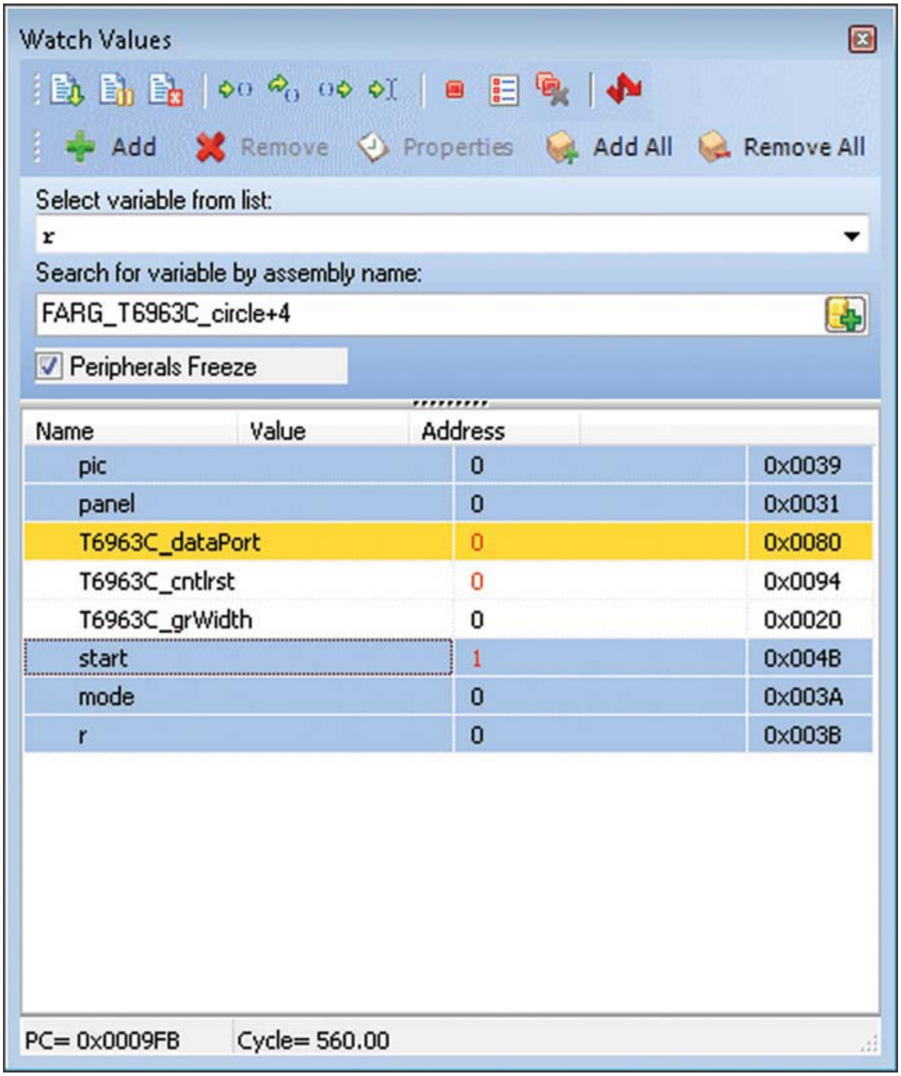
Variables can also be removed from the Watch window, just select the variable that you want to remove and then click the Remove Button Remove.

Add All Button  adds all variables.

Remove All Button  removes all variables.

You can also expand/collapse complex variables, i.e. struct type variables, strings...

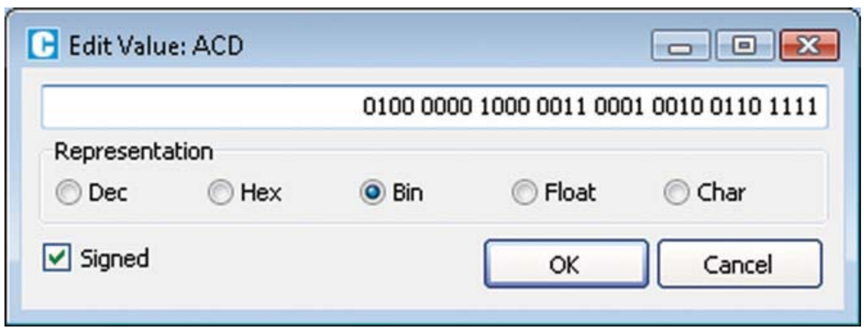
Values are updated as you go through the simulation. Recently changed items are colored red.



Double clicking a variable or clicking the Properties Button 

opens the Edit Value window in which you can assign a new value to the selected variable/register. Also, you can choose the format of variable/register representation between decimal, hexadecimal, binary, float or character. All representations except float are unsigned by default. For signed representation click the check box next to the Signed label.

An item's value can be also changed by double clicking item's value field and typing the new value directly.

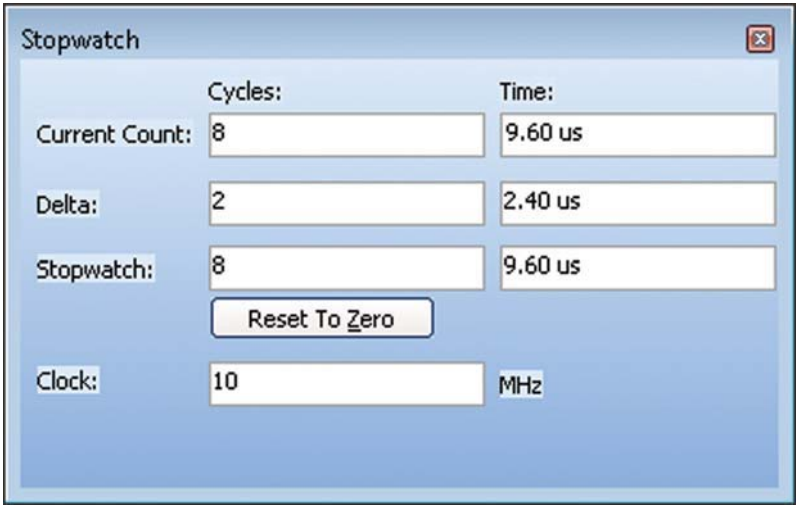


Stopwatch Window

The Software Simulator Stopwatch Window is available from the drop-down menu, **View › Debug Windows › Stopwatch**.

The Stopwatch Window displays a current count of cycles/time since the last Software Simulator action. Stopwatch measures the execution time (number of cycles) from the moment Software Simulator has started and can be reset at any time. Delta represents the number of cycles between the lines where Software Simulator action has started and ended.

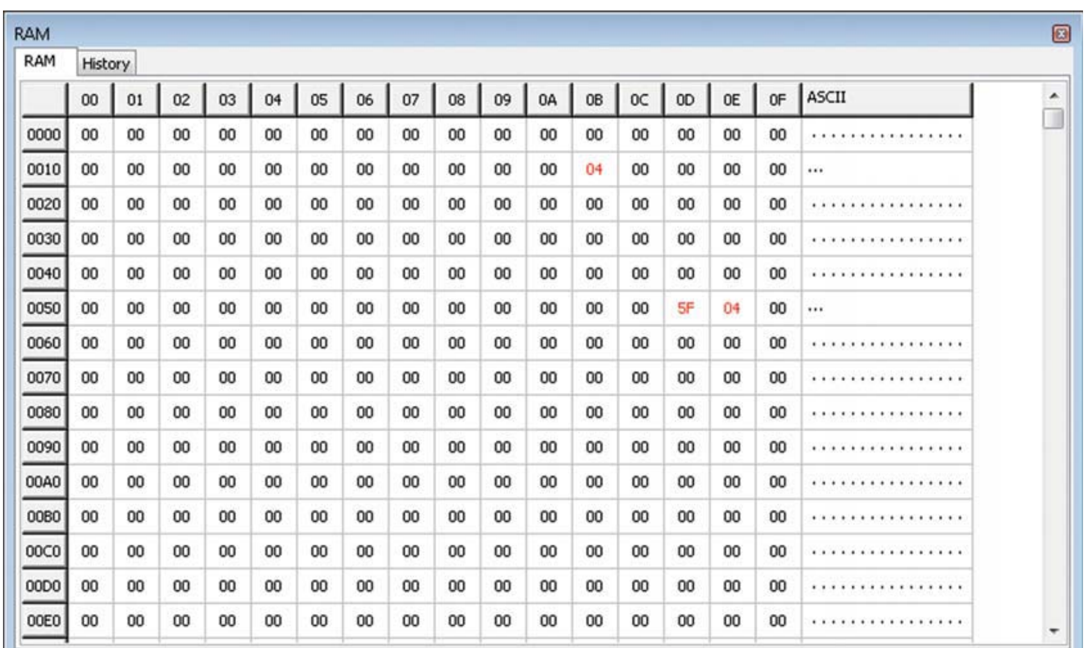
Note: The user can change the clock in the Stopwatch Window, which will recalculate values for the latest specified frequency. Changing the clock in the Stopwatch Window does not affect actual project settings – it only provides a simulation.



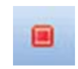
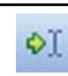
RAM Window

The Software Simulator RAM Window is available from the drop-down menu, **View › Debug Windows › RAM**.

The RAM Window displays a map of MCU's RAM, with recently changed items colored red. You can change value of any field by double-clicking it.



SOFTWARE SIMULATOR OPTIONS

Name	Description	Function Key	Toolbar Icon
`Start Debugger`	Start Software Simulator.	[F9]	
`Run/Pause Debugger`	Run or pause Software Simulator.	[F6]	
`Stop Debugger`	Stop Software Simulator.	[Ctrl+F2]	
`Toggle Breakpoints`	Toggle breakpoint at the current cursor position. To view all breakpoints, select Run > View Breakpoints from the drop–down menu. Double clicking an item in the Breakpoints Window List locates the breakpoint.	[F5]	
`Run to cursor`	Execute all instructions between the current instruction and cursor position.	[F4]	
`Step Into`	Execute the current C (single or multi–cycle) instruction, then halt. If the instruction is a routine call, enter the routine and halt at the first instruction following the call.	[F7]	
`Step Over`	Execute the current C (single or multi–cycle) instruction, then halt.	[F8]	
`Step Out`	Execute all remaining instructions in the current routine, return and then halt.	[Ctrl+F8]	

Related topics: Run Menu, Debug Toolbar

CREATING NEW LIBRARY

mikroC PRO for AVR allows you to create your own libraries. In order to create a library in mikroC PRO for AVR follow the steps bellow:

1. Create a new C source file, see Managing Source Files
2. Save the file in the compiler's Uses folder:
`DriveName:\ProgramFiles\Mikroelektronika\mikroC PRO for AVR\Uses\__Lib_Example`
3. Write a code for your library and save it.
4. Add `__Lib_Example` file in some project, see Project Manager. Recompile the project.
5. Compiled file `__Lib_Example.mcl` should appear in `...\mikroC PRO for AVR\Uses\` folder.
6. Open the definition file for the MCU that you want to use. This file is placed in the compiler's Defs folder:
`DriveName:\Program Files\Mikroelektronika\mikroC PRO for AVR\Defs\`
and it is named `MCU_NAME.mlk`, for example `ATMEGA16.mlk`
7. Add the `Library_Alias` and `Library_Name` at the end of the definition file, for example `#pragma SetLib([Example_Library, __Lib_Example])`
8. Add Library to mlk file for each MCU that you want to use with your library.
9. Click Refresh button in Library Manager
10. `Example_Library` should appear in the Library manager window.

Multiple Library Versions

Library Alias represents unique name that is linked to corresponding Library `.mcl` file. For example UART library for ATMEGA16 is different from UART library for ATMEGA128 MCU. Therefore, two different UART Library versions were made, see `mlk` files for these two MCUs. Note that these two libraries have the same Library Alias (UART) in both `mlk` files. This approach enables you to have identical representation of UART library for both MCUs in Library Manager.

Related topics: Library Manager, Project Manager, Managing Source Files

CHAPTER 3

mikroC PRO for AVR Specifics

The following topics cover the specifics of mikroC PRO for AVR compiler:

- ANSI Standard Issues
- Predefined Globals and Constants
- Accessing Individual Bits
- Interrupts
- AVR Pointers
- Linker Directives
- Built-in Routines
- Code Optimization
- Memory Type Specifiers

Notes:

- Directive absolute in Rx memory space guarantees only that defined variable will be overlapped with the given memory address.
- Addresses of all registers are RAM Space addresses. RAM Space is continuous region of RAM memory including all AVR RAM memory spaces (RAM space = Rx Space + IO Space + SRAM Space). When using instructions dedicated to IO Space in asm blocks, IO registers should be accessed by their RAM Space addresses. Refer to AVR memory organization for details on RAM Space addresses.
- Currently, Boot Loader section of the flash memory is not supported by the compiler.
- Rx space not used by the compiler may be used for user variables. So, the size of the available Rx space is not fixed, because it depends on the memory consumtion of the project itself. Compiler uses not less than 7 Rx registers.
- Literal strings are stored according to the destination (Flash or RAM). If stored in RAM, they are linked as a global and always exist by default. There is an option for storing literal string on the function frame.
- Constants may be stored only in the first 64kb of Flash memory.
- Available RAM memory is divided on static and dynamic link. Static link grows upwards (from lower to higher addresses). Dynamic link grows downwards (from higher to lower addresses).
- In case of intensive cross-callings, recursions, etc. it is not guaranteed that the dynamic link will be enough for the program execution. If this happens, dynamic link can get out of its boundaries and overwrite static link.

ANSI STANDARD ISSUES

Divergence from the ANSI C Standard

- Tentative declarations are not supported.

C Language Exstensions

mikroC PRO for AVR has additional set of keywords that do not belong to the ANSI standard C language keywords:

```
- code
- data
- io
- rx
- at
- sbit
- bit
- sfr
```

Related topics: Keywords, AVR Specific

PREDEFINED GLOBALS AND CONSTANTS

To facilitate programming of AVR compliant MCUs, the mikroC PRO for AVR implements a number of predefined globals and constants.

All AVR **SFR registers** and their **bits** are implicitly declared as global variables. These identifiers have an external linkage, and are visible in the entire project. When creating a project, the mikroC PRO for AVR will include an appropriate (*) file from defs folder, containing declarations of available **SFR registers** and constants.

For a complete set of predefined globals and constants, look for “Defs” in the mikroC PRO for AVR installation folder, or probe the Code Assistant for specific letters (Ctrl+Space in the Code Editor).

Predefined project level defines

There are 2 predefined project level defines for any project you make. These defines are based on values that you have entered/edited in the current project:

- First one is equal to the name of selected device for the project i.e. if ATmega16 is selected device, then ATmega16 token will be defined as 1, so it can be used for conditional compilation.

```
#ifdef ATmega16
...
#endif
```

- The second one is __FOSC__ value of frequency (in Khz) for which the project is built
- Third one is for identifying mikroC PRO for AVR compiler:

```
#ifdef __MIKROC_PRO_FOR_AVR__
...
#endif
```

- Fourth one is for identifying the build version. For instance, if a desired build version is 142, user should put this in his code:

```
#if __MIKROC_PRO_FOR_AVR_BUILD__ = 142
...
#endif
```

User can define custom project level defines.

ACCESSING INDIVIDUAL BITS

The mikroC PRO for AVR allows you to access individual bits of 8-bit variables. It also supports sbit and bit data types

Accessing Individual Bits Of Variables

If you are familiar with a particular MCU, you can access bits by name:

```
// Clear bit 0 on PORTA
PORTA0_bit = 0;
```

Also, you can simply use the direct member selector (`.`) with a variable, followed by one of identifiers `B0, B1, … , B7` with `B7` being the most significant bit:

```
// Clear bit 0 on PORTA
PORTA.B0 = 0;
```

There is no need of any special declarations. This kind of selective access is an intrinsic feature of mikroC PRO for AVR and can be used anywhere in the code. Identifiers `B0-B7` are not case sensitive and have a specific namespace. You may override them with your own members `B0-B7` within any given structure.

See Predefined Globals and Constants for more information on register/bit names.

Note: If aiming at portability, avoid this style of accessing individual bits, use the bit fields instead.

sbit type

The mikroC PRO for AVR compiler has `sbit` data type which provides access to bit-addressable SFRs. For example:

```
sbit LEDA at PORTA.B0;
sbit name at sfr-name.B<bit-position>;
```

The previously declared SFR (sfr-name) is the base address for the sbit. The bit-position (which must be a number from 0-7) follows the dot symbol ('.') and specifies the bit position to access. For example:

```
sbit OV at SREG.B2;
sbit CY at SREG.B7;
```

bit type

The mikroC PRO Compiler provides a `bit` data type that may be used for variable declarations. It can not be used for argument lists, and function-return values.

```
bit bf;     // bit variable
```

There are no pointers to bit variables:

```
bit *ptr;     // invalid
```

An array of type bit is not valid:

```
bit arr [5];      // invalid
```

Note :

- Bit variables can not be initialized.
- Bit variables can not be members of structures and unions.
- Bit variables do not have addresses, therefore unary operator & (address of) is not applicable to these variables.

Related topics: Bit fields, Predefined globals and constants

INTERRUPTS

AVR derivates acknowledges an interrupt request by executing a hardware generated CALL to the appropriate servicing routine ISRs. ISRs are organized in IVT. ISR is defined as a standard function but with the org directive afterwards which connects the function with specific interrupt vector. For example org 0x000B is IVT address of Timer/Counter 2 Overflow interrupt source of the ATMEGA16.
For more information on interrupts and IVT refer to the specific data sheet.

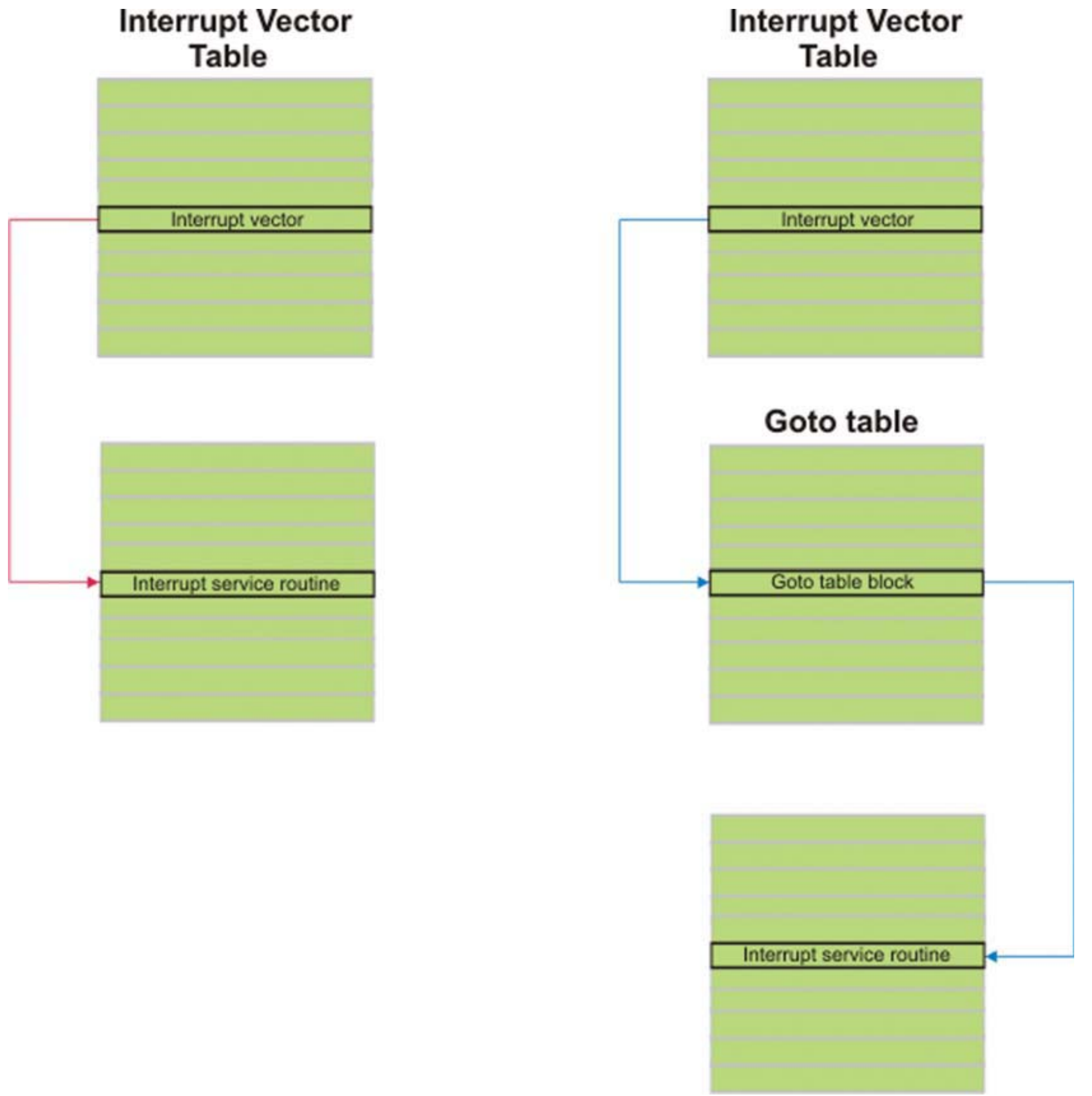
Function Calls from Interrupt

Calling functions from within the interrupt routine is allowed. The compiler takes care about the registers being used, both in "interrupt" and in "main" thread, and performs "smart" context-switching between them two, saving only the registers that have been used in both threads. It is not recommended to use function call from interrupt. In case of doing that take care of stack depth.

```
// Interrupt routine
void Interrupt() org 0x16 {
  RS485Master_Receive(dat);
}
```

Most of the MCUs can access interrupt service routines directly, but some can not reach interrupt service routines if they are allocated on addresses greater than 2K from the IVT. In this case, compiler automatically creates Goto table, in order to jump to such interrupt service routines.

These principles can be explained on the picture below :



Direct accessing interrupt service routine and accessing interrupt service routine via Goto table.

LINKER DIRECTIVES

The mikroC PRO uses an internal algorithm to distribute objects within memory. If you need to have a variable or routine at specific predefined address, use the linker directives `absolute` and `org`.

Directive absolute

Directive `absolute` specifies the starting address in RAM for a variable. If the variable is multi-byte, higher bytes will be stored at the consecutive locations.

Directive `absolute` is appended to declaration of a variable:

```
short x absolute 0x22;
// Variable x will occupy 1 byte at address 0x22

int y absolute 0x23;
// Variable y will occupy 2 bytes at addresses 0x23 and 0x24
```

Be careful when using the `absolute` directive, as you may overlap two variables by accident. For example:

```
char i absolute 0x33;
// Variable i will occupy 1 byte at address 0x33

long jjjj absolute 0x30;
// Variable will occupy 4 bytes at 0x30, 0x31, 0x32, 0x33; thus,
// changing i changes jjjj highest byte at the same time, and vice
versa
```

Directive org

Directive `org` specifies a starting address of a routine in ROM.

Directive `org` is appended to the function definition. Directives applied to non-defining declarations will be ignored, with an appropriate warning issued by the linker.

Here is a simple example:

```
void func(int par) org 0x200 {
// Function will start at address 0x200
  nop;
}
```

It is possible to use org directive with functions that are defined externally (such as library functions). Simply add org directive to function declaration:

```
void UART1_Write(char data) org 0x200;
```

Note: Directive org can be applied to any routin except for interrupt.
Note: See also funcall pragma.

Directive orgal

If the user wants to place its routines, constants, etc, above a specified address in ROM, `#pragma orgall` directive should be used:

```
#pragma orgall 0x200
```

This doesn't apply to IVT, Handler table and Goto table.

Directive funcorg

You can use the `#pragma orgall` directive to specify the starting address of a routine in ROM using routine name only:

```
#pragma funcorg <func_name> <starting_address>
```

INDIRECT FUNCTION CALLS

If the linker encounters an indirect function call (by a pointer to function), it assumes that any of the functions addresses of which were taken anywhere in the program, can be called at that point. Use the `#pragma funcall` directive to instruct the linker which functions can be called indirectly from the current function:

```
#pragma funcall <func_name> <called_func>[ , <called_func>,...]
```

A corresponding pragma must be placed in the source module where the function `func_name` is implemented. This module must also include declarations of all functions listed in the `called_func` list.

These functions will be linked if the function `func_name` is called in the code no matter whether any of them was called or not.

Note: The `#pragma funcall` directive can help the linker to optimize function frame allocation in the compiled stack.

BUILT-IN ROUTINES

The mikroC PRO for AVR compiler provides a set of useful built-in utility functions.

The `Lo, Hi, Higher, Highest` routines are implemented as macros. If you want to use these functions you must include `built_in.h` header file (located in the `inlclude` folder of the compiler) into your project.

The `Delay_us` and `Delay_ms` routines are implemented as "inline"; i.e. code is generated in the place of a call, so the call doesn't count against the nested call limit.

The `Vdelay_ms`, `Delay_Cyc` and `Get_Fosc_kHz` are actual C routines. Their sources can be found in `Delays` file located in the `uses` folder of the compiler.

- Lo
- Hi
- Higher
- Highest

- Delay_us
- Delay_ms
- Vdelay_ms
- Delay_Cyc

- Clock_kHz
- Clock_MHz
- Get_Fosc_kHz

Lo

Prototype	`unsigned short Lo(long number);`
Returns	Lowest 8 bits (byte)of `number`, bits `7..0`.
Description	Function returns the lowest byte of `number`. Function does not interpret bit patterns of `number` – it merely returns 8 bits as found in register. This is an "inline" routine; code is generated in the place of the call, so the call doesn't count against the nested call limit.
Requires	Arguments must be variable of scalar type (i.e. Arithmetic Types and Pointers).
Example	`d = 0x1AC30F4;` `tmp = Lo(d);   // Equals 0xF4`

Hi

Prototype	`unsigned short Hi(long number);`
Returns	Returns next to the lowest byte of `number`, bits 8..15.
Description	Function returns next to the lowest byte of `number`. Function does not interpret bit patterns of `number` – it merely returns 8 bits as found in register. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Arguments must be variable of scalar type (i.e. Arithmetic Types and Pointers).
Example	`d = 0x1AC30F4;` `tmp = Hi(d);   // Equals 0x30`

Higher

Prototype	`unsigned short Higher(long number);`
Returns	Returns next to the highest byte of number, bits 16..23.
Description	Function returns next to the highest byte of `number`. Function does not interpret bit patterns of `number` – it merely returns 8 bits as found in register. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Arguments must be variable of scalar type (i.e. Arithmetic Types and Pointers).
Example	`d = 0x1AC30F4;` `tmp = Higher(d);   // Equals 0xAC`

Highest

Prototype	`unsigned short Highest(long number);`
Returns	Returns the highest byte of number, bits 24..31.
Description	Function returns the highest byte of `number`. Function does not interpret bit patterns of `number` – it merely returns 8 bits as found in register. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Arguments must be variable of scalar type (i.e. Arithmetic Types and Pointers).
Example	`d = 0x1AC30F4;` `tmp = Highest(d);   // Equals 0x01`

Delay_us

Prototype	`void Delay_us(const unsigned long time_in_us);`
Returns	Nothing.
Description	Creates a software delay in duration of `time_in_us` microseconds (a constant). Range of applicable constants depends on the oscillator frequency. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Nothing.
Example	`Delay_us(1000);  /* One millisecond pause */`

Delay_ms

Prototype	`void Delay_ms(const unsigned long time_in_ms);`
Returns	Nothing.
Description	Creates a software delay in duration of `time_in_ms` milliseconds (a constant). Range of applicable constants depends on the oscillator frequency. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Nothing.
Example	`Delay_ms(1000);  /* One second pause */`

Vdelay_ms

Prototype	`void Vdelay_ms(unsigned time_in_ms);`
Returns	Nothing.
Description	Creates a software delay in duration of `time_in_ms` milliseconds (a variable). Generated delay is not as precise as the delay created by Delay_ms. Note that `Vdelay_ms` is library function rather than a built-in routine; it is presented in this topic for the sake of convenience.
Requires	Nothing.

Example	`pause = 1000;`
	`// ...`
	`Vdelay_ms(pause);  // ~ one second pause`

Delay_Cyc

Prototype	`void Delay_Cyc(char Cycles_div_by_10);`
Returns	Nothing.
Description	Creates a delay based on MCU clock. Delay lasts for 10 times the input parameter in MCU cycles. Note that `Delay_Cyc` is library function rather than a built-in routine; it is presented in this topic for the sake of convenience. There are limitations for Cycles_div_by_10 value. Value Cycles_div_by_10 must be between 2 and 257
Requires	Nothing.
Example	`Delay_Cyc(10);   /* Hundred MCU cycles pause */`

Clock_kHz

Prototype	`unsigned Clock_kHz(void);`
Returns	Device clock in kHz, rounded to the nearest integer.
Description	Function returns device clock in kHz, rounded to the nearest integer. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Nothing.
Example	`clk = Clock_kHz();`

Clock_MHz

Prototype	`unsigned short Clock_MHz(void);`
Returns	Device clock in MHz, rounded to the nearest integer.
Description	Function returns device clock in MHz, rounded to the nearest integer. This is an “inline” routine; code is generated in the place of the call, so the call doesn’t count against the nested call limit.
Requires	Nothing.
Example	`clk = Clock_MHz();`

Get_Fosc_kHz

Prototype	`unsigned long Get_Fosc_kHz(void);`
Returns	Device clock in kHz, rounded to the nearest integer.
Description	Function returns device clock in kHz, rounded to the nearest integer. Note that `Get_Fosc_kHz` is library function rather than a built-in routine; it is presented in this topic for the sake of convenience.
Requires	Nothing.
Example	`clk = Get_Fosc_kHz();`

CODE OPTIMIZATION

Optimizer has been added to extend the compiler usability, cut down the amount of code generated and speed-up its execution. The main features are:

Constant folding

All expressions that can be evaluated in the compile time (i.e. are constant) are being replaced by their results. (3 + 5 -> 8);

Constant propagation

When a constant value is being assigned to a certain variable, the compiler recognizes this and replaces the use of the variable by constant in the code that follows, as long as the value of a variable remains unchanged.

Copy propagation

The compiler recognizes that two variables have the same value and eliminates one of them further in the code.

Value numbering

The compiler "recognizes" if two expressions yield the same result and can therefore eliminate the entire computation for one of them.

"Dead code" ellimination

The code snippets that are not being used elsewhere in the programme do not affect the final result of the application. They are automatically removed.

Stack allocation

Temporary registers ("Stacks") are being used more rationally, allowing VERY complex expressions to be evaluated with a minimum stack consumption.

Local vars optimization

No local variables are being used if their result does not affect some of the global or volatile variables.

Better code generation and local optimization

Code generation is more consistent and more attention is payed to implement specific solutions for the code "building bricks" that further reduce output code size.

Related topics: AVR specifics, mikroC PRO for AVR specifics, Memory type specifiers

CHAPTER 4

AVR Specifics

Types Efficiency

First of all, you should know that AVR ALU, which performs arithmetic operations, is optimized for working with bytes. Although mikroC PRO is capable of handling very complex data types, AVR may choke on them, especially if you are working on some of the older models. This can dramatically increase the time needed for performing even simple operations. Universal advice is to use the smallest possible type in every situation. It applies to all programming in general, and doubly so with microcontrollers. Types efficiency is determined by the part of RAM memory that is used to store a variable/constant.

Nested Calls Limitations

There are no Nested Calls Limitations, except by RAM size. A Nested call represents a function call to another function within the function body. With each function call, the stack increases for the size of the returned address. Number of nested calls is equel to the capacity of RAM which is left out after allocation of all variables.

Important notes:

- There are many different types of derivates, so it is necessary to be familiar with characteristics and special features of the microcontroller in you are using.
- Some of the AVR MCUs have hardware multiplier. Due to this, be sure to pay attention when porting code from one MCU to another, because com piled code can vary by its size.
- Not all microcontrollers share the same instruction set. It is advisable to carefully read the instruction set of the desired MCU, before you start writing your code. Compiler automatically takes care of appropiate instruction set, and if unapropriate asm instruction is used in in-line assembly, compiler will report an error.
- Program counter size is MCU dependent. Thus, there are two sets of libraries :
  - MCUs with program counter size larger than 16 bits (flash memory size larger than 128kb)
  - MCUs with program counter size less or equal 16 bits (flash memory size smaller than 128kb)
- Assembly SPM instruction and its derivates must reside in Boot Loader section of program memory.
- Part of flash memory can be dedicated to Boot Loader code. For details, refer to AVR memory organization.

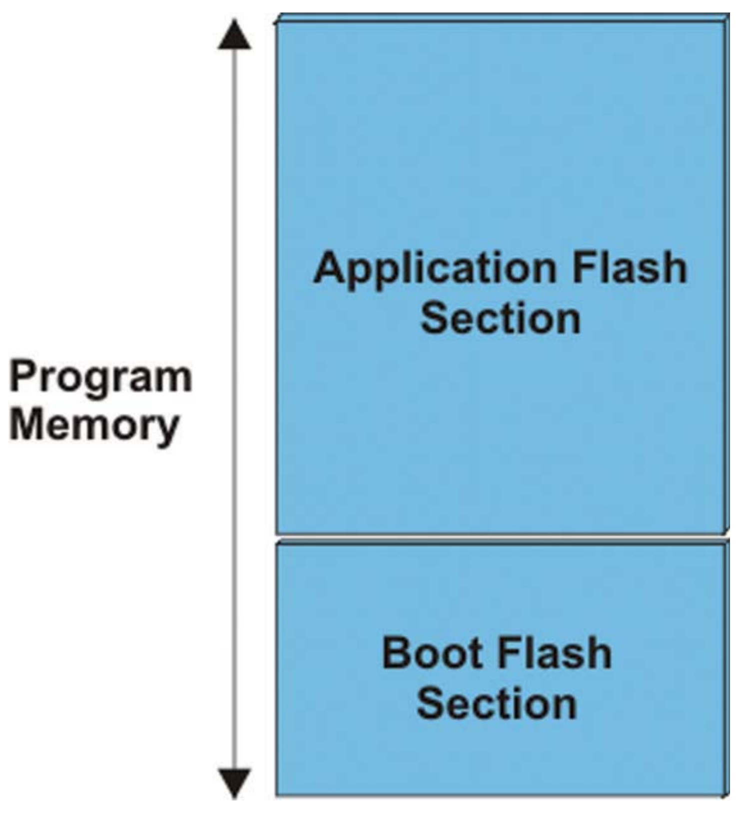
Related topics: mikroC PRO for AVR specifics, AVR memory organization

AVR MEMORY ORGANIZATION

The AVR microcontroller's memory is divided into Program Memory and Data Memory. Program Memory (ROM) is used for permanent saving program being executed, while Data Memory (RAM) is used for temporarily storing and keeping intermediate results and variables.

Program Memory (ROM)

Program Memory (ROM) is used for permanent saving program (CODE) being executed, and it is divided into two sections, Boot Program section and the Application Program section. The size of these sections is configured by the BOOTSZ fuse. These two sections can have different level of protection since they have different sets of Lock bits.
Depending on the settings made in compiler, program memory may also used to store a constant variables. The AVR executes programs stored in program memory only. code memory type specifier is used to refer to program memory.



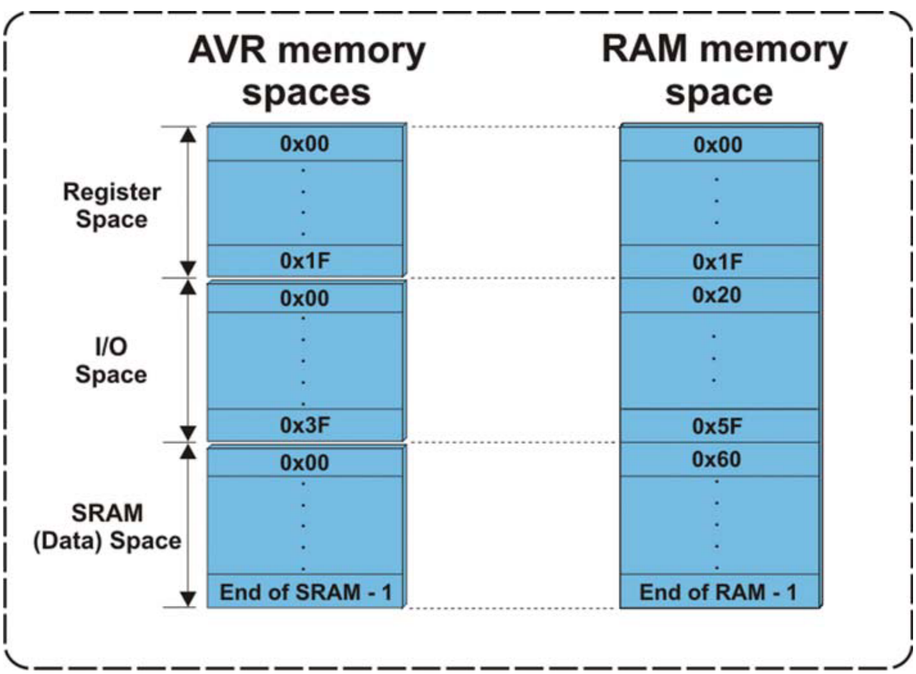
Data Memory

Data memory consists of :

- Rx space
- I/O Memory
- Extended I/O Memory (MCU dependent)
- Internal SRAM

Rx space consists of 32 general purpose working 8-bit registers (R0-R31). These registers have the shortest (fastest) access time, which allows single-cycle Arithmetic Logic Unit (ALU) operation.
I/O Memory space contains addresses for CPU peripheral function, such as Control registers, SPI, and other I/O functions.
Due to the complexity, some AVR microcontrollers with more peripherals have Extended I/O memory, which occupies part of the internal SRAM. Extended I/O memory is MCU dependent.
Storing data in I/O and Extended I/O memory is handled by the compiler only. Users can not use this memory space for storing their data.
Internal SRAM (Data Memory) is used for temporarily storing and keeping intermediate results and variables (static link and dynamic link).

There are four memory type specifiers that can be used to refer to the data memory: rx, data, io and sfr.



MEMORY TYPE SPECIFIERS

The mikroC PRO for AVR supports usage of all memory areas. Each variable may be explicitly assigned to a specific memory space by including a memory type specifier in the declaration, or implicitly assigned.

The following memory type specifiers can be used:

```
- code
- data
- rx
- io
- sfr
```

Memory type specifiers can be included in variable declaration.
For example:

```
char data             data_buffer;             // puts data_buffer in data ram
const char code txt[] = "ENTER PARAMETER:"; // puts text in program memory
```

code

Description	The code memory type may be used for allocating constants in program memory.
Example	`// puts txt in program memory` `const char code txt[] = "ENTER PARAMETER:";`

data

Description	This memory specifier is used when storing variable to the internal data SRAM.
Example	`// puts PORTG in data ram` `sfr data unsigned short PORTG absolute 0x65;`

rx

Description	This memory specifier allows variable to be stored in the Rx space (Register file). Note: In most of the cases, there will be enough space left for the user variables in the Rx space. However, since compiler uses Rx space for storing temporary variables, it might happen that user variables will be stored in the internal data SRAM, when writing complex programs.
Example	`// puts y in Rx space` `sfr char rx y;`

io

Description	This memory specifier allows user to access the I/O Memory space.
Example	`// put PORTB in io memory space` `sfr io unsigned short PORTB absolute 0x38;`

sfr

Description	This memory specifier in combination with (`rx, io, data`) allows user to access special function registers. It also instructs compiler to maintain same identifier in C and assembly.

Example	`sfr io unsigned short PORTB absolute 0x38; // put PORTB in I/O memory space`
	`sfr rx char y;       // puts y in Rx space sfr data unsigned short PORTG absolute 0x65; and sfr unsigned short PORTG absolute 0x65;` are equivalent, and put PORTG in Extended I/O Space.

Note: If none of the memory specifiers are used when declaring a variable, data specifier will be set as default by the compiler.

Related topics: AVR Memory Organization, Accessing individual bits, SFRs, Constants, Functions

CHAPTER 5

mikroC PRO for AVR Language Reference

The mikroC PRO for AVR Language Reference describes the syntax, semantics and implementation of the mikroC PRO for AVR language.

The aim of this reference guide is to provide a more understandable description of the mikroC PRO for AVR language to the user.

MIKROC PRO FOR AVR LANGUAGE REFERENCE

LEXICAL ELEMENTS OVERVIEW

The following topics provide a formal definition of the mikroC PRO for AVR lexical elements. They describe different categories of word-like units (tokens) recognized by the mikroC PRO for AVR.

In the tokenizing phase of compilation, the source code file is parsed (that is, broken down) into tokens and whitespace. The tokens in the mikroC PRO for AVR are derived from a series of operations performed on your programs by the compiler and its built-in preprocessor.

WHITESPACE

Whitespace is a collective name given to spaces (blanks), horizontal and vertical tabs, newline characters and comments. Whitespace can serve to indicate where tokens start and end, but beyond this function, any surplus whitespace is discarded. For example, two sequences

```
int i; float f;
```

and

```
int
  i;

    float f;
```

are lexically equivalent and parse identically to give six tokens:

```
int
i
;
float
f
;
```

Whitespace in Strings

The ASCII characters representing whitespace can occur within string literals. In that case they are protected from the normal parsing process (they remain as a part of the string). For example,

```
char name[] = "mikro foo";
```

parses into seven tokens, including a single string literal token:

```
char
name
[
]
=
"mikro foo"    /* just one token here! */
;
```

Line Splicing with Backslash (\)

A special case occurs if a line ends with a backslash (`\`). Both backslash and new line character are discarded, allowing two physical lines of a text to be treated as one unit. So, the following code

```
"mikroC PRO \

Compiler"
```

parses into `"mikroC PRO Compiler"`. Refer to String Constants for more information.

COMMENTS

Comments are pieces of a text used to annotate a program and technically are another form of whitespace. Comments are for the programmer's use only; they are stripped from the source text before parsing. There are two ways to delineate comments: the C method and the C++ method. Both are supported by mikroC PRO for AVR.

You should also follow the guidelines on the use of whitespace and delimiters in comments, discussed later in this topic to avoid other portability problems.

C comments

C comment is any sequence of characters placed after the symbol pair /*. The comment terminates at the first occurance of the pair */ following the initial /*. The entire sequence, including four comment-delimiter symbols, is replaced by one space after macro expansion.

In the mikroC PRO for AVR,

```
int /* type */ i /* identifier */;
```

parses as:

```
int i;
```

Note that the mikroC PRO for AVR does not support a nonportable token pasting strategy using /**/. For more information on token pasting, refer to the Preprocessor Operators.

C++ comments

The mikroC PRO for AVR allows single-line comments using two adjacent slashes (`//`). The comment can start in any position and extends until the next new line.

The following code

```
int i;  // this is a comment
int j;
```

parses as:

```
int i;
int j;
```

Nested comments

ANSI C doesn't allow nested comments. The attempt to nest a comment like this

```
/*  int /* declaration */ i; */
```

fails, because the scope of the first `/*` ends at the first `*/`. This gives us

```
i ; */
```

which would generate a syntax error.

TOKENS

Token is the smallest element of a C program that compiler can recognize. The parser separates tokens from the input stream by creating the longest token possible using the input characters in a left–to–right scan.

The mikroC PRO for AVR recognizes the following kinds of tokens:

- keywords
- identifiers
- constants
- operators
- punctuators (also known as separators)

Tokens can be concatenated (pasted) by means of the preprocessor operator `##`. See the Preprocessor Operators for details.

Token Extraction Example

Here is an example of token extraction. Take a look at the following example code sequence:

```
inter =  a+++b;
```

First, note that `inter` would be parsed as a single identifier, rather than as the keyword `int` followed by the identifier `er`.

The programmer who has written the code might have intended to write `inter = a + (++b)`, but it wouldn't work that way. The compiler would parse it into the seven following tokens:

```
inter     // variable identifier
=          // assignment operator
a          // variable identifier
++         // postincrement operator
+          // addition operator
b          // variable identifier
;          // statement terminator
```

Note that `+++` parses as `++` (the longest token possible) followed by `+`.

According to the operator precedence rules, our code sequence is actually:

```
inter (a++)+b;
```

CONSTANTS

Constants or literals are tokens representing fixed numeric or character values.

The mikroC PRO for AVR supports:

- integer constants
- floating point constants
- character constants
- string constants (strings literals)
- enumeration constants

The data type of a constant is deduced by the compiler using such clues as a numeric value and format used in the source code.

INTEGER CONSTANTS

Integer constants can be decimal (base 10), hexadecimal (base 16), binary (base 2), or octal (base 8). In the absence of any overriding suffixes, the data type of an integer constant is derived from its value.

Long and Unsigned Suffixes

The suffix `L` (or `l`) attached to any constant forces that constant to be represented as a `long`. Similarly, the suffix `U` (or `u`) forces a constant to be unsigned. Both `L` and `U` suffixes can be used with the same constant in any order or case: `ul, Lu, UL,` etc.

In the absence of any suffix (`U, u, L,` or `l`), a constant is assigned the "smallest" of the following types that can accommodate its value: `short, unsigned short, int, unsigned int, long int, unsigned long int.`

Otherwise:

- If a constant has the `U` suffix, its data type will be the first of the following that can accommodate its value: `unsigned short, unsigned int, unsigned long int.`
- If a constant has the `L` suffix, its data type will be the first of the following that can accommodate its value: `long int, unsigned long int.`
- If a constant has both `L` and `U` suffixes, (`LU` or `UL`), its data type will be `unsigned long int.`

Decimal

Decimal constants from -2147483648 to 4294967295 are allowed. Constants exceeding these bounds will produce an "Out of range" error. Decimal constants must not use an initial zero. An integer constant that has an initial zero is interpreted as an octal constant. Thus,

```
int i = 10;    /* decimal 10 */
int i = 010;   /* decimal 8  */
int i = 0;     /* decimal 0 = octal 0 */
```

In the absence of any overriding suffixes, the data type of a decimal constant is derived from its value, as shown below:

Value Assigned to Constant	Assumed Type
< -2147483648	Error: Out of range!
-2147483648 – -32769	`long`
-32768 – -129	`int`
-128 – 127	`short`
128 – 255	`unsigned short`
256 – 32767	`int`
32768 – 65535	`unsigned int`
65536 – 2147483647	`long`
2147483648 – 4294967295	`unsigned long`
> 4294967295	Error: Out of range!

Hexadecimal

All constants starting with `0x` (or `0X`) are taken to be hexadecimal. In the absence of any overriding suffixes, the data type of an hexadecimal constant is derived from its value, according to the rules presented above. For example, `0xC367` will be treated as `unsigned int`.

Binary

All constants starting with `0b` (or `0B`) are taken to be binary. In the absence of any overriding suffixes, the data type of an binary constant is derived from its value, according to the rules presented above. For example, `0b11101` will be treated as `short`.

Octal

All constants with an initial zero are taken to be octal. If an octal constant contains the illegal digits 8 or 9, an error is reported. In the absence of any overriding suffixes, the data type of an octal constant is derived from its value, according to the rules presented above. For example, `0777` will be treated as `int`.

FLOATING POINT CONSTANTS

A floating-point constant consists of:

- Decimal integer
- Decimal point
- Decimal fraction
- `e` or `E` and a signed integer exponent (optional)
- Type suffix: `f` or `F` or `l` or `L` (optional)

Either decimal integer or decimal fraction (but not both) can be omitted. Either decimal point or letter `e` (or `E`) with a signed integer exponent (but not both) can be omitted. These rules allow conventional and scientific (exponent) notations.

Negative floating constants are taken as positive constants with an unary operator minus (-) prefixed.

The mikroC PRO for AVR limits floating-point constants to the range ±1.17549435082 * 10-38 .. ±6.80564774407 * 1038.

Here are some examples:

```
0.         // = 0.0
-1.23      // = -1.23
23.45e6    // = 23.45 * 10^6
2e-5       // = 2.0 * 10^-5
3E+10      // = 3.0 * 10^10
.09E34     // = 0.09 * 10^34
```

The mikroC PRO for AVR floating-point constants are of the type `double`. Note that the mikroC PRO for AVR's implementation of ANSI Standard considers `float` and `double` (together with the `long double` variant) to be the same type.

CHARACTER CONSTANTS

A character constant is one or more characters enclosed in single quotes, such as `'A'`, `'+'`, or `'\n'`. In the mikroC PRO for AVR, single-character constants are of the `unsigned int` type. Multi-character constants are referred to as string constants or string literals. For more information refer to String Constants.

Escape Sequences

A backslash character (`\`) is used to introduce an escape sequence, which allows a visual representation of certain nongraphic characters. One of the most common escape constants is the newline character (`\n`).

A backslash is used with octal or hexadecimal numbers to represent an ASCII symbol or control code corresponding to that value; for example, `'\x3F'` for the question mark. Any value within legal range for data type char (`0` to `0xFF` for the mikroC PRO for AVR) can be used. Larger numbers will generate the compiler error “Out of range”.

For example, the octal number `\777` is larger than the maximum value allowed (`\377`) and will generate an error. The first nonoctal or nonhexadecimal character encountered in an octal or hexadecimal escape sequence marks the end of the sequence.

Note: You must use the sequence `\\` to represent an ASCII backslash, as used in operating system paths.

The following table shows the available escape sequences:

Sequence	Value	Char	What it does
`\a`	0x07	BEL	Audible bell
`\b`	0x08	BS	Backspace
`\f`	0x0C	FF	Formfeed
`\n`	0x0A	LF	Newline (Linefeed)
`\r`	0x0D	CR	Carriage Return
`\t`	0x09	HT	Tab (horizontal)
`\v`	0x0B	VT	Vertical Tab
`\\`	0x5C	/	Backslash
`\'`	0x27	'	Single quote (Apostrophe)
`\"`	0x22	"	Double quote
`\?`	0x3F	?	Question mark
`\O`		any	O = string of up to 3 octal digits
`\xH`		any	H = string of hex digits
`\XH`		any	H = string of hex digits

Disambiguation

Some ambiguous situations might arise when using escape sequences.

Here is an example:

```
Lcd_Out_Cp("\x091.0 Intro");
```

This is intended to be interpreted as `\x09` and `"1.0 Intro"`. However, the mikroC PRO for AVR compiles it as the hexadecimal number `\x091` and literal string `".0 Intro"`. To avoid such problems, we could rewrite the code in the following way:

```
Lcd_Out_Cp("\x09" "1.0 Intro");
```

For more information on the previous line, refer to String Constants.

Ambiguities might also arise if an octal escape sequence is followed by a nonoctal digit. For example, the following constant:

```
"\118"
```

would be interpreted as a two-character constant made up of the characters `\11` and `8`, because `8` is not a legal octal digit.

STRING CONSTANTS

String constants, also known as string literals, are a special type of constants which store fixed sequences of characters. A string literal is a sequence of any number of characters surrounded by double quotes:

```
"This is a string."
```

The null string, or empty string, is written like `""`. A literal string is stored internally as a given sequence of characters plus a final null character. A null string is stored as a single null character.

The characters inside the double quotes can include escape sequences. This code, for example:

```
"\t\"Name\"\\\tAddress\n\n"
```

prints like this:

```
        "Name"\       Address
```

The "Name" is preceded by two tabs; The Address is preceded by one tab. The line is followed by two new lines. The `\"` provides interior double quotes. The escape character sequence `\\` is translated into `\` by the compiler.

Adjacent string literals separated only by whitespace are concatenated during the parsing phase. For example:

```
"This is "  "just"
     " an example."
```

is equivalent to

```
"This is just an example."
```

Line Continuation with Backslash

You can also use the backslash (`\`) as a continuation character to extend a string constant across line boundaries:

```
"This is really \
          a one-line string."
```

ENUMERATION CONSTANTS

Enumeration constants are identifiers defined in `enum` type declarations. The identifiers are usually chosen as mnemonics to contribute to legibility. Enumeration constants are of `int` type. They can be used in any expression where integer constants are valid.

For example:

```
enum weekdays {  SUN = 0, MON, TUE, WED, THU, FRI, SAT };
```

The identifiers (enumerators) used must be unique within the scope of the enum declaration. Negative initializers are allowed. See Enumerations for details about `enum` declarations.

Pointer Constants

A pointer or pointed-at object can be declared with the `const` modifier. Anything declared as `const` cannot change its value. It is also illegal to create a pointer that might violate a non-assignability of the constant object.

Consider the following examples:

```
int i;                         // i is an int
int * pi;                      // pi is a pointer to int (uninitial-
ized)
int * const cp = &i;           // cp is a constant pointer to int
const int ci = 7;              // ci is a constant int
const int * pci;               // pci is a pointer to constant int
const int * const cpc = &ci;   // cpc is a constant pointer to a
                               //      constant int
```

The following assignments are legal:

```
i = ci;                        // Assign const-int to int
*cp = ci;                      // Assign const-int to
                              //   object-pointed-at-by-a-const-pointer
++pci;                         // Increment a pointer-to-const
pci = cpc;                     // Assign a const-pointer-to-a-const to
a
                               //      pointer-to-const
```

The following assignments are illegal:

```
ci = 0;                        // NO--cannot assign to a const-int
ci--;                          // NO--cannot change a const-int
*pci = 3;                      // NO--cannot assign to an object
                               //      pointed at by pointer-to-const.
cp = &ci;                      // NO--cannot assign to a const-pointer,
                               //      even if value would be unchanged.
cpc++;                         // NO--cannot change const-pointer
pi = pci;                      // NO--if this assignment were allowed,
                               //      you would be able to assign to *pci
                               //      (a const value) by assigning to *pi.
```

Similar rules are applayed to the `volatile` modifier. Note that both `const` and `volatile` can appear as modifiers to the same identifier.

CONSTANT EXPRESSIONS

A constant expressions can be evaluated during translation rather that runtime and accordingly may be used in any place that a constant may be.

Constant expressions can consist only of the following:

- literals,
- enumeration constants,
- simple constants (no constant arrays or structures),
- `sizeof` operators.

Constant expressions cannot contain any of the following operators, unless the operators are contained within the operand of a `sizeof` operator: assignment, comma, decrement, function call, increment.

Each constant expression can evaluate to a constant that is in the range of representable values for its type.

Constant expression can be used anywhere a constant is legal.

KEYWORDS

Keywords are words reserved for special purposes and must not be used as normal identifier names.

Beside standard C keywords, all relevant SFR are defined as global variables and represent reserved words that cannot be redefined (for example: `TMR0`, `PCL`, etc). Probe the Code Assistant for specific letters (Ctrl+Space in Editor) or refer to Predefined Globals and Constants.

Here is an alphabetical listing of keywords in C:

```
- asm
- auto
- break
- case
- char
- const
- continue
- default
- do
- double
- else
- enum
- extern
- float
- for
- goto
- if
- int
- long
- register
- return
- short
- signed
- sizeof
- static
- struct
- switch
- typedef
- union
- unsigned
- void
- volatile
- while
```

Also, the mikroC PRO for AVR includes a number of predefined identifiers used in libraries. You could replace them by your own definitions, if you want to develop your own libraries. For more information, see mikroC PRO for AVR Libraries.

IDENTIFIERS

Identifiers are arbitrary names of any length given to functions, variables, symbolic constants, user-defined data types, and labels. All these program elements will be referred to as objects throughout the help (don't get confused with the meaning of object in object-oriented programming).

Identifiers can contain the letters a to z and A to Z, underscore character "_", and digits 0 to 9. The only restriction is that the first character must be a letter or an underscore.

Case Sensitivity

The mikroC PRO for AVR identifiers are not case sensitive by default, so that `Sum`, `sum`, and `suM` represent an equivalent identifier. Case sensitivity can be activated or suspended in Output Settings window. Even if case sensitivity is turned off Keywords remain case sensitive and they must be written in lower case.

Uniqueness and Scope

Although identifier names are arbitrary (according to the stated rules), if the same name is used for more than one identifier within the same scope and sharing the same name space then error arises. Duplicate names are legal for different name spaces regardless of scope rules. For more information on scope, refer to Scope and Visibility.

Identifier Examples

Here are some valid identifiers:

```
temperature_V1
Pressure
no_hit
dat2string
SUM3
_vtext
```

… and here are some invalid identifiers:

```
7temp         // NO -- cannot begin with a numeral
%higher       // NO -- cannot contain special characters
int           // NO -- cannot match reserved word
j23.07.04     // NO -- cannot contain special characters (dot)
```

PUNCTUATORS

The mikroC PRO for AVR punctuators (also known as separators) are:

- [ ] – Brackets
- ( ) – Parentheses
- { } – Braces
- , – Comma
- ; – Semicolon
- : – Colon
- * – Asterisk
- = – Equal sign
- # – Pound sign

Most of these punctuators also function as operators.

Brackets

Brackets `[ ]` indicate single and multidimensional array subscripts:

```
char ch, str[] = "mikro";

int mat[3][4];         /* 3 x 4 matrix */
ch = str[3];           /* 4th element */
```

Parentheses

Parentheses `( )` are used to group expressions, isolate conditional expressions, and indicate function calls and function parameters:

```
d = c * (a + b);      /* override normal precedence */

if (d == z) ++x;      /* essential with conditional statement */
func();               /* function call, no args */
void func2(int n);    /* function declaration with parameters */
```

Parentheses are recommended in macro definitions to avoid potential precedence problems during an expansion:

```
#define CUBE(x) ((x) * (x) * (x))
```

For more information, refer to Operators Precedence And Associativity and Expressions.

Braces

Braces { } indicate the start and end of a compound statement:

```
if (d == z) {
  ++x;
  func();
}
```

Closing brace serves as a terminator for the compound statement, so a semicolon is not required after `}` , except in structure declarations. Sometimes, the semicolon can be illegal, as in

```
if (statement)
   { ... };    /* illegal semicolon! */
else
   { ... };
```

For more information, refer to the Compound Statements.

Comma

Comma (`,`) separates the elements of a function argument list:

```
void func(int n, float f, char ch);
```

Comma is also used as an operator in comma expressions. Mixing two uses of comma is legal, but you must use parentheses to distinguish them. Note that (exp1, exp2) evalutates both but is equal to the second:

```
func(i, j);                          /* call func with two args */
func((exp1, exp2), (exp3, exp4, exp5));  /* also calls func with two
args! */
```

Semicolon

Semicolon (;) is a statement terminator. Any legal C expression (including the empty expression) followed by a semicolon is interpreted as a statement, known as an expression statement. The expression is evaluated and its value is discarded. If the expression statement has no side effects, the mikroC PRO for AVR might ignore it.

```
a + b;     /* Evaluate a + b, but discard value */
++a;       /* Side effect on a, but discard value of ++a */
;          /* Empty expression, or a null statement */
```

Semicolons are sometimes used to create an empty statement:

```
for (i = 0; i < n; i++) ;
```

For more information, see the Statements.

Colon

Use colon (:) to indicate the labeled statement:

```
start:  x = 0;
  ...
goto start;
```

Labels are discussed in the Labeled Statements.

Asterisk (Pointer Declaration)

Asterisk (*) in a variable declaration denotes the creation of a pointer to a type:

```
char *char_ptr;  /* a pointer to char is declared */
```

Pointers with multiple levels of indirection can be declared by indicating a pertinent number of asterisks:

```
int **int_ptr;          /* a pointer to an array of integers */
double ***double_ptr;  /* a pointer to a matrix of doubles */
```

You can also use asterisk as an operator to either dereference a pointer or as multiplication operator:

```
i = *int_ptr;
a = b * 3.14;
```

For more information, see the Pointers.

Equal Sign

Equal sign (=) separates variable declarations from initialization lists:

```
int test[5] = { 1, 2, 3, 4, 5 };
int x = 5;
```

Equal sign is also used as an assignment operator in expressions:

```
int a, b, c;
a = b + c;
```

For more information, see Assignment Operators.

Pound Sign (Preprocessor Directive)

Pound sign (`#`) indicates a preprocessor directive when it occurs as the first non-whitespace character on a line. It signifies a compiler action, not necessarily associated with a code generation. See the Preprocessor Directives for more information.

`#` and `##` are also used as operators to perform token replacement and merging during the preprocessor scanning phase. See the Preprocessor Operators.

CONCEPTS

This section covers some basic concepts of language, essential for understanding of how C programs work. First, we need to establish the following terms that will be used throughout the help:

- Objects and lvalues
- Scope and Visibility
- Name Spaces
- Duration

OBJECTS

An object is a specific region of memory that can hold a fixed or variable value (or set of values). This use of a term object is different from the same term, used in object-oriented languages, which is more general. Our definiton of the word would encompass functions, variables, symbolic constants, user-defined data types, and labels.

Each value has an associated name and type (also known as a data type). The name is used to access the object and can be a simple identifier or complex expression that uniquely refers the object.

Objects and Declarations

Declarations establish a necessary mapping between identifiers and objects. Each declaration associates an identifier with a data type.

Associating identifiers with objects requires each identifier to have at least two attributes: storage class and type (sometimes referred to as data type). The mikroC PRO for AVR compiler deduces these attributes from implicit or explicit declarations in the source code. Usually, only the type is explicitly specified and the storage class specifier assumes the automatic value auto.

Generally speaking, an identifier cannot be legally used in a program before its declaration point in the source code. Legal exceptions to this rule (known as forward references) are labels, calls to undeclared functions, and struct or union tags.

The range of objects that can be declared includes:

- Variables
- Functions
- Types
- Arrays of other types
- Structure, union, and enumeration tags
- Structure members
- Union members
- Enumeration constants
- Statement labels
- Preprocessor macros

The recursive nature of the declarator syntax allows complex declarators. You'll probably want to use typedefs to improve legibility if constructing complex objects.

Lvalues

Lvalue is an object locator: an expression that designates an object. An example of lvalue expression is `*P`, where `P` is any expression evaluating to a non-null pointer. A modifiable lvalue is an identifier or expression that relates to an object that can be accessed and legally changed in memory. A const pointer to a constant, for example, is not a modifiable lvalue. A pointer to a constant can be changed (but its dereferenced value cannot).

Historically, `l` stood for "left", meaning that lvalue could legally stand on the left (the receiving end) of an assignment statement. Now only modifiable lvalues can legally stand to the left of an assignment operator. For example, if `a` and `b` are nonconstant integer identifiers with properly allocated memory storage, they are both modifiable lvalues, and assignments such as `a = 1` and `b = a + b` are legal.

Rvalues

The expression `a + b` is not lvalue: `a + b = a` is illegal because the expression on the left is not related to an object. Such expressions are sometimes called rvalues (short for right values).

SCOPE AND VISIBILITY

Scope

The scope of an identifier is a part of the program in which the identifier can be used to access its object. There are different categories of scope: block (or local), function, function prototype, and file. These categories depend on how and where identifiers are declared.

- **Block**: The scope of an identifier with block (or local) scope starts at the declaration point and ends at the end of the block containing the declaration (such block is known as the enclosing block). Parameter declarations with a function definition also have block scope, limited to the scope of the function body.
- **File**: File scope identifiers, also known as globals, are declared outside of all blocks; their scope is from the point of declaration to the end of the source file.
- **Function**: The only identifiers having function scope are statement labels. Label names can be used with goto statements anywhere in the function in which the label is declared. Labels are declared implicitly by writing label_name: followed by a statement. Label names must be unique within a function.
- **Function prototype**: Identifiers declared within the list of parameter declarations in a function prototype (not as a part of a function definition) have a function prototype scope. This scope ends at the end of the function prototype.

Visibility

The visibility of an identifier is a region of the program source code from which an identifier's associated object can be legally accessed.

Scope and visibility usually coincide, though there are circumstances under which an object becomes temporarily hidden by the appearance of a duplicate identifier: the object still exists but the original identifier cannot be used to access it until the scope of the duplicate identifier ends.

Technically, visibility cannot exceed a scope, but a scope can exceed visibility. See the following example:

```
void f (int i) {
 int j;           // auto by default
 j = 3;           // int i and j are in scope and visible

   {               // nested block
    double j;     // j is local name in the nested block
    j = 0.1;      // i and double j are visible;
                   // int j = 3 in scope but hidden
   }
                   // double j out of scope
 j += 1;          // int j visible and = 4
}
// i and j are both out of scope
```

NAME SPACES

Name space is a scope within which an identifier must be unique. The mikroC PRO for AVR uses four distinct categories of identifiers:

1. `goto` label names - must be unique within the function in which they are declared.
2. Structure, union, and enumeration tags - must be unique within the block in which they are defined. Tags declared outside of any function must be unique.
3. Structure and union member names - must be unique within the structure or union in which they are defined. There is no restriction on the type or offset of members with the same member name in different structures.
4. Variables, typedefs, functions, and enumeration members - must be unique within the scope in which they are defined. Externally declared identifiers must be unique among externally declared variables.

Duplicate names are legal for different name spaces regardless of the scope rules.

For example:

```
int blue = 73;

{  // open a block
   enum colors {  black, red, green, blue, violet, white }  c;
   /* enumerator blue = 3 now hides outer declaration of int blue */

   struct colors {  int i, j; };    // ILLEGAL: colors duplicate tag
   double red = 2;                   // ILLEGAL: redefinition of red
}

blue = 37;                          // back in int blue scope
```

DURATION

Duration, closely related to a storage class, defines a period during which the declared identifiers have real, physical objects allocated in memory. We also distinguish between compile-time and run-time objects. Variables, for instance, unlike typedefs and types, have real memory allocated during run time. There are two kinds of duration: *static* and *local*.

Static Duration

Memory is allocated to objects with static duration as soon as execution is underway; this storage allocation lasts until the program terminates. Static duration objects usually reside in fixed data segments allocated according to the memory model in force. All globals have static duration. All functions, wherever defined, are objects with static duration. Other variables can be given static duration by using the explicit `static` or `extern` storage class specifiers.

In the mikroC PRO for AVR, static duration objects are not initialized to zero (or null) in the absence of any explicit initializer.

Don't mix static duration with file or global scope. An object can have static duration and local scope – see the example below.

Local Duration

Local duration objects are also known as automatic objects. They are created on the stack (or in a register) when an enclosing block or a function is entered. They are deallocated when the program exits that block or function. Local duration objects must be explicitly initialized; otherwise, their contents are unpredictable.

The storage class specifier `auto` can be used when declaring local duration variables, but it is usually redundant, because `auto` is default for variables declared within a block.

An object with local duration also has local scope because it does not exist outside of its enclosing block. On the other hand, a local scope object can have static duration. For example:

```
void f() {
  /* local duration variable; init a upon every call to f */
  int a = 1;
  /* static duration variable; init b only upon first call to f */
  static int b = 1;
  /* checkpoint! */
  a++;
  b++;
}

void main() {
/* At checkpoint, we will have: */
f(); // a=1, b=1, after first call,
f(); // a=1, b=2, after second call,
f(); // a=1, b=3, after third call,
     // etc.
}
```

TYPES

The mikroC PRO for AVR is a strictly typed language, which means that every object, function, and expression must have a strictly defined type, known in the time of compilation. Note that the mikroC PRO for AVR works exclusively with numeric types.

The type serves:

- to determine the correct memory allocation required initially.
- to interpret the bit patterns found in the object during subsequent access.
- in many type-checking situations, to ensure that illegal assignments are trapped.

The mikroC PRO for AVR supports many standard (predefined) and user-defined data types, including signed and unsigned integers in various sizes, floating-point numbers with various precisions, arrays, structures, and unions. In addition, pointers to most of these objects can be established and manipulated in memory.

The type determines how much memory is allocated to an object and how the program will interpret the bit patterns found in the object's storage allocation. A given data type can be viewed as a set of values (often implementation-dependent) that identifiers of that type can assume, together with a set of operations allowed with these values. The compile-time operator `sizeof` allows you to determine the size in bytes of any standard or user-defined type.

The mikroC PRO for AVR standard libraries and your own program and header files must provide unambiguous identifiers (or expressions derived from them) and types so that the mikroC PRO for AVR can consistently access, interpret, and (possibly) change the bit patterns in memory corresponding to each active object in your program.

Type Categories

A common way to categorize types is to divide them into:

- fundamental
- derived

The fudamental types represent types that cannot be split up into smaller parts. They are sometimes referred to as unstructured types. The fundamental types are `void`, `char`, `int`, `float`, and `double`, together with `short`, `long`, `signed`, and `unsigned` variants of some of them. For more information on fundamental types, refer to the topic Fundamental Types.

The derived types are also known as structured types and they include pointers to other types, arrays of other types, function types, structures, and unions. For more information on derived types, refer to the topic Derived Types.

FUNDAMENTAL TYPES

The fudamental types represent types that cannot be divided into more basic elements, and are the model for representing elementary data on machine level. The fudamental types are sometimes referred to as *unstructured types*, and are used as elements in creating more complex derived or user-defined types.

The fundamental types include:

- Arithmetic Types
- Enumerations
- Void Type

ARITHMETIC TYPES

The arithmetic type specifiers are built up from the following keywords: void, char, int, float and double, together with the prefixes short, long, signed and unsigned. From these keywords you can build both integral and floating-point types.

Integral Types

The types `char` and `int`, together with their variants, are considered to be integral data types. Variants are created by using one of the prefix modifiers `short`, `long`, `signed` and `unsigned`.

In the table below is an overview of the integral types – keywords in parentheses can be (and often are) omitted.

The modifiers `signed` and `unsigned` can be applied to both `char` and `int`. In the absence of the `unsigned` prefix, `signed` is automatically assumed for integral types. The only exception is `char`, which is `unsigned` by default. The keywords `signed` and `unsigned`, when used on their own, mean `signed int` and `unsigned int`, respectively.

The modifiers `short` and `long` can only be applied to `int`. The keywords `short` and `long`, used on their own, mean `short int` and `long int`, respectively.

Type	Size in bytes	Range
`(unsigned) char`	1	0 .. 255
`signed char`	1	- 128 .. 127
`(signed) short (int)`	1	- 128 .. 127
`unsigned short (int)`	1	0 .. 255
`(signed) int`	2	-32768 .. 32767
`unsigned (int)`	2	0 .. 65535
`(signed) long (int)`	4	-2147483648 .. 2147483647
`unsigned long (int)`	4	0 .. 4294967295

Floating-point Types

The types `float` and `double`, together with the `long double` variant, are considered to be floating-point types. The mikroC PRO for AVR's implementation of an ANSI Standard considers all three to be the same type.

Floating point in the mikroC PRO for AVR is implemented using the Microchip AN575 32-bit format (IEEE 754 compliant).

An overview of the floating-point types is shown in the table below:

Type	Size in bytes	Range
`float`	4	$-1.5 * 10^{45}$ .. $+3.4 * 10^{38}$
`double`	4	$-1.5 * 10^{45}$ .. $+3.4 * 10^{38}$
`double`	4	$-1.5 * 10^{45}$ .. $+3.4 * 10^{38}$

ENUMERATIONS

An enumeration data type is used for representing an abstract, discreet set of values with appropriate symbolic names.

Enumeration Declaration

Enumeration is declared like this:

```
enum tag {enumeration-list};
```

Here, tag is an optional name of the enumeration; `enumeration-list` is a comma-delimited list of discreet values, enumerators (or enumeration constants). Each enumerator is assigned a fixed integral value. In the absence of explicit initializers, the first enumerator is set to zero, and the value of each succeeding enumerator is set to a value of its predecessor increased by one.

Variables of the enum type are declared the same as variables of any other type. For example, the following declaration:

```
enum colors { black, red, green, blue, violet, white } c;
```

establishes a unique integral type, `enum colors`, variable `c` of this type, and set of enumerators with constant integer values (black = 0, red = 1, ...). In the mikroC PRO for AVR, a variable of an enumerated type can be assigned any value of the type `int` – no type checking beyond that is enforced. That is:

```
c = red;      // OK
c = 1;        // Also OK, means the same
```

With explicit integral initializers, you can set one or more enumerators to specific values. The initializer can be any expression yielding a positive or negative integer value (after possible integer promotions). Any subsequent names without initializers will be increased by one. These values are usually unique, but duplicates are legal.

The order of constants can be explicitly re-arranged. For example:

```
enum colors { black,       // value 0
               red,         // value 1
               green,       // value 2
               blue=6,      // value 6
               violet,      // value 7
               white=4 };   // value 4
```

Initializer expression can include previously declared enumerators. For example, in the following declaration:

```
enum memory_sizes { bit = 1, nibble = 4 * bit, byte = 2 * nibble,
                     kilobyte = 1024 * byte };
```

nibble would acquire the value 4, byte the value 8, and kilobyte the value 8192.

Anonymous Enum Type

In our previous declaration, the identifier `colors` is an optional enumeration tag that can be used in subsequent declarations of enumeration variables of the `enum colors` type:

```
enum colors bg, border;  /* declare variables bg and border */
```

Like with struct and union declarations, you can omit the tag if no further variables of this `enum` type are required:

```
/* Anonymous enum type: */
enum { black, red, green, blue, violet, white } color;
```

Enumeration Scope

Enumeration tags share the same name space as structure and union tags. Enumerators share the same name space as ordinary variable identifiers:

```
int blue = 73;

{ // open a block
    enum colors { black, red, green, blue, violet, white } c;
    /* enumerator blue = 3 now hides outer declaration of int blue */

    struct colors { int i, j; };    // ILLEGAL: colors duplicate tag
    double red = 2;                 // ILLEGAL: redefinition of red
}

blue = 37;                          // back in int blue scope
```

VOID TYPE

void is a special type indicating the absence of any value. There are no objects of void; instead, void is used for deriving more complex types.

Void Functions

Use the void keyword as a function return type if the function does not return a value.

```
void print_temp(char temp) {
  Lcd_Out_Cp("Temperature:");
  Lcd_Out_Cp(temp);
  Lcd_Chr_Cp(223);  // degree character
  Lcd_Chr_Cp('C');
}
```

Use void as a function heading if the function does not take any parameters. Alternatively, you can just write empty parentheses:

```
main(void) {  // same as main()
 ...
}
```

Generic Pointers

Pointers can be declared as void, which means that they can point to any type. These pointers are sometimes called generic.

DERIVED TYPES

The derived types are also known as structured types. They are used as elements in creating more complex user-defined types.

The derived types include:

- arrays
- pointers
- structures
- unions

ARRAYS

Array is the simplest and most commonly used structured type. A variable of array type is actually an array of objects of the same type. These objects represent elements of an array and are identified by their position in array. An array consists of a contiguous region of storage exactly large enough to hold all of its elements.

Array Declaration

Array declaration is similar to variable declaration, with the brackets added after identifer:

```
type array_name[constant-expression]
```

This declares an array named as `array_name` and composed of elements of type. The type can be any scalar type (except `void`), user-defined type, pointer, enumeration, or another array. Result of `constant-expression` within the brackets determines a number of elements in array. If an expression is given in an array declarator, it must evaluate to a positive constant integer. The value is a number of elements in an array.

Each of the elements of an array is indexed from 0 to the number of elements minus one. If a number of elements is n, elements of array can be approached as variables `array_name[0] .. array_name[n-1]` of `type`.

Here are a few examples of array declaration:

```
#define MAX = 50
int    vector_one[10];       /* declares an array of 10 integers */
float  vector_two[MAX];       /* declares an array of 50 floats   */
float  vector_three[MAX - 20]; /* declares an array of 30 floats   */
```

Array Initialization

An array can be initialized in declaration by assigning it a comma-delimited sequence of values within braces. When initializing an array in declaration, you can omit the number of elements – it will be automatically determined according to the number of elements assigned. For example:

```
/* Declare an array which holds number of days in each month: */
int days[12] = {31,28,31,30,31,30,31,31,30,31,30,31};

/* This declaration is identical to the previous one */
int days[] = {31,28,31,30,31,30,31,31,30,31,30,31};
```

If you specify both the length and starting values, the number of starting values must not exceed the specified length. The opposite is possible, in this case the trailing “excess” elements will be assigned to some encountered runtime values from memory.

In case of array of `char`, you can use a shorter string literal notation. For example:

```
/* The two declarations are identical: */
const char msg1[] = {'T', 'e', 's', 't', '\0'};
const char msg2[] = "Test";
```

For more information on string literals, refer to String Constants.

Arrays in Expressions

When the name of an array comes up in expression evaluation (except with operators & and `sizeof`), it is implicitly converted to the pointer pointing to array’s first element. See Arrays and Pointers for more information.

Multi-dimensional Arrays

An array is one-dimensional if it is of scalar type. One-dimensional arrays are sometimes referred to as vectors.

Multidimensional arrays are constructed by declaring arrays of array type. These arrays are stored in memory in such way that the right most subscript changes fastest, i.e. arrays are stored “in rows”. Here is a sample of 2-dimensional array:

```
float m[50][20];   /* 2-dimensional array of size 50x20 */
```

A variable `m` is an array of 50 elements, which in turn are arrays of 20 floats each. Thus, we have a matrix of 50x20 elements: the first element is `m[0][0]`, the last one is `m[49][19]`. The first element of the 5th row would be `m[4][0]`.

If you don't initialize the array in the declaration, you can omit the first dimension of multi-dimensional array. In that case, array is located elsewhere, e.g. in another file. This is a commonly used technique when passing arrays as function parameters:

```
int a[3][2][4];   /* 3-dimensional array of size 3x2x4 */

void func(int n[][2][4]) {  /* we can omit first dimension */
  ...
  n[2][1][3]++;   /* increment the last element*/
}//~

void main() {
  ...
  func(a);
}
```

You can initialize a multi-dimensional array with an appropriate set of values within braces. For example:

```
int a[3][2] = {{1,2}, {2,6}, {3,7}};
```

POINTERS

Pointers are special objects for holding (or "pointing to") memory addresses. In the mikroC PRO for AVR, address of an object in memory can be obtained by means of an unary operator &. To reach the pointed object, we use an indirection operator (*) on a pointer.

A pointer of type "pointer to object of type" holds the address of (that is, points to) an object of `type`. Since pointers are objects, you can have a pointer pointing to a pointer (and so on). Other objects commonly pointed to include arrays, structures, and unions.

A pointer to a function is best thought of as an address, usually in a code segment, where that function's executable code is stored; that is, the address to which control is transferred when that function is called.

Although pointers contain numbers with most of the characteristics of unsigned integers, they have their own rules and restrictions for declarations, assignments, conversions, and arithmetic. The examples in the next few sections illustrate these rules and restrictions.

Pointer Declarations

Pointers are declared the same as any other variable, but with `*` ahead of identifier. A type at the beginning of declaration specifies the type of a pointed object. A pointer must be declared as pointing to some particular type, even if that type is `void`, which really means a pointer to anything. Pointers to `void` are often called generic pointers, and are treated as pointers to `char` in the mikroC PRO for AVR.

If `type` is any predefined or user-defined type, including `void`, the declaration

```
type *p;    /* Uninitialized pointer */
```

declares p to be of type "pointer to `type`". All scoping, duration, and visibility rules are applied to the p object just declared. You can view the declaration in this way: if `*p` is an object of `type`, then p has to be a pointer to such object (object of `type`).

Note: You must initialize pointers before using them! Our previously declared pointer `*p` is not initialized (i.e. assigned a value), so it cannot be used yet.

Note: In case of multiple pointer declarations, each identifier requires an indirect operator. For example:

```
int *pa, *pb, *pc;

/* is same as: */

int *pa;
int *pb;
int *pc;
```

Once declared, though, a pointer can usually be reassigned so that it points to an object of another type. The mikroC PRO for AVR lets you reassign pointers without typecasting, but the compiler will warn you unless the pointer was originally declared to be pointing to `void`. You can assign the `void*` pointer to the non-`void*` pointer – refer to `void` for details.

Null Pointers

A null pointer value is an address that is guaranteed to be different from any valid pointer in use in a program. Assigning the integer constant 0 to a pointer assigns a null pointer value to it.

For example:

```
int *pn = 0;       /* Here's one null pointer */

/* We can test the pointer like this: */
if ( pn == 0 ) {  ... }
```

The pointer type "pointer to void" must not be confused with the null pointer. The declaration

```
void *vp;
```

declares that `vp` is a generic pointer capable of being assigned to by any "pointer to type" value, including null, without complaint.

Assignments without proper casting between a "pointer to `type1`" and a "pointer to `type2`", where `type1` and `type2` are different types, can invoke a compiler warning or error. If `type1` is a function and `type2` isn't (or vice versa), pointer assignments are illegal. If `type1` is a pointer to `void`, no cast is needed. If `type2` is a pointer to `void`, no cast is needed.

FUNCTION POINTERS

Function Pointers are pointers, i.e. variables, which point to the address of a function.

```
// Define a function pointer
   int (*pt2Function) (float, char, char);
```

Note: Thus functions and function pointers with different calling convention (argument order, arguments type or return type is different) are incompatible with each other.

Assign an address to a Function Pointer

It's quite easy to assign the address of a function to a function pointer. Simply take the name of a suitable and known function. Using the address operator & infront of the function's name is optional.

```
   //Assign an address to the function pointer

  int DoIt  (float a, char b, char c){ return a+b+c; }
  pt2Function = &DoIt;  // assignment
```

Example:

```
int addC(char x,char y){

  return x+y;
}

int subC(char x,char y){

  return x-y;
}

int mulC(char x,char y){

  return x*y;
}


int divC(char x,char y){

  return x/y;
}
```

```
int modC(char x,char y){

  return x%y;
}


//array of pointer to functions that receive two chars and returns
int
int  (*arrpf[])(char,char) = { addC ,subC,mulC,divC,modC};


int res;
char i;
void main() {

   for (i=0;i<5;i++){
     res = arrpf[i](10,20);
   }

}
```

POINTER ARITHMETIC

Pointer arithmetic in the mikroC PRO for AVR is limited to:

- assigning one pointer to another,
- comparing two pointers,
- comparing pointer to zero,
- adding/subtracting pointer and an integer value,
- subtracting two pointers.

The internal arithmetic performed on pointers depends on the memory model in force and the presence of any overriding pointer modifiers. When performing arithmetic with pointers, it is assumed that the pointer points to an array of objects.

Arrays and Pointers

Arrays and pointers are not completely independent types in the mikroC PRO for AVR. When the name of an array comes up in expression evaluation (except with operators `&` and `sizeof`), it is implicitly converted to the pointer pointing to array's first element. Due to this fact, arrays are not modifiable lvalues.

Brackets `[ ]` indicate array subscripts. The expression

```
id[exp]
```

is defined as

```
*((id) + (exp))
```

where either:

- id is a pointer and exp is an integer, or
- id is an integer and exp is a pointer.

The following statements are true:

```
&a[i]   =  a + i
 a[i]   =  *(a + i)
```

According to these guidelines, it can be written:

```
pa = &a[4];        // pa points to a[4]
x = *(pa + 3);     // x = a[7]

/* .. but: */
y = *pa + 3;        // y = a[4] + 3
```

Also the care should be taken when using operator precedence:

```
*pa++;              // Equal to *(pa++), increments the pointer
(*pa)++;            // Increments the pointed object!
```

The following examples are also valid, but better avoid this syntax as it can make the code really illegible:

```
(a + 1)[i] = 3;
// same as: *((a + 1) + i) = 3, i.e. a[i + 1] = 3

(i + 2)[a] = 0;
// same as: *((i + 2) + a) = 0, i.e. a[i + 2] = 0
```

Assignment and Comparison

The simple assignment operator (=) can be used to assign value of one pointer to another if they are of the same type. If they are of different types, you must use a typecast operator. Explicit type conversion is not necessary if one of the pointers is generic (of the void type).

Assigning the integer constant 0 to a pointer assigns a null pointer value to it.

Two pointers pointing to the same array may be compared by using relational operators `==`, `!=`, `<`, `<=`, `>`, and `>=`. Results of these operations are the same as if they were used on subscript values of array elements in question:

```
int *pa = &a[4], *pb = &a[2];

if (pa == pb) {... /* won't be executed as 4 is not equal to 2 */ }
if (pa > pb)  {... /* will be executed as 4 is greater than 2 */ }
```

You can also compare pointers to zero value – testing in that way if the pointer actually points to anything. All pointers can be successfully tested for equality or inequality to null:

```
if (pa == 0) { ... }
if (pb != 0) { ... }
```

Note: Comparing pointers pointing to different objects/arrays can be performed at programmer's own responsibility — a precise overview of data's physical storage is required.

Pointer Addition

You can use operators `+`, `++`, and `+=` to add an integral value to a pointer. The result of addition is defined only if the pointer points to an element of an array and if the result is a pointer pointing to the same array (or one element beyond it).

If a pointer is declared to point to `type`, adding an integral value `n` to the pointer increments the pointer value by `n * sizeof(type)` as long as the pointer remains within the legal range (first element to one beyond the last element). If `type` has a size of 10 bytes, then adding 5 to a pointer to type advances the pointer 50 bytes in memory. In case of the `void` type, the size of a step is one byte.

For example:

```
int a[10];          /* array a containing 10 elements of type int */
int *pa = &a[0];    /* pa is pointer to int, pointing to a[0] */
*(pa + 3) = 6;       /* pa+3 is a pointer pointing to a[3], so a[3]
now equals 6 */
pa++;               /* pa now points to the next element of array a:
a[1] */
```

There is no such element as "one past the last element", of course, but the pointer is allowed to assume such value. C "guarantees" that the result of addition is defined even when pointing to one element past array. If `P` points to the last array element, `P + 1` is legal, but `P + 2` is undefined.

This allows you to write loops which access the array elements in a sequence by means of incrementing pointer — in the last iteration you will have the pointer pointing to one element past the array, which is legal. However, applying an indirection operator (*) to a “pointer to one past the last element” leads to undefined behavior.

For example:

```
void f (some_type a[], int n) {
    /* function f handles elements of array a; */
    /* array a has n elements of type some_type */

  int i;
  some_type *p=&a[0];

  for ( i = 0; i < n; i++ ) {
          /* .. here we do something with *p .. */
    p++;  /* .. and with the last iteration p exceeds
                the last element of array a */
  }
  /* at this point, *p is undefined! */
}
```

Pointer Subtraction

Similar to addition, you can use operators `-`, `--`, and `-=` to subtract an integral value from a pointer.

Also, you may subtract two pointers. The difference will be equal to the distance between two pointed addresses, in bytes.

For example:

```
int a[10];
int *pi1 = &a[0];
int *pi2 = &a[4];
i = pi2 - pi1;       /* i equals 8 */
pi2 -= (i >> 1);     /* pi2 = pi2 - 4: pi2 now points to [0] */
```

STRUCTURES

A structure is a derived type usually representing a user-defined collection of named members (or components). These members can be of any type, either fundamental or derived (with some restrictions to be discussed later), in any sequence. In addition, a structure member can be a bit field.

Unlike arrays, structures are considered to be single objects. The mikroC PRO for AVR structure type lets you handle complex data structures almost as easily as single variables.

Note: the mikroC PRO for AVR does not support anonymous structures (ANSI divergence).

Structure Declaration and Initialization

Structures are declared using the keyword `struct`:

```
struct tag {member-declarator-list};
```

Here, `tag` is the name of a structure; `member-declarator-list` is a list of structure members, actually a list of variable declarations. Variables of structured type are declared the same as variables of any other type.

The member type cannot be the same as the struct type being currently declared. However, a member can be a pointer to the structure being declared, as in the following example:

```
struct mystruct {mystruct s;};    /* illegal! */
struct mystruct {mystruct *ps;}; /* OK */
```

Also, a structure can contain previously defined structure types when declaring an instance of declared structure. Here is an example:

```
/* Structure defining a dot: */
struct Dot {float x, y;};

/* Structure defining a circle: */
struct Circle {
  float r;
  struct Dot center;
} o1, o2;
/* declare variables o1 and o2 of Circle */
```

Note that the structure tag can be omitted, but then additional objects of this type cannot be declared elsewhere. For more information, see the Untagged Structures below.

Structure is initialized by assigning it a comma-delimited sequence of values within braces, similar to array. For example:

```
/* Referring to declarations from the example above: */

/* Declare and initialize dots p and q: */
struct Dot p = {1., 1.}, q = {3.7, -0.5};

/* Declare and initialize circle o1: */
struct Circle o1 = {1., {0., 0.}};  // radius is 1, center is at (0,
0)
```

Incomplete Declarations

Incomplete declarations are also known as forward declarations. A pointer to a structure type A can legally appear in the declaration of another structure `B` before `A` has been declared:

```
struct A;  // incomplete
struct B {struct A *pa;};
struct A {struct B *pb;};
```

The first appearance of A is called incomplete because there is no definition for it at that point. An incomplete declaration is allowed here, because the definition of `B` doesn't need the size of `A`.

Untagged Structures and Typedefs

If the structure tag is omitted, an untagged structure is created. The untagged structures can be used to declare the identifiers in the comma-delimited `member-declarator-list` to be of the given structure type (or derived from it), but additional objects of this type cannot be declared elsewhere.

```
/* With tag: */
typedef struct mystruct { ... } Mystruct;
Mystruct s, *ps, arrs[10];  /* same as struct mystruct s, etc. */

/* Without tag: */
typedef struct { ... } Mystruct;
Mystruct s, *ps, arrs[10];
```

Usually, there is no need to use both `tag` and `typedef:` either can be used in structure type declarations.

Untagged structure and union members are ignored during initialization.

Note: See also Working with structures.

WORKING WITH STRUCTURES

Structures represent user-defined types. A set of rules regarding the application of structures is strictly defined.

Assignment

Variables of the same structured type may be assigned one to another by means of simple assignment operator (=). This will copy the entire contents of the variable to destination, regardless of the inner complexity of a given structure.

Note that two variables are of the same structured type only if they are both defined by the same instruction or using the same type identifier. For example:

```
/* a and b are of the same type: */
struct {int m1, m2;} a, b;

/* But c and d are _not_ of the same type although
  their structure descriptions are identical: */
struct {int m1, m2;} c;
struct {int m1, m2;} d;
```

Size of Structure

The size of the structure in memory can be retrieved by means of the operator `sizeof`. It is not necessary that the size of the structure is equal to the sum of its members' sizes. It is often greater due to certain limitations of memory storage.

Structures and Functions

A function can return a structure type or a pointer to a structure type:

```
mystruct func1(void);      /* func1() returns a structure */
mystruct *func2(void);     /* func2() returns pointer to structure */
```

A structure can be passed as an argument to a function in the following ways:

```
void func1(mystruct s;);       /* directly */
void func2(mystruct *sptr;);   /* via a pointer */
```

STRUCTURE MEMBER ACCESS

Structure and union members are accessed using the following two selection operators:

. (period)
-> (right arrow)

The operator `.` is called the direct member selector and it is used to directly access one of the structure's members. Suppose that the object s is of the struct type `S` and `m` is a member identifier of the type `M` declared in `s`, then the expression

```
s.m    // direct access to member m
```

is of the type M, and represents the member object `m` in S.

The operator `->` is called the indirect (or pointer) member selector. Suppose that the object `s` is of the struct type `S` and `ps` is a pointer to s. Then if m is a member identifier of the type `M` declared in `s,` the expression

```
ps->m    // indirect access to member m;
          // identical to (*ps).m
```

is of the type `M`, and represents the member object `m` in `s`. The expression `ps->m` is a convenient shorthand for `(*ps).m`.

For example:

```
struct mystruct {
  int i;
  char str[21];
  double d;
} s, *sptr = &s;

...

s.i = 3;              // assign to the i member of mystruct s
sptr -> d = 1.23;    // assign to the d member of mystruct s
```

The expression `s.m` is lvalue, providing that `s` is lvalue and `m` is not an array type. The expression `sptr->m` is an lvalue unless `m` is an array type.

Accessing Nested Structures

If the structure B contains a field whose type is the structure A, the members of A can be accessed by two applications of the member selectors:

```
struct A {
  int j; double x;
};
struct B {
  int i; struct A aa; double d;
} s, *sptr;

...

s.i = 3;              // assign 3 to the i member of B
s.aa.j = 2;           // assign 2 to the j member of A
sptr->d = 1.23;       // assign 1.23 to the d member of B
sptr->aa.x = 3.14;    // assign 3.14 to x member of A
```

Structure Uniqueness

Each structure declaration introduces a unique structure type, so that in

```
struct A {
  int i,j; double d;
} aa, aaa;

struct B {
  int i,j; double d;
} bb;
```

the objects `aa` and `aaa` are both of the type struct `A`, but the objects `aa` and `bb` are of different structure types. Structures can be assigned only if the source and destination have the same type:

```
aa = aaa;    /* OK: same type, member by member assignment */
aa = bb;     /* ILLEGAL: different types */

/* but you can assign member by member: */
aa.i = bb.i;
aa.j = bb.j;
aa.d = bb.d;
```

UNIONS

Union types are derived types sharing many of syntactic and functional features of structure types. The key difference is that a union members share the same memory space.

Note: The mikroC PRO for AVR does not support anonymous unions (ANSI divergence).

Union Declaration

Unions have the same declaration as structures, with the keyword union used instead of struct:

```
union tag { member-declarator-list };
```

Unlike structures' members, the value of only one of union's members can be stored at any time. Here is a simple example:

```
union myunion {   // union tag is 'myunion'
  int i;
  double d;
  char ch;
} mu, *pm;
```

The identifier `mu`, of the type `myunion`, can be used to hold a 2-byte `int`, 4-byte `double` or single-byte `char`, but only one of them at a certain moment. The identifier `pm` is a pointer to union `myunion`.

Size of Union

The size of a union is the size of its largest member. In our previous example, both `sizeof(union myunion)` and `sizeof(mu)` return 4, but 2 bytes are unused (padded) when `mu` holds the `int` object, and 3 bytes are unused when `mu` holds `char`.

Union Member Access

Union members can be accessed with the structure member selectors (`.` and `->`), be careful when doing this:

```
/* Referring to declarations from the example above: */
pm = &mu;
mu.d = 4.016;
tmp = mu.d;  // OK: mu.d = 4.016
tmp = mu.i;  // peculiar result

pm->i = 3;
tmp = mu.i;  // OK: mu.i = 3
```

The third line is legal, since `mu.i` is an integral type. However, the bit pattern in `mu.i` corresponds to parts of the previously assigned `double`. As such, it probably won't provide an useful integer interpretation.

When properly converted, a pointer to a union points to each of its members, and vice versa.

BIT FIELDS

Bit fields are specified numbers of bits that may or may not have an associated identifier. Bit fields offer a way of subdividing structures into named parts of user-defined sizes.

Structures and unions can contain bit fields that can be up to 16 bits.

You cannot take the address of a bit field.

Note: If you need to handle specific bits of 8-bit variables (`char` and `unsigned short`) or registers, you don't need to declare bit fields. Much more elegant solution is to use the mikroC PRO for AVR's intrinsic ability for individual bit access — see Accessing Individual Bits for more information.

Bit Fields Declaration

Bit fields can be declared only in structures and unions. Declare a structure normally and assign individual fields like this (fields need to be `unsigned`):

```
struct tag {
  unsigned bitfield-declarator-list;
}
```

Here, `tag` is an optional name of the structure; `bitfield-declarator-list` is a list of bit fields. Each component identifer requires a colon and its width in bits to be explicitly specified. Total width of all components cannot exceed two bytes (16 bits).

As an object, bit fields structure takes two bytes. Individual fields are packed within two bytes from right to left. In `bitfield-declarator-list`, you can omit identifier(s) to create an artificial "padding", thus skipping irrelevant bits.

For example, if there is a need to manipulate only bits 2–4 of a register as one block, create a structure like this:

```
struct {
  unsigned  : 2,  // Skip bits 0 and 1, no identifier here
     mybits : 3;  // Relevant bits 2, 3 and 4
                  // Bits 5, 6 and 7 are implicitly left out
} myreg;
```

Here is an example:

```
typedef struct {
  lo_nibble  : 4;
  hi_nibble  : 4;
  high_byte  : 8;} myunsigned;
```

which declares the structured type `myunsigned` containing three components: `lo_nibble` (bits 3..0), `hi_nibble` (bits 7..4) and `high_byte` (bits 15..8).

Bit Fields Access

Bit fields can be accessed in the same way as the structure members. Use direct and indirect member selector (`.` and `->`). For example, we could work with our previously declared `myunsigned` like this:

```
// This example writes low byte of bit field of myunsigned type to
PORT0:
myunsigned Value_For_PORT0;

void main() {
  ...
  Value_For_PORT0.lo_nibble  = 7;
  Value_For_PORT0.hi_nibble  = 0x0C;
  P0 = *(char *) (void *)&Value_For_PORT0;
      // typecasting :
        // 1. address of structure to pointer to void
        // 2. pointer to void to pointer to char
        // 3. dereferencing to obtain the value
}
```

TYPES CONVERSIONS

The mikroC PRO for AVR is a strictly typed language, with each operator, statement and function demanding appropriately typed operands/arguments. However, we often have to use objects of “mismatching” types in expressions. In that case, type conversion is needed.

Conversion of object of one type means that object's type is changed into another type. The mikroC PRO for AVR defines a set of standard conversions for built-in types, provided by compiler when necessary. For more information, refer to the Standard Conversions.

Conversion is required in the following situations:

- if a statement requires an expression of particular type (according to lan guage definition), and we use an expression of different type,
- if an operator requires an operand of particular type, and we use an operand of different type,
- if a function requires a formal parameter of particular type, and we pass it an object of different type,
- if an expression following the keyword `return` does not match the declared function return type,
- if intializing an object (in declaration) with an object of different type.

In these situations, compiler will provide an automatic implicit conversion of types, without any programmer's interference. Also, the programmer can demand conversion explicitly by means of the typecast operator. For more information, refer to the Explicit Typecasting.

STANDARD CONVERSIONS

Standard conversions are built in the mikroC PRO for AVR. These conversions are performed automatically, whenever required in the program. They can also be explicitly required by means of the typecast operator (refer to the Explicit Typecasting).

The basic rule of automatic (implicit) conversion is that the operand of simpler type is converted (promoted) to the type of more complex operand. Then, the type of the result is that of more complex operand.

Arithmetic Conversions

When using arithmetic expression, such as `a + b`, where `a` and `b` are of different arithmetic types, the mikroC PRO for AVR performs implicit type conversions before the expression is evaluated. These standard conversions include promotions of “lower” types to “higher” types in the interests of accuracy and consistency.

Assigning a signed character object (such as a variable) to an integral object results in automatic sign extension. Objects of type signed char always use sign extension; objects of type unsigned char always has its high byte set to zero when converted to int.

Converting a longer integral type to a shorter type truncates the higher order bits and leaves low-order bits unchanged. Converting a shorter integral type to a longer type either sign-extends or zero-fills the extra bits of the new value, depending on whether the shorter type is signed or unsigned, respectively.

Note: Conversion of floating point data into integral value (in assignments or via explicit typecast) produces correct results only if the `float` value does not exceed the scope of destination integral type.

In details:

Here are the steps the mikroC PRO for AVR uses to convert the operands in an arithmetic expression:

First, any small integral types are converted according to the following rules:

1. `char` converts to `int`
2. `signed char` converts to `int`, with the same value
3. `short` converts to `int`, with the same value, sign-extended
4. `unsigned short` converts to `int`, with the same value, zero-filled
5. `enum` converts to `int`, with the same value

After this, any two values associated with an operator are either `int` (including the `long` and `unsigned` modifiers) or `float` (equivalent with `double` and `long double` in the mikroC PRO for AVR).

1. If either operand is `float`, the other operand is converted to `float`.
2. Otherwise, if either operand is `unsigned long`, the other operand is converted to `unsigned long`.
3. Otherwise, if either operand is `long`, then the other operand is converted to `long`.
4. Otherwise, if either operand is `unsigned`, then the other operand is converted to `unsigned`.
5. Otherwise, both operands are `int`.

The result of the expression is the same type as that of the two operands.

Here are several examples of implicit conversion:

```
2 + 3.1        /* ? 2. + 3.1 ? 5.1 */
5 / 4 * 3.     /* ? (5/4)*3. ? 1*3. ? 1.*3. ? 3. */
3. * 5 / 4     /* ? (3.*5)/4 ? (3.*5.)/4 ? 15./4 ? 15./4. ? 3.75 */
```

Pointer Conversions

Pointer types can be converted to other pointer types using the typecasting mechanism:

```
char *str;
int *ip;
str = (char *)ip;
```

More generally, the cast `type*` will convert a pointer to type “pointer to `type`”.

EXPLICIT TYPES CONVERSIONS (TYPECASTING)

In most situations, compiler will provide an automatic implicit conversion of types where needed, without any user's interference. Also, the user can explicitly convert an operand to another type using the prefix unary typecast operator:

```
(type) object
```

This will convert `object` to a specified `type`. Parentheses are mandatory.

For example:

```
/* Let's have two variables of char type: */
char a, b;

/* Following line will coerce a to unsigned int: */
(unsigned int) a;

/* Following line will coerce a to double,
   then coerce b to double automatically,
   resulting in double type value: */
(double) a + b;     // equivalent to ((double) a) + b;
```

DECLARATIONS

A declaration introduces one or several names to a program – it informs the compiler what the name represents, what its type is, what operations are allowed with it, etc. This section reviews concepts related to declarations: declarations, definitions, declaration specifiers, and initialization.

The range of objects that can be declared includes:

- Variables
- Constants
- Functions
- Types
- Structure, union, and enumeration tags
- Structure members
- Union members
- Arrays of other types
- Statement labels
- Preprocessor macros

Declarations and Definitions

Defining declarations, also known as definitions, beside introducing the name of an object, also establish the creation (where and when) of an object; that is, the allocation of physical memory and its possible initialization. Referencing declarations, or just declarations, simply make their identifiers and types known to the compiler.

Here is an overview. Declaration is also a definition, except if:

- it declares a function without specifying its body
- it has the `extern` specifier, and has no initializator or body (in case of func.)
- it is the `typedef` declaration

There can be many referencing declarations for the same identifier, especially in a multifile program, but only one defining declaration for that identifier is allowed.

For example:

```
/*  Here is a nondefining declaration of function max; */
/*  it merely informs compiler that max is a function */
int max();

/*  Here is a definition of function max: */
int max(int x, int y) {
  return (x >= y) ? x : y;
}
```

```
/*  Definition of variable i: */
int i;

/*  Following line is an error, i is already defined! */
int i;
```

Declarations and Declarators

The declaration contains specifier(s) followed by one or more identifiers (declarators). The declaration begins with optional storage class specifiers, type specifiers, and other modifiers. The identifiers are separated by commas and the list is terminated by a semicolon.

Declarations of variable identifiers have the following pattern:

```
storage-class [ type-qualifier]  type var1 [ =init1] , var2 [ =init2] , ... ;
```

where `var1, var2,...` are any sequence of distinct identifiers with optional initializers. Each of the variables is declared to be of type; if omitted, type defaults to int. The specifier `storage-class` can take the values `extern`, `static`, `register`, or the default `auto`. Optional `type-qualifier` can take values `const` or `volatile`. For more details, refer to Storage Classes and Type Qualifiers.

For example:

```
/*  Create 3 integer variables called x, y, and z
    and initialize x and y to the values 1 and 2, respectively: */
int x = 1, y = 2, z;    // z remains uninitialized

/*  Create a floating-point variable q with static modifier,
    and initialize it to 0.25: */
static float q = .25;
```

These are all defining declarations; storage is allocated and any optional initializers are applied.

LINKAGE

An executable program is usually created by compiling several independent translation units, then linking the resulting object files with preexisting libraries. A term translation unit refers to a source code file together with any included files, but without the source lines omitted by conditional preprocessor directives. A problem arises when the same identifier is declared in different scopes (for example, in different files), or declared more than once in the same scope.

The linkage is a process that allows each instance of an identifier to be associated correctly with one particular object or function. All identifiers have one of two linkage attributes, closely related to their scope: external linkage or internal linkage. These attributes are determined by the placement and format of your declarations, together with an explicit (or implicit by default) use of the storage class specifier `static` or `extern`.

Each instance of a particular identifier with external linkage represents the same object or function throughout the entire set of files and libraries making up the program. Each instance of a particular identifier with internal linkage represents the same object or function within one file only.

Linkage Rules

Local names have internal linkage; the same identifier can be used in different files to signify different objects. Global names have external linkage; identifier signifies the same object throughout all program files.

If the same identifier appears with both internal and external linkage within the same file, the identifier will have internal linkage.

Internal Linkage Rules

1. names having file scope, explicitly declared as `static`, have internal linkage
2. names having file scope, explicitly declared as `const` and not explicitly declared as `extern`, have internal linkage
3. `typedef` names have internal linkage
4. enumeration constants have internal linkage

External Linkage Rules

1. names having file scope, that do not comply to any of previously stated internal linkage rules, have external linkage

The storage class specifiers `auto` and `register` cannot appear in an external declaration. No more than one external definition can be given for each identifier in a translation unit declared with internal linkage. An external definition is an external declaration that defines an object or a function and also allocates a storage. If an identifier declared with external linkage is used in an expression (other than as part of the operand of `sizeof`), then exactly one external definition of that identifier must be somewhere in the entire program.

STORAGE CLASSES

Associating identifiers with objects requires each identifier to have at least two attributes: storage class and type (sometimes referred to as data type). The mikroC PRO for AVR compiler deduces these attributes from implicit or explicit declarations in the source code.

A storage class dictates the location (data segment, register, heap, or stack) of object and its duration or lifetime (the entire running time of the program, or during execution of some blocks of code). A storage class can be established by the syntax of a declaration, by its placement in the source code, or by both of these factors:

```
storage-class type identifier
```

The storage class specifiers in the mikroC PRO for AVR are:

- auto
- register
- static
- extern

Auto

The `auto` modifer is used to define that a local variable has a local duration. This is the default for local variables and is rarely used. `auto` can not be used with globals. See also Functions.

Register

At the moment the modifier `register` technically has no special meaning. The mikroC PRO for AVR compiler simply ignores requests for register allocation.

Static

A global name declared with the `static` specifier has internal linkage, meaning that it is local for a given file. See Linkage for more information.

A local name declared with the `static` specifier has static duration. Use `static` with a local variable to preserve the last value between successive calls to that function. See Duration for more information.

Extern

A name declared with the `extern` specifier has external linkage, unless it has been previously declared as having internal linkage. A declaration is not a definition if it has the `extern` specifier and is not initialized. The keyword `extern` is optional for a function prototype.

Use the `extern` modifier to indicate that the actual storage and initial value of the variable, or body of the function, is defined in a separate source code module. Functions declared with `extern` are visible throughout all source files in the program, unless the function is redefined as `static`.

See Linkage for more information.

TYPE QUALIFIERS

The type qualifiers `const` and `volatile` are optional in declarations and do not actually affect the type of declared object.

Qualifier const

The qualifier `const` implies that a declared object will not change its value during runtime. In declarations with the `const` qualifier all objects need to be initialized.

The mikroC PRO for AVR treats objects declared with the `const` qualifier the same as literals or preprocessor constants. If the user tries to change an object declared with the `const` qualifier compiler will report an error.

For example:

```
const double PI = 3.14159;
```

Qualifier volatile

The qualifier `volatile` implies that a variable may change its value during runtime independently from the program. Use the volatile modifier to indicate that a variable can be changed by a background routine, an interrupt routine, or I/O port. Declaring an object to be volatile warns the compiler not to make assumptions concerning the value of an object while evaluating expressions in which it occurs because the value could be changed at any moment.

TYPEDEF SPECIFIER

The specifier `typedef` introduces a synonym for a specified type. The `typedef` declarations are used to construct shorter or more convenient names for types already defined by the language or declared by the user.

The specifier `typedef` stands first in the declaration:

```
typedef <type_definition> synonym;
```

The `typedef` keyword assigns `synonym` to `<type_definition>`. The `synonym` needs to be a valid identifier.

A declaration starting with the `typedef` specifier does not introduce an object or a function of a given type, but rather a new name for a given type. In other words, the `typedef` declaration is identical to a “normal” declaration, but instead of objects, it declares types. It is a common practice to name custom type identifiers with starting capital letter — this is not required by the mikroC PRO for AVR.

For example:

```
/* Let's declare a synonym for "unsigned long int" */
typedef unsigned long int Distance;

/* Now, synonym "Distance" can be used as type identifier: */
Distance i; // declare variable i of unsigned long int
```

In the `typedef` declaration, as in any other declaration, several types can be declared at once. For example:

```
typedef int  *Pti, Array[10];
```

Here, `Pti` is a synonym for type “pointer to `int`”, and `Array` is a synonym for type “array of 10 `int` elements”.

ASM DECLARATION

The mikroC PRO for AVR allows embedding assembly in the source code by means of the `asm` declaration. The declarations `_asm` and `__asm` are also allowed in the mikroC PRO for AVR and have the same meaning. Note that numerals cannot be used as absolute addresses for SFR or GPR variables in assembly instructions. Symbolic names may be used instead (listing will display these names as well as addresses).

Assembly instructions can be grouped by the asm keyword (or `_asm`, or `__asm`):

```
asm {
  block of assembly instructions
}
```

There are two ways to embeding single assembly instruction to C code:

```
asm assembly instruction ;
```

and

```
asm assembly instruction
```

Note: semicolon and LF are terminating asm scope for single assembly instructions. This is the reason why the following syntax is not asm block:

```
asm
  {
  block of assembly instructions
  }
```

This code will be interpreted as single empty asm line followed by C compound statement.

The mikroC PRO for AVR comments (both single-line and multi-line) are allowed in embedded assembly code.

Accessing individual bytes is different as well. For example, a global variable "g_var" of type char (i.e. 1 byte) can be accessed like this:

```
STS   _g_var+0, R10
```

If you want to know details about asm syntax supported by mikroC PRO for AVR it is recomended to study `asm` and `lst` files generated by compiler. It is also recomended to check "Include source lines in output files" checkbox in Output settings

Related topics: mikroC PRO for AVR specifcs

Initialization

The initial value of a declared object can be set at the time of declaration (initialization). A part of the declaration which specifies the initialization is called initializer.

Initializers for globals and `static` objects must be constants or constant expressions. The initializer for an automatic object can be any legal expression that evaluates to an assignment-compatible value for the type of the variable involved.

Scalar types are initialized with a single expression, which can optionally be enclosed in braces. The initial value of an object is that of the expression; the same constraints for type and conversions as for simple assignments are applied to initializations too.

For example:

```
int i = 1;
char *s = "hello";
struct complex c = {0.1, -0.2};
// where 'complex' is a structure (float, float)
```

For structures or unions with automatic storage duration, the initializer must be one of the following:

- An initializer list.
- A single expression with compatible union or structure type. In this case, the initial value of the object is that of the expression.

For example:

```
struct dot {int x; int y; } m = {30, 40};
```

For more information, refer to Structures and Unions.

Also, you can initialize arrays of character type with a literal string, optionally enclosed in braces. Each character in the string, including the null terminator, initializes successive elements in the array. For more information, refer to Arrays.

Automatic Initialization

The mikroC PRO for AVR does not provide automatic initialization for objects. Uninitialized globals and objects with static duration will take random values from memory.

FUNCTIONS

Functions are central to C programming. Functions are usually defined as subprograms which return a value based on a number of input parameters. Return value of the function can be used in expressions – technically, function call is considered to be an expression like any other.

C allows a function to create results other than its return value, referred to as side effects. Often, the function return value is not used at all, depending on the side effects. These functions are equivalent to procedures of other programming languages, such as Pascal. C does not distinguish between procedure and function – functions play both roles.

Each program must have a single external function named `main` marking the entry point of the program. Functions are usually declared as prototypes in standard or user-supplied header files, or within program files. Functions have external linkage by default and are normally accessible from any file in the program. This can be restricted by using the `static` storage class specifier in function declaration (see Storage Classes and Linkage).

Note: Check the AVR Specifics for more information on functions' limitations on the AVR compliant micros.

Function Declaration

Functions are declared in user's source files or made available by linking precompiled libraries. The declaration syntax of the function is:

```
type function_name(parameter-declarator-list);
```

The `function_name` must be a valid identifier. This name is used to call the function; see Function Calls for more information.

`type` represents the type of function result, and can be of any standard or user-defined type. For functions that do not return value the `void` type should be used. The type can be omitted in global function declarations, and function will assume the `int` type by default.

Function type can also be a pointer. For example, `float*` means that a function result is a pointer to float. The generic pointer `void*` is also allowed.

The function cannot return an array or another function.

Within parentheses, `parameter-declarator-list` is a list of formal arguments that function takes. These declarators specify the type of each function parameter. The compiler uses this information to check validity of function calls. If the list is empty, a function does not take any arguments. Also, if the list is `void`, a function also does not take any arguments; note that this is the only case when `void` can be used as an argument's type.

Unlike variable declaration, each argument in the list needs its own type specifier and possible qualifier `const` or `volatile`.

Function Prototypes

A function can be defined only once in the program, but can be declared several times, assuming that the declarations are compatible. When declaring a function, the formal argument's identifier does not have to be specified, but its type does.

This kind of declaration, commonly known as the function prototype, allows better control over argument number, type checking and type conversions. The name of a parameter in function prototype has its scope limited to the prototype. This allows one parameter identifier to have different name in different declarations of the same function:

```
/* Here are two prototypes of the same function: */

int test(const char*)    /* declares function test */
int test(const char*p)   /* declares the same function test */
```

Function prototypes are very useful in documenting code. For example, the function `Cf_Init` takes two parameters: Control Port and Data Port. The question is, which is which? The function prototype:

```
void Cf_Init(char *ctrlport, char *dataport);
```

makes it clear. If a header file contains function prototypes, the user can read that file to get the information needed for writing programs that call these functions. If a prototype parameter includes an identifier, then the indentifier is only used for error checking.

FUNCTION DEFINITION

Function definition consists of its declaration and function body. The `function body` is technically a block – a sequence of local definitions and statements enclosed within braces `{}`. All variables declared within function body are local to the function, i.e. they have function scope.

The function itself can be defined only within the file scope, which means that function declarations cannot be nested.

To return the function result, use the return statement. The statement return in functions of the `void` type cannot have a parameter – in fact, the `return` statement can be omitted altogether if it is the last statement in the function body.

Here is a sample function definition:

```
/* function max returns greater one of its 2 arguments: */

int max(int x, int y) {
  return (x>=y) ? x : y;
}
```

Here is a sample function which depends on side effects rather than return value:

```
/* function converts Descartes coordinates (x,y) to polar (r,fi): */
#include <math.h>

void polar(double x, double y, double *r, double *fi) {
  *r = sqrt(x * x + y * y);
  *fi = (x == 0 && y == 0) ? 0 : atan2(y, x);
  return; /* this line can be omitted */
}
```

Functions reentrancy

Functions reentrancy is allowed. Remember that the AVR has stack and memory limitations which can varies greatly between MCUs.

FUNCTION CALLS AND ARGUMENT CONVERSIONS

Function Calls

A function is called with actual arguments placed in the same sequence as their matching formal parameters. Use the function-call operator `()`:

```
function_name(expression_1, ... , expression_n)
```

Each `expression` in the function call is an actual argument. Number and types of actual arguments should match those of formal function parameters. If types do not match, implicit type conversions rules will be applied. Actual arguments can be of any complexity, but order of their evaluation is not specified.

Upon function call, all formal parameters are created as local objects initialized by the values of actual arguments. Upon return from a function, a temporary object is created in the place of the call, and it is initialized by the expression of the return statement. This means that the function call as an operand in complex expression is treated as a function result.

If the function has no result (type `void`) or the result is not needed, then the function call can be written as a self-contained expression.

In C, scalar arguments are always passed to the function by value. The function can modify the values of its formal parameters, but this has no effect on the actual arguments in the calling routine. A scalar object can be passed by the address if a formal parameter is declared as a pointer. The pointed object can be accessed by using the indirection operator `*` .

```
// For example, Soft_Uart_Read takes the pointer to error variable,
// so it can change the value of an actual argument:
Soft_Uart_Read(&error);

// The following code would be wrong; you would pass the value
// of error variable to the function:
Soft_Uart_Read(error);
```

Argument Conversions

If a function prototype has not been previously declared, the mikroC PRO for AVR converts integral arguments to a function call according to the integral widening (expansion) rules described in Standard Conversions. If a function prototype is in scope, the mikroC PRO for AVR converts the passed argument to the type of the declared parameter according to the same conversion rules as in assignment statements.

If a prototype is present, the number of arguments must match. The types need to be compatible only to the extent that an assignment can legally convert them. The user can always use an explicit cast to convert an argument to a type that is acceptable to a function prototype.

Note: If the function prototype does not match the actual function definition, the mikroC PRO for AVR will detect this if and only if that definition is in the same compilation unit as the prototype. If you create a library of routines with the corresponding header file of prototypes, consider including that header file when you compile the library, so that any discrepancies between the prototypes and actual definitions will be detected.

The compiler is also able to force arguments to change their type to a proper one. Consider the following code:

```
int limit = 32;
char ch = 'A';
long res;

// prototype
extern long func(long par1, long par2);

main() {
   ...
   res = func(limit, ch);  // function call
}
```

Since the program has the function prototype for `func`, it converts `limit` and `ch` to `long`, using the standard rules of assignment, before it places them on the stack for the call to `func`.

Without the function prototype, `limit` and `ch` would be placed on the stack as an integer and a character, respectively; in that case, the stack passed to `func` will not match size or content that `func` expects, which can cause problems.

Ellipsis ('...') Operator

The ellipsis (`'...'`) consists of three successive periods with no whitespace intervening. An ellipsis can be used in the formal argument lists of function prototypes to indicate a variable number of arguments, or arguments with varying types.
For example:

```
void func (int n, char ch, ...);
```

This declaration indicates that func will be defined in such a way that calls must have at least two arguments, `int` and `char`, but can also have any number of additional arguments.

Example:

```
#include <stdarg.h>


int addvararg(char a1,...){
va_list ap;
char temp;
va_start(ap,a1);

while( temp = va_arg(ap,char))
  a1 += temp;
return a1;
}


int res;
void main() {


  res = addvararg(1,2,3,4,5,0);

  res = addvararg(1,2,3,4,5,6,7,8,9,10,0);

}
```

OPERATORS

Operators are tokens that trigger some computation when applied to variables and other objects in an expression.

- Arithmetic Operators
- Assignment Operators
- Bitwise Operators
- Logical Operators
- Reference/Indirect Operators
- Relational Operators
- Structure Member Selectors

- Comma Operator `,`
- Conditional Operator `? :`

- Array subscript operator `[]`
- Function call operator `()`

- sizeof Operator

- Preprocessor Operators `#` and `##`

OPERATORS PRECEDENCE AND ASSOCIATIVITY

There are 15 precedence categories, some of them contain only one operator. Operators in the same category have equal precedence.

If duplicates of operators appear in the table, the first occurrence is unary and the second binary. Each category has an associativity rule: left-to-right (→), or right-to-left (←). In the absence of parentheses, these rules resolve a grouping of expressions with operators of equal precedence.

<table>
<tr><th>Precedence</th><th>Operands</th><th>Operators</th><th>Associativity</th></tr>
<tr><td>15</td><td>2</td><td><code>()   []   .   -></code></td><td>→</td></tr>
<tr><td>14</td><td>1</td><td><code>!   ~   ++   --   +   -   *   &</code>
<code>(type)   sizeof</code></td><td>←</td></tr>
<tr><td>13</td><td>2</td><td><code>*   /   %</code></td><td>→</td></tr>
<tr><td>12</td><td>2</td><td><code>+   -</code></td><td>→</td></tr>
<tr><td>11</td><td>2</td><td><code><<   >></code></td><td>→</td></tr>
<tr><td>10</td><td>2</td><td><code><   <=   >   >=</code></td><td>→</td></tr>
<tr><td>9</td><td>2</td><td><code>==   !=</code></td><td>→</td></tr>
<tr><td>8</td><td>2</td><td><code>&</code></td><td>→</td></tr>
<tr><td>7</td><td>2</td><td><code>^</code></td><td>→</td></tr>
<tr><td>6</td><td>2</td><td><code>|</code></td><td>→</td></tr>
<tr><td>5</td><td>2</td><td><code>&&</code></td><td>→</td></tr>
<tr><td>4</td><td>2</td><td><code>||</code></td><td>→</td></tr>
<tr><td>3</td><td>3</td><td><code>?:</code></td><td>←</td></tr>
<tr><td>2</td><td>2</td><td><code>=   *=   /=   %=   +=   -=   &=</code>
<code>^= |=   <<=   >>=</code></td><td>←</td></tr>
<tr><td>1</td><td>2</td><td><code>,</code></td><td>→</td></tr>
</table>

ARITHMETIC OPERATORS

Arithmetic operators are used to perform mathematical computations. They have numerical operands and return numerical results. The type `char` technically represents small integers, so the `char` variables can be used as operands in arithmetic operations.

All arithmetic operators associate from left to right.

Arithmetic Operators Overview

Operator	Operation	Precedence Type
Binary Operators		
+	addition	12
-	subtraction	12
*	multiplication	13
/	division	13
%	modulus operator returns the remainder of integer division (cannot be used with floating points)	13
Unary Operators		
+	unary plus does not affect the operand	14
-	unary minus changes the sign of the operand	14
++	increment adds one to the value of the operand. Postincrement adds one to the value of the operand after it evaluates; while preincrement adds one before it evaluates	14
--	decrement subtracts one from the value of the operand. Postdecrement subtracts one from the value of the operand after it evaluates; while predecrement subtracts one before it evaluates	14

Note: Operator `*` is context sensitive and can also represent the pointer reference operator.

Binary Arithmetic Operators

Division of two integers returns an integer, while remainder is simply truncated:

```
/* for example: */
7 / 4;            /* equals 1 */
7 * 3 / 4;        /* equals 5 */

/* but: */
7. * 3. / 4.;    /* equals 5.25 because we are working with floats */
```

Remainder operand % works only with integers; the sign of result is equal to the sign of the first operand:

```
/* for example: */
9 % 3;            /* equals 0 */
7 % 3;            /* equals 1 */
-7 % 3;           /* equals -1 */
```

Arithmetic operators can be used for manipulating characters:

```
'A' + 32;           /* equals 'a' (ASCII only) */
'G' - 'A' + 'a';    /* equals 'g' (both ASCII and EBCDIC) */
```

Unary Arithmetic Operators

Unary operators `++` and `--` are the only operators in C which can be either prefix (e.g. `++k, --k`) or postfix (e.g. `k++, k--`).

When used as prefix, operators `++` and `--` (preincrement and predecrement) add or subtract one from the value of the operand before the evaluation. When used as suffix, operators `++` and `--` (postincrement and postdecrement) add or subtract one from the value of the operand after the evaluation.

For example:

```
int j = 5;
j = ++k;          /* k = k + 1, j = k, which gives us j = 6, k = 6 */
```

but:

```
int j = 5;
j = k++;          /* j = k, k = k + 1, which gives us j = 5, k = 6 */
```

RELATIONAL OPERATORS

Use relational operators to test equality or inequality of expressions. If an expression evaluates to be true, it returns 1; otherwise it returns 0.

All relational operators associate from left to right.

Relational Operators Overview

Operator	Operation	Precedence
`==`	equal	9
`!=`	not equal	9
`>`	greater than	10
`<`	less than	10
`>=`	greater than or equal	10
`<=`	less than or equal	10

Relational Operators in Expressions

Precedence of arithmetic and relational operators is designated in such a way to allow complex expressions without parentheses to have expected meaning:

```
a + 5 >= c - 1.0 / e    /* ? (a + 5) >= (c - (1.0 / e)) */
```

Do not forget that relational operators return either 0 or 1. Consider the following examples:

```
/* ok: */
5 > 7                    /* returns 0 */
10 <= 20                 /* returns 1 */

/* this can be tricky: */
8 == 13 > 5              /* returns 0, as: 8 == (13 > 5)  ?  8 == 1
?  0 */
14 > 5 < 3              /* returns 1, as: (14 > 5) < 3  ?  1 < 3  ?
1 */
a < b < 5                /* returns 1, as: (a < b) < 5  ?  (0 or 1)
< 5  ?  1*/
```

BITWISE OPERATORS

Use the bitwise operators to modify individual bits of numerical operands.

Bitwise operators associate from left to right. The only exception is the bitwise complement operator ~ which associates from right to left.

Bitwise Operators Overview

Operator	Operation	Precedence
`&`	bitwise AND; compares pairs of bits and returns 1 if both bits are 1, otherwise returns 0	8
`|`	bitwise (inclusive) OR; compares pairs of bits and returns 1 if either or both bits are 1, otherwise returns 0	6
`^`	bitwise exclusive OR (XOR); compares pairs of bits and returns 1 if the bits are complementary, otherwise returns 0	7
`~`	bitwise complement (unary); inverts each bit	14
`<<`	bitwise shift left; moves the bits to the left, discards the far left bit and assigns 0 to the far right bit.	11
`>>`	bitwise shift right; moves the bits to the right, discards the far right bit and if unsigned assigns 0 to the far left bit, otherwise sign extends	11

Logical Operations on Bit Level

`&`	**0**	**1**
0	0	0
1	0	1

`|`	**0**	**1**
0	0	1
1	1	1

`^`	**0**	**1**
0	0	1
1	1	0

`~`	**0**	**1**
	1	0

Bitwise operators `&`, `|` and `^` perform logical operations on the appropriate pairs of bits of their operands. Operator `~` complements each bit of its operand. For example:

```
0x1234 & 0x5678         /* equals 0x1230 */

/* because ..

0x1234 : 0001 0010 0011 0100
0x5678 : 0101 0110 0111 1000
```

```
-----------------------------
   &     : 0001 0010 0011 0000

.. that is, 0x1230 */

/* Similarly: */

0x1234 | 0x5678;        /* equals 0x567C */
0x1234 ^ 0x5678;        /* equals 0x444C */
~ 0x1234;                /* equals 0xEDCB */
```

Note: Operator & can also be a pointer reference operator. Refer to Pointers for more information.

Bitwise Shift Operators

Binary operators << and >> move the bits of the left operand by a number of positions specified by the right operand, to the left or right, respectively. Right operand has to be positive.

With shift left (<<), far left bits are discarded and "new" bits on the right are assigned zeroes. Thus, shifting unsigned operand to the left by n positions is equivalent to multiplying it by 2n if all discarded bits are zero. This is also true for signed operands if all discarded bits are equal to a sign bit.

```
000001 <<  5;    /* equals 000040 */
0x3801 <<  4;    /* equals 0x8010, overflow! */
```

With shift right (>>), far right bits are discarded and the "freed" bits on the left are assigned zeroes (in case of unsigned operand) or the value of a sign bit (in case of signed operand). Shifting operand to the right by n positions is equivalent to dividing it by 2^n.

```
0xFF56  >>  4;    /* equals 0xFFF5 */
0xFF56u >>  4;    /* equals 0x0FF5 */
```

Bitwise vs. Logical

Do not forget of the principle difference between how bitwise and logical operators work. For example:

```
0222222 &  0555555;    /* equals 000000 */
0222222 && 0555555;    /* equals 1 */

~ 0x1234;              /* equals 0xEDCB */
! 0x1234;              /* equals 0 */
```

LOGICAL OPERATORS

Operands of logical operations are considered true or false, that is non-zero or zero. Logical operators always return 1 or 0. Operands in a logical expression must be of scalar type.

Logical operators `&&` and `||` associate from left to right. Logical negation operator `!` associates from right to left.

Logical Operators Overview

Operator	Operation	Precedence
`&&`	logical AND	5
`||`	logical OR	4
`!`	logical negation	14

Logical Operations

`&&`	**0**	**x**
0	0	0
x	0	1

`||`	**0**	**x**
0	0	1
x	1	1

`!`	**0**	**x**
	1	0

Precedence of logical, relational, and arithmetic operators was designated in such a way to allow complex expressions without parentheses to have an expected meaning:

```
c >= '0' && c <= '9';   /* reads as: (c >= '0') && (c <= '9') */
a + 1 == b || ! f(x);   /* reads as: ((a + 1) == b) || (! (f(x))) */
```

Logical AND `&&` returns 1 only if both expressions evaluate to be nonzero, otherwise returns 0. If the first expression evaluates to false, the second expression will not be evaluated. For example:

```
a > b && c < d;      /* reads as  (a > b) && (c < d) */
/* if (a > b) is false (0), (c < d) will not be evaluated */
```

Logical OR `||` returns 1 if either of expression evaluates to be nonzero, otherwise returns 0. If the first expression evaluates to true, the second expression is not evaluated. For example:

```
a && b || c && d;  /* reads as: (a && b) || (c && d) */
/* if (a && b) is true (1), (c && d) will not be evaluated */
```

LOGICAL EXPRESSIONS AND SIDE EFFECTS

General rule regarding complex logical expressions is that the evaluation of consecutive logical operands stops at the very moment the final result is known. For example, if we have an expression `a && b && c` where a is false (0), then operands b and `c` will not be evaluated. This is very important if `b` and `c` are expressions, as their possible side effects will not take place!

LOGICAL VS. BITWISE

Be aware of the principle difference between how bitwise and logical operators work. For example:

```
0222222 &  0555555      /* equals 000000 */
0222222 && 0555555      /* equals 1 */

~ 0x1234                 /* equals 0xEDCB */
! 0x1234                 /* equals 0 */
```

CONDITIONAL OPERATOR ? :

The conditional operator `? :` is the only ternary operator in C. Syntax of the conditional operator is:

```
expression1 ? expression2 : expression3
```

The `expression1` is evaluated first. If its value is true, then `expression2` evaluates and `expression3` is ignored. If `expression1` evaluates to false, then `expression3` evaluates and `expression2` is ignored. The result will be a value of either `expression2` or `expression3` depending upon which of them evaluates.

Note: The fact that only one of these two expressions evaluates is very important if they are expected to produce side effects!

Conditional operator associates from right to left.

Here are a couple of practical examples:

```
/* Find max(a, b): */
max = ( a > b ) ? a : b;

/* Convert small letter to capital: */
/* (no parentheses are actually necessary) */
c = ( c >= 'a' && c <= 'z' ) ? ( c - 32 ) : c;
```

Conditional Operator Rules

`expression1` must be a scalar expression; `expression2` and `expression3` must obey one of the following rules:

1. Both expressions have to be of arithmetic type. `expression2` and `expression3` are subject to usual arithmetic conversions, which determines the resulting type.
2. Both expressions have to be of compatible `struct` or `union` types. The resulting type is a structure or union type of `expression2` and `expression3`.
3. Both expressions have to be of `void` type. The resulting type is `void`.
4. Both expressions have to be of type pointer to qualified or unqualified versions of compatible types. The resulting type is a pointer to a type qualified with all type qualifiers of the types pointed to by both expressions.
5. One expression is a pointer, and the other is a null pointer constant. The resulting type is a pointer to a type qualified with all type qualifiers of the types pointed to by both expressions.
6. One expression is a pointer to an object or incomplete type, and the other is a pointer to a qualified or unqualified version of `void`. The resulting type is that of the non-pointer-to-`void` expression.

ASSIGNMENT OPERATORS

Unlike many other programming languages, C treats value assignment as operation (represented by an operator) rather than instruction.

Simple Assignment Operator

For a common value assignment, a simple assignment operator (=) is used:

```
expression1 = expression2
```

The `expression1` is an object (memory location) to which the value of `expression2` is assigned. Operand `expression1` has to be lvalue and `expression2` can be any expression. The assignment expression itself is not lvalue.

If `expression1` and `expression2` are of different types, the result of the `expression2` will be converted to the type of `expression1`, if necessary. Refer to Type Conversions for more information.

Compound Assignment Operators

C allows more comlex assignments by means of compound assignment operators. The syntax of compound assignment operators is:

```
expression1 op= expression2
```

where `op` can be one of binary operators `+, -, *, /, %, &, |, ^, <<`, or `>>`.

Thus, we have 10 different compound assignment operators: `+=, -=, *=, /=, %=, &=, |=, ^=, <<=` and `>>=`. All of them associate from right to left. Spaces separating compound operators (e.g. `+ =`) will generate error.

Compound assignment has the same effect as

```
expression1 = expression1 op expression2
```

except the lvalue `expression1` is evaluated only once. For example, `expression1 += expression2` is the same as `expression1 = expression1 + expression2`.

Assignment Rules

For both simple and compound assignment, the operands `expression1` and `expression2` must obey one of the following rules:

1. `expression1` is of qualified or unqualified arithmetic type and `expression2` is of arithmetic type.
2. `expression1` has a qualified or unqualified version of structure or union type compatible with the type of `expression2`.
3. `expression1` and `expression2` are pointers to qualified or unqualified versions of compatible types and the type pointed to by left has all qualifiers of the type pointed to by right.
4. Either `expression1` or `expression2` is a pointer to an object or incomplete type and the other is a pointer to a qualified or unqualified version of void. The type pointed to by left has all qualifiers of the type pointed to by right.
5. `expression1` is a pointer and `expression2` is a null pointer constant.

SIZEOF OPERATOR

The prefix unary operator sizeof returns an integer constant that represents the size of memory space (in bytes) used by its operand (determined by its type, with some exceptions).

The operator sizeof can take either a type identifier or an unary expression as an operand. You cannot use sizeof with expressions of function type, incomplete types, parenthesized names of such types, or with lvalue that designates a bit field object.

Sizeof Applied to Expression

If applied to expression, the size of an operand is determined without evaluating the expression (and therefore without side effects). The result of the operation will be the size of the type of the expression's result.

Sizeof Applied to Type

If applied to a type identifier, `sizeof` returns the size of the specified type. The unit for type size is `sizeof(char)` which is equivalent to one byte. The operation sizeof(char) gives the result 1, whether `char` is `signed` or `unsigned`.

Thus:

```
sizeof(char)              /* returns 1 */
sizeof(int)               /* returns 2 */
sizeof(unsigned long)     /* returns 4 */
sizeof(float)             /* returns 4 */
```

When the operand is a non-parameter of array type, the result is the total number of bytes in the array (in other words, an array name is not converted to a pointer type):

```
int i, j, a[10];
...
j = sizeof(a[1]);   /* j = sizeof(int) = 2 */
i = sizeof(a);      /* i = 10*sizeof(int) = 20 */

/* To get the number of elements in an array: */
int num_elem = i/j;
```

If the operand is a parameter declared as array type or function type, `sizeof` gives the size of the pointer. When applied to structures and unions, `sizeof` gives the total number of bytes, including any padding. The operator `sizeof` cannot be applied to a function.

Expressions

Expression is a sequence of operators, operands, and punctuators that specifies a computation. Formally, expressions are defined recursively: subexpressions can be nested without formal limit. However, the compiler will report an out-of-memory error if it can't compile an expression that is too complex.

In ANSI C, the primary expressions are: constant (also referred to as literal), identifier, and (`expression`), defined recursively.

Expressions are evaluated according to a certain conversion, grouping, associativity and precedence rules, which depends on the operators used, presence of parentheses and data types of the operands. The precedence and associativity of the operators are summarized in Operator Precedence and Associativity. The way operands and subexpressions are grouped does not necessarily specify the actual order in which they are evaluated by the mikroC PRO for AVR.

Expressions can produce lvalue, rvalue, or no value. Expressions might cause side effects whether they produce a value or not.

COMMA EXPRESSIONS

One of the specifics of C is that it allows using of comma as a sequence operator to form so-called comma expressions or sequences. Comma expression is a comma-delimited list of expressions – it is formally treated as a single expression so it can be used in places where an expression is expected. The following sequence:

```
expression_1, expression_2;
```

results in the left-to-right evaluation of each `expression`, with the value and type of `expression_2` giving the result of the whole expression. Result of `expression_1` is discarded.

Binary operator comma (`,`) has the lowest precedence and associates from left to right, so that `a, b, c` is the same as `(a, b), c`. This allows writing sequences with any number of expressions:

```
expression_1, expression_2, ... expression_n;
```

which results in the left-to-right evaluation of each `expression`, with the value and type of `expression_n` giving the result of the whole expression. Results of other `expressions` are discarded, but their (possible) side-effect do occur.

For example:

```
result = ( a = 5, b /= 2, c++ );
/* returns preincremented value of variable c,
   but also intializes a, divides b by 2 and increments c */

result = ( x = 10, y = x + 3, x--, z -= x * 3 - --y );
/* returns computed value of variable z,
   and also computes x and y */
```

Note

Do not confuse comma operator (sequence operator) with comma punctuator which separates elements in a function argument list and initializator lists. To avoid ambiguity with commas in function argument and initializer lists, use parentheses. For example,

```
func(i, (j = 1, j + 4), k);
```

calls the function `func` with three arguments (i, 5, k), not four.

STATEMENTS

Statements specify a flow of control as the program executes. In the absence of specific jump and selection statements, statements are executed sequentially in the order of appearance in the source code.

Statements can be roughly divided into:

- Labeled Statements
- Expression Statements
- Selection Statements
- Iteration Statements (Loops)
- Jump Statements
- Compound Statements (Blocks)

Labeled Statements

Each statement in a program can be labeled. A label is an identifier added before the statement like this:

```
label_identifier: statement;
```

There is no special declaration of a label – it just “tags” the `statement`. `Label_identifier` has a function scope and the same label cannot be redefined within the same function.

Labels have their own namespace: label identifier can match any other identifier in the program.

A statement can be labeled for two reasons:

1. The label identifier serves as a target for the unconditional goto statement,

2. The label identifier serves as a target for the switch statement. For this purpose, only `case` and `default` labeled statements are used:

```
case constant-expression : statement
default : statement
```

EXPRESSION STATEMENTS

Any expression followed by a semicolon forms an expression statement:

```
expression;
```

The mikroC PRO for AVR executes an expression statement by evaluating the `expression`. All side effects from this evaluation are completed before the next statement starts executing. Most of expression statements are assignment statements or function calls.

A null statement is a special case, consisting of a single semicolon (`;`). The null statement does nothing, and therefore is useful in situations where the mikroC PRO for AVR syntax expects a statement but the program does not need one. For example, a null statement is commonly used in “empty” loops:

```
for (; *q++ = *p++ ;);  /* body of this loop is a null statement */
```

SELECTION STATEMENTS

Selection or flow-control statements select one of alternative courses of action by testing certain values. There are two types of selection statements:

- if
- switch

IF STATEMENT

The `if` statement is used to implement a conditional statement. The syntax of the `if` statement is:

```
if (expression) statement1 [ else statement2]
```

If `expression` evaluates to true, `statement1` executes. If `expression` is false, `statement2` executes. The `expression` must evaluate to an integral value; otherwise, the condition is ill-formed. Parentheses around the `expression` are mandatory.

The `else` keyword is optional, but no statements can come between `if` and `else`.

Nested If statements

Nested `if` statements require additional attention. A general rule is that the nested conditionals are parsed starting from the innermost conditional, with each `else` bound to the nearest available `if` on its left:

```
if (expression1) statement1
else if (expression2)
  if (expression3) statement2
  else statement3         /* this belongs to: if (expression3) */
else statement4           /* this belongs to: if (expression2) */
```

Note

`#if` and `#else` preprocessor statements (directives) look similar to `if` and `else` statements, but have very different effects. They control which source file lines are compiled and which are ignored.

SWITCH STATEMENT

The switch statement is used to pass control to a specific program branch, based on a certain condition. The syntax of the `switch` statement is:

```
switch (expression) {
  case constant-expression_1 : statement_1;
    .
    .
    .
  case constant-expression_n : statement_n;
  [ default : statement;]
}
```

First, the `expression` (condition) is evaluated. The `switch` statement then compares it to all available `constant-expressions` following the keyword case. If a match is found, `switch` passes control to that matching `case` causing the `statement` following the match evaluates. Note that `constant-expressions` must evaluate to integer. It is not possible to have two same constant expressions evaluating to the same value.

Parentheses around `expression` are mandatory.

Upon finding a match, program flow continues normally: the following instructions will be executed in natural order regardless of the possible `case` label. If no `case` satisfies the condition, the `default` case evaluates (if the label `default` is specified).

For example, if a variable `i` has value between 1 and 3, the following switch would always return it as 4:

```
switch (i) {
  case 1: i++;
  case 2: i++;
  case 3: i++;
}
```

To avoid evaluating any other cases and relinquish control from `switch`, each `case` should be terminated with break.

Here is a simple example with `switch`. Suppose we have a variable `phase` with only 3 different states (0, 1, or 2) and a corresponding function (event) for each of these states. This is how we could switch the code to the appopriate routine:

```
switch (phase) {
  case 0: Lo();  break;
  case 1: Mid(); break;
  case 2: Hi();  break;
  default: Message("Invalid state!");
}
```

Nested switch

Conditional `switch` statements can be nested – labels `case` and `default` are then assigned to the innermost enclosing `switch` statement.

ITERATION STATEMENTS (LOOPS)

Iteration statements allows to loop a set of statements. There are three forms of iteration statements in the mikroC PRO for AVR:

- while
- do
- for

WHILE STATEMENT

The `while` keyword is used to conditionally iterate a statement. The syntax of the `while` statement is:

while (expression) statement

The `statement` executes repeatedly until the value of `expression` is false. The test takes place before `statement` is executed. Thus, if `expression` evaluates to false on the first pass, the loop does not execute. Note that parentheses around `expression` are mandatory.

Here is an example of calculating scalar product of two vectors, using the `while` statement:

```
int s = 0, i = 0;
while (i < n) {
  s += a[i] * b[i];
  i++;
}
```

Note that body of the loop can be a null statement. For example:

```
while (*q++ = *p++);
```

DO STATEMENT

The `do` statement executes until the condition becomes false. The syntax of the `do` statement is:

```
do statement while (expression);
```

The `statement` is executed repeatedly as long as the value of `expression` remains non-zero. The `expression` is evaluated after each iteration, so the loop will execute `statement` at least once.

Parentheses around `expression` are mandatory.

Note that `do` is the only control structure in C which explicitly ends with semicolon (`;`). Other control structures end with `statement`, which means that they implicitly include a semicolon or closing brace.

Here is an example of calculating scalar product of two vectors, using the `do` statement:

```
s = 0; i = 0;
do {
  s += a[ i]  *  b[ i] ;
  i++;
} while ( i < n );
```

FOR STATEMENT

The for statement implements an iterative loop. The syntax of the for statement is:

```
for ([init-expression]; [condition-expression]; [increment-expres-
sion]) statement
```

Before the first iteration of the loop, `init-expression` sets the starting variables for the loop. You cannot pass declarations in `init-expression`.

`condition-expression` is checked before the first entry into the block; `statement` is executed repeatedly until the value of `condition-expression` is false. After each iteration of the loop, `increment-expression` increments a loop counter. Consequently, `i++` is functionally the same as `++i`.

All expressions are optional. If `condition-expression` is left out, it is assumed to be always true. Thus, "empty" `for` statement is commonly used to create an endless loop in C:

```
for ( ; ; ) statement
```

The only way to break out of this loop is by means of the `break` statement.

Here is an example of calculating scalar product of two vectors, using the `for` statement:

```
for ( s = 0, i = 0; i < n; i++ ) s += a[i] * b[i];
```

There is another way to do this:

```
for ( s = 0, i = 0; i < n; s += a[i] * b[i], i++ );  /* valid, but
ugly */
```

but it is considered a bad programming style. Although legal, calculating the sum should not be a part of the incrementing expression, because it is not in the service of loop routine. Note that null statement (`;`) is used for the loop body.

JUMP STATEMENTS

The jump statement, when executed, transfers control unconditionally. There are four such statements in the mikroC PRO for AVR:

- break
- continue
- goto
- return

BREAK AND CONTINUE STATEMENTS

Break Statement

Sometimes it is necessary to stop the loop within its body. Use the `break` statement within loops to pass control to the first statement following the innermost `switch`, `for`, `while`, or `do` block.

`Break` is commonly used in the `switch` statements to stop its execution upon the first positive match. For example:

```
switch (state) {
  case 0: Lo();   break;
  case 1: Mid(); break;
  case 2: Hi();   break;
  default: Message("Invalid state!");
}
```

Continue Statement

The `continue` statement within loops is used to “skip the cycle”. It passes control to the end of the innermost enclosing end brace belonging to a looping construct. At that point the loop continuation condition is re-evaluated. This means that `continue` demands the next iteration if the loop continuation condition is true.

Specifically, the `continue` statement within the loop will jump to the marked position as it is shown below:

```
while (..) {
...
if (val>0) continue;
...
// continue jumps here
}
```

```
do {
...
if (val>0) continue;
...
// continue jumps here
while (..);
```

```
for (..;..;..) {
...
if (val>0) continue;
...
// continue jumps here
}
```

GOTO STATEMENT

The goto statement is used for unconditional jump to a local label — for more information on labels, refer to Labeled Statements. The syntax of the goto statement is:

```
goto label_identifier ;
```

This will transfer control to the location of a local label specified by `label_identifier`. The `label_identifier` has to be a name of the label within the same function in which the `goto` statement is. The `goto` line can come before or after the label.

`goto` is used to break out from any level of nested control structures but it cannot be used to jump into block while skipping that block's initializations – for example, jumping into loop's body, etc.

The use of `goto` statement is generally discouraged as practically every algorithm can be realized without it, resulting in legible structured programs. One possible application of the `goto` statement is breaking out from deeply nested control structures:

```
for (...) {
  for (...) {
  ...
    if (disaster) goto Error;
  ...
  }
}
 .
 .
 .
Error: /* error handling code */
```

RETURN STATEMENT

The `return` statement is used to exit from the current function back to the calling routine, optionally returning a value. The syntax is:

```
return [expression];
```

This will evaluate `expression` and return the result. Returned value will be automatically converted to the expected function type, if needed. The `expression` is optional; if omitted, the function will return a random value from memory.

Note: The statement `return` in functions of the `void` type cannot have `expression` – in fact, the `return` statement can be omitted altogether if it is the last statement in the function body.

COMPOUND STATEMENTS (BLOCKS)

The compound statement, or block, is a list (possibly empty) of statements enclosed in matching braces `{ }`. Syntactically, the block can be considered to be a single statement, but it also plays a role in the scoping of identifiers. An identifier declared within the block has a scope starting at the point of declaration and ending at the closing brace. Blocks can be nested to any depth up to the limits of memory.

For example, the `for` loop expects one statement in its body, so we can pass it a compound statement:

```
for (i = 0; i < n; i++ ) {
  int temp = a[i];
  a[i] = b[i];
  b[i] = temp;
}
```

Note that, unlike other statements, compound statements do not end with semicolon (`;`), i.e. there is never a semicolon following the closing brace.

PREPROCESSOR

Preprocessor is an integrated text processor which prepares the source code for compiling. Preprocessor allows:

- inserting text from a specifed file to a certain point in the code (see File Inclusion),
- replacing specific lexical symbols with other symbols (see Macros),
- conditional compiling which conditionally includes or omits parts of the code (see Conditional Compilation).

Note that preprocessor analyzes text at token level, not at individual character level. Preprocessor is controled by means of preprocessor directives and preprocessor operators.

PREPROCESSOR DIRECTIVES

Any line in the source code with a leading # is taken as a preprocessing directive (or control line), unless # is within a string literal, in a character constant, or embedded in a comment. The initial # can be preceded or followed by a whitespace (excluding new lines).

A null directive consists of a line containing the single character #. This line is always ignored.

Preprocessor directives are usually placed at the beginning of the source code, but they can legally appear at any point in a program. The mikroC PRO for AVR preprocessor detects preprocessor directives and parses the tokens embedded in them. A directive is in effect from its declaration to the end of the program file.

Here is one commonly used directive:

```
#include <math.h>
```

For more information on including files with the `#include` directive, refer to File Inclusion.

The mikroC PRO for AVR supports standard preprocessor directives:

```
# (null directive)      #if
#define                  #ifdef
#elif                    #ifndef
#else                    #include
#endif                   #line
#error                   #undef
```

Note: For the time being only funcall pragma is supported.

Line Continuation with Backslash (\)

To break directive into multiple lines end the line with a backslash (\):

```
#define MACRO  This directive continues to \
                the following line.
```

MACROS

Macros provide a mechanism for a token replacement, prior to compilation, with or without a set of formal, function-like parameters.

Defining Macros and Macro Expansions

The `#define` directive defines a macro:

```
#define macro_identifier <token_sequence>
```

Each occurrence of `macro_identifier` in the source code following this control line will be replaced in the original position with the possibly empty `token_sequence` (there are some exceptions, which are discussed later). Such replacements are known as macro expansions.`token_sequence` is sometimes called the body of a macro. An empty token sequence results in the removal of each affected macro identifier from the source code.

No semicolon (`;`) is needed to terminate a preprocessor directive. Any character found in the token sequence, including semicolons, will appear in a macro expansion.`token_sequence` terminates at the first non-backslashed new line encountered. Any sequence of whitespace, including comments in the token sequence, is replaced with a single-space character.

After each individual macro expansion, a further scan is made of the newly expanded text. This allows the possibility of using nested macros: the expanded text can contain macro identifiers that are subject to replacement. However, if the macro expands into something that looks like a preprocessing directive, such directive will not be recognized by the preprocessor. Any occurrences of the macro identifier found within literal strings, character constants, or comments in the source code will not be expanded.

A macro won't be expanded during its own expansion (so `#define MACRO MACRO` won't expand indefinitely).

Here is an example:

```
/* Here are some simple macros: */
#define ERR_MSG "Out of range!"
#define EVERLOOP for( ; ; )

/* which we could use like this: */

main() {
  EVERLOOP {
    ...
    if (error) { Lcd_Out_Cp(ERR_MSG); break; }
    ...
  }
}
```

Attempting to redefine an already defined macro identifier will result in a warning unless a new definition is exactly the same token-by-token definition as the existing one. The preferred strategy when definitions might exist in other header files is as follows:

```
#ifndef BLOCK_SIZE
  #define BLOCK_SIZE 512
#endif
```

The middle line is bypassed if `BLOCK_SIZE` is currently defined; if `BLOCK_SIZE` is not currently defined, the middle line is invoked to define it.

MACROS WITH PARAMETERS

The following syntax is used to define a macro with parameters:

```
#define macro_identifier(<arg_list>) <token_sequence>
```

Note that there can be no whitespace between `macro_identifier` and "`(`". The optional `arg_list` is a sequence of identifiers separated by commas, like the argument list of a C function. Each comma-delimited identifier has the role of a formal argument or placeholder.

Such macros are called by writing

```
macro_identifier(<actual_arg_list>)
```

in the subsequent source code. The syntax is identical to that of a function call; indeed, many standard library C "functions" are implemented as macros. However, there are some important semantic differences.

The optional `actual_arg_list` must contain the same number of comma-delimited token sequences, known as actual arguments, as found in the formal arg_list of the `#define` line – there must be an actual argument for each formal argument. An error will be reported if the number of arguments in two lists is not the same.

A macro call results in two sets of replacements. First, the macro identifier and the parenthesis-enclosed arguments are replaced by the token sequence. Next, any formal arguments occurring in the token sequence are replaced by the corresponding real arguments appearing in `actual_arg_list`. Like with simple macro definitions, rescanning occurs to detect any embedded macro identifiers eligible for expansion.

Here is a simple example:

```
/* A simple macro which returns greater of its 2 arguments: */
#define _MAX(A, B) ((A) > (B)) ? (A) : (B)

/* Let's call it: */
x = _MAX(a + b, c + d);

/* Preprocessor will transform the previous line into:
x = ((a + b) > (c + d)) ? (a + b) : (c + d) */
```

It is highly recommended to put parentheses around each argument in the macro body in order to avoid possible problems with operator precedence.

Undefining Macros

The `#undef` directive is used to undefine a macro.

```
#undef macro_identifier
```

The directive `#undef` detaches any previous token sequence from `macro_identifier`; the macro definition has been forgotten, and `macro_identifier` is undefined. No macro expansion occurs within the `#undef` lines.

The state of being defined or undefined is an important property of an identifier, regardless of the actual definition. The `#ifdef` and `#ifndef` conditional directives, used to test whether any identifier is currently defined or not, offer a flexible mechanism for controlling many aspects of a compilation.

After a macro identifier has been undefined, it can be redefined with `#define`, using the same or different token sequence.

FILE INCLUSION

The preprocessor directive #include pulls in header files (extension .h) into the source code. Do not rely on preprocessor to include source files (extension) — see Add/Remove Files from Project for more information.

The syntax of the `#include` directive has two formats:

```
#include <header_name>
#include "header_name"
```

The preprocessor removes the `#include` line and replaces it with the entire text of a header file at that point in the source code. The placement of `#include` can therefore influence the scope and duration of any identifiers in the included file.

The difference between these two formats lies in searching algorithm employed in trying to locate the include file.

If the `#include` directive is used with the `<header_name>` version, the search is made successively in each of the following locations, in this particular order:

1. the mikroC PRO for AVR installation folder › “include” folder
2. user's custom search paths

The `"header_name"` version specifies a user-supplied include file; the mikroC PRO for AVR will look for the header file in the following locations, in this particular order:

1. the project folder (folder which contains the project file `.ppc`)
2. the mikroC PRO for AVR installation folder › “include” folder
3. user's custom search paths

Explicit Path

By placing an explicit path in `header_name`, only that directory will be searched. For example:

```
#include "C:\my_files\test.h"
```

Note

There is also a third version of the `#include` directive, rarely used, which assumes that neither `<` nor `"` appear as the first non-whitespace character following `#include:`

```
#include macro_identifier
```

It assumes that macro definition that will expand `macro identifier` into a valid delimited header name with either `<header_name>` or "header_name" formats exists.

PREPROCESSOR OPERATORS

The # (pound sign) is a preprocessor directive when it occurs as the first non-white-space character on a line. Also, # and ## perform operator replacement and merging during the preprocessor scanning phase.

Operator

In C preprocessor, a character sequence enclosed by quotes is considered a token and its content is not analyzed. This means that macro names within quotes are not expanded.

If you need an actual argument (the exact sequence of characters within quotes) as a result of preprocessing, use the # operator in macro body. It can be placed in front of a formal macro argument in definition in order to convert the actual argument to a string after replacement.

For example, let's have macro LCD_PRINT for printing variable name and value on LCD:

```
#define LCD_PRINT(val) Lcd_Custom_Out_Cp(#val ": "); \
                        Lcd_Custom_Out_Cp(IntToStr(val));
```

Now, the following code,

```
LCD_PRINT(temp)
```

will be preprocessed to this:

```
 Lcd_Custom_Out_Cp("temp" ": "); Lcd_Custom_Out_Cp(IntToStr(temp));
```

Operator

Operator ## is used for token pasting. Two tokens can be pasted(merged) together by placing ## in between them (plus optional whitespace on either side). The preprocessor removes whitespace and ##, combining the separate tokens into one new token. This is commonly used for constructing identifiers.

For example, see the definition of macro SPLICE for pasting two tokens into one identifier:

```
#define SPLICE(x,y) x ## _ ## y
```

Now, the call SPLICE(cnt, 2) will expand to the identifier cnt_2.

Note

The mikroC PRO for AVR does not support the older nonportable method of token pasting using (l/**/r).

CONDITIONAL COMPILATION

Conditional compilation directives are typically used to make source programs easy to change and easy to compile in different execution environments. The mikroC PRO for AVR supports conditional compilation by replacing the appropriate source-code lines with a blank line.

All conditional compilation directives must be completed in the source or include file in which they have begun.

Directives #if, #elif, #else, and #endif

The conditional directives `#if`, `#elif`, `#else`, and `#endif` work very similar to the common C conditional statements. If the expression you write after `#if` has a nonzero value, the line group immediately following the `#if` directive is retained in the translation unit.

The syntax is:

```
#if constant_expression_1
<section_1>

[ #elif constant_expression_2
<section_2>]
  ...
[ #elif constant_expression_n
<section_n>]

[ #else
<final_section>]

#endif
```

Each `#if` directive in a source file must be matched by a closing `#endif` directive. Any number of `#elif` directives can appear between `#if` and `#endif` directives, but at most one `#else` directive is allowed. The `#else` directive, if present, must be the last directive before `#endif`.

`sections` can be any program text that has meaning to compiler or preprocessor. The preprocessor selects a single `section` by evaluating `constant_expression` following each `#if` or `#elif` directive until it finds a true (nonzero) constant expression. The constant expressions are subject to macro expansion.

If all occurrences of constant-expression are false, or if no `#elif` directives appear, the preprocessor selects the text block after the #else clause. If the `#else` clause is omitted and all instances of `constant_expression` in the `#if` block are false, no section is `selected` for further processing.

Any processed section can contain further conditional clauses, nested to any depth. Each nested `#else`, `#elif`, or `#endif` directive belongs to the closest preceding the `#if` directive.

The net result of the preceding scenario is that only one code `section` (possibly empty) will be compiled.

Directives #ifdef and #ifndef

The `#ifdef` and `#ifndef` directives can be used anywhere `#if` can be used and they can test whether an identifier is currently defined or not. The line

```
#ifdef identifier
```

has exactly the same effect as `#if 1` if `identifier` is currently defined, and the same effect as `#if 0` if `identifier` is currently undefined. The other directive, `#ifndef`, tests true for the “not-defined” condition, producing the opposite results.

The syntax thereafter follows that of `#if`, `#elif`, `#else`, and `#endif`.

An identifier defined as `NULL` is considered to be defined.

CHAPTER 6

mikroC PRO for AVR Libraries

mikroC PRO for AVR provides a set of libraries which simplify the initialization and use of AVR compliant MCUs and their modules:

Use Library manager to include mikroC PRO for AVR Libraries in you project.

Hardware AVR-specific Libraries

- ADC Library
- CANSPI Library
- Compact Flash Library
- EEPROM Library
- Flash Memory Library
- Graphic LCD Library
- Keypad Library
- LCD Library
- Manchester Code Library
- Multi Media Card library
- OneWire Library
- Port Expander Library
- PS/2 Library
- PWM Library
- PWM 16 bit Library
- RS-485 Library
- Software I2C Library
- Software SPI Library
- Software UART Library
- Sound Library
- SPI Library
- SPI Ethernet Library
- SPI Graphic LCD Library
- SPI LCD Library
- SPI LCD8 Library
- SPI T6963C Graphic LCD Library
- T6963C Graphic LCD Library
- TWI Library
- UART Library

Standard ANSI C Libraries

- ANSI C Ctype Library
- ANSI C Math Library
- ANSI C Stdlib Library
- ANSI C String Library

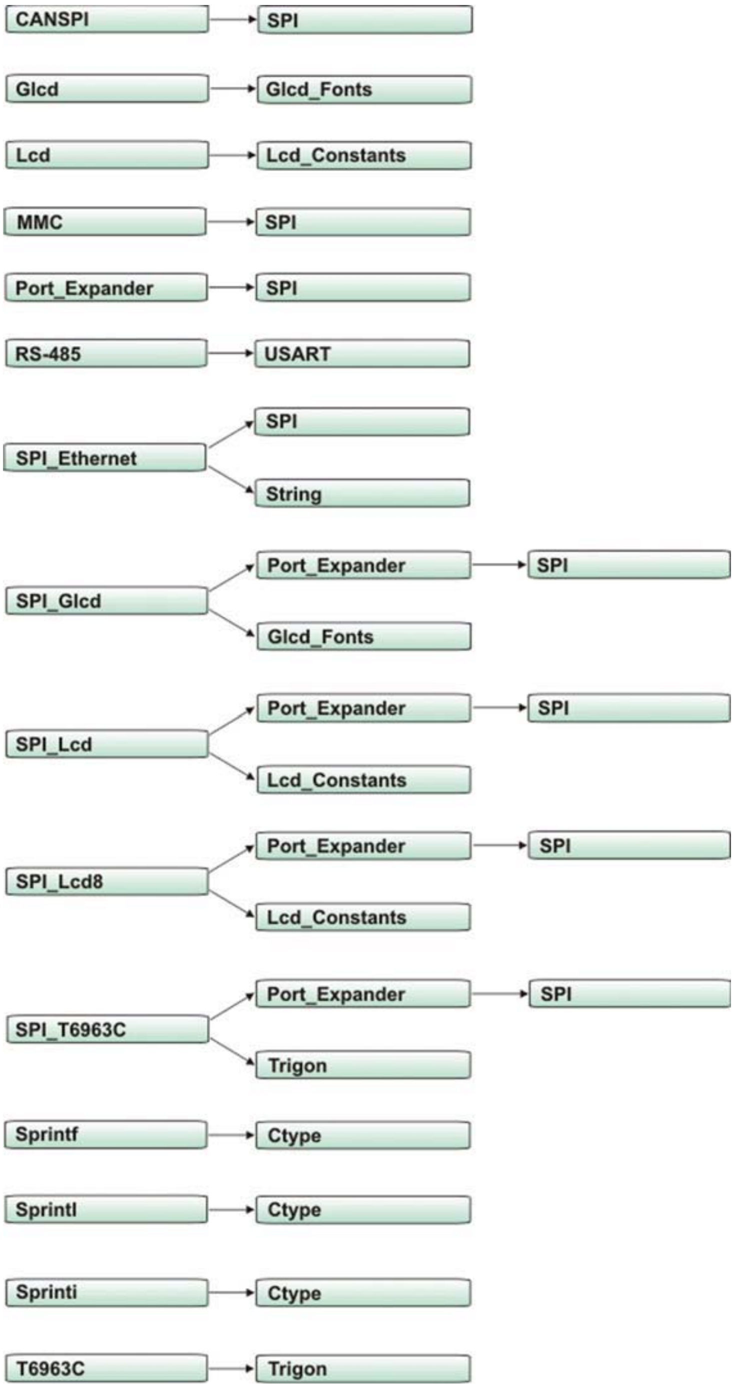
Miscellaneous Libraries

- Button Library
- Conversions Library
- Sprint Library
- Time Library
- Trigonometry Library
- See also Built-in Routines.

LIBRARY DEPENDENCIES

Certain libraries use (depend on) function and/or variables, constants defined in other libraries.
Image below shows clear representation about these dependencies.

For example, SPI_Glcd uses Glcd_Fonts and Port_Expander library which uses SPI library.
This means that if you check SPI_Glcd library in Library manager, all libraries on which it depends will be checked too.



Related topics: Library manager, AVR Libraries

ADC LIBRARY

ADC (Analog to Digital Converter) module is available with a number of AVR micros. Library function ADC_Read is included to provide you comfortable work with the module in single-ended mode.

ADC_Read

Prototype	`unsigned ADC_Read(char channel);`
Returns	10-bit or 12-bit (MCU dependent) unsigned value from the specified `channel`.
Description	Initializes AVR 's internal ADC module to work with XTAL frequency prescaled by 128. Clock determines the time period necessary for performing A/D conversion. Parameter `channel` represents the channel from which the analog value is to be acquired. Refer to the appropriate datasheet for channel-to-pin mapping.
Requires	Nothing.

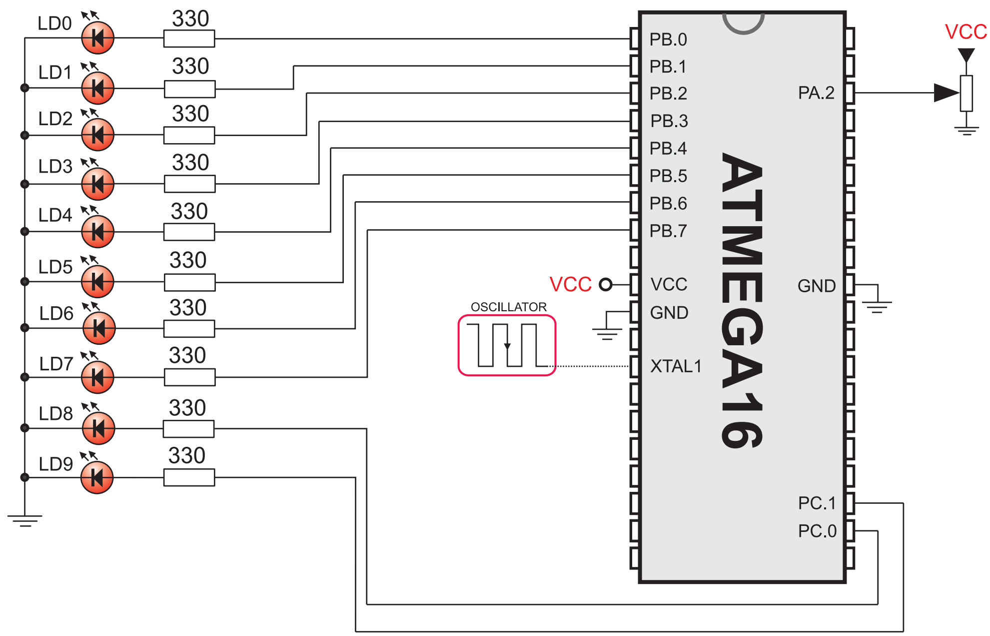
Example	`unsigned tmp;`
	`...`
	`tmp = ADC_Read(2);   // Read analog value from channel 1`

Library Example

This example code reads analog value from channel 2 and displays it on PORTB and PORTC.

```
#include <built_in.h>
unsigned int adc_rd;

void main() {

  DDRB = 0xFF;                    // Set PORTB as output
  DDRC = 0xFF;                    // Set PORTC as output

  while (1) {
    adc_rd = ADC_Read(2);      // get ADC value from 2nd channel
    PORTB = adc_rd;            // display adc_rd[7..0]
    PORTC = Hi(adc_rd);        // display adc_rd[9..8]
  }
}
```

HW Connection



ADC HW connection

CANSPI LIBRARY

The SPI module is available with a number of the AVR compliant MCUs. The mikroC PRO for AVR provides a library (driver) for working with mikroElektronika's CANSPI Add-on boards (with MCP2515 or MCP2510) via SPI interface.

The CAN is a very robust protocol that has error detection and signalization, self–checking and fault confinement. Faulty CAN data and remote frames are re-transmitted automatically, similar to the Ethernet.

Data transfer rates depend on distance. For example, 1 Mbit/s can be achieved at network lengths below 40m while 250 Kbit/s can be achieved at network lengths below 250m. The greater distance the lower maximum bitrate that can be achieved. The lowest bitrate defined by the standard is 200Kbit/s. Cables used are shielded twisted pairs.

CAN supports two message formats:

Standard format, with 11 identifier bits and
Extended format, with 29 identifier bits

Note:

- Consult the CAN standard about CAN bus termination resistance.
- An effective CANSPI communication speed depends on SPI and certainly is slower than “real” CAN.
- CANSPI module refers to mikroElektronika's CANSPI Add-on board con nected to SPI module of MCU.
- Prior to calling any of this library routines, Spi_Rd_Ptr needs to be initial-ized with the appropriate SPI_Read routine.

External dependecies of CANSPI Library

The following variables must be defined in all projects using CANSPI Library:	Description :	Example :
`extern sfr sbit CanSpi_CS;`	Chip Select line.	`sbit CanSpi_CS at PORTB.B0;`
`extern sfr sbit CanSpi_Rst;`	Reset line.	`sbit CanSpi_Rst at PORTB.B2;`
`extern sfr sbit CanSpi_CS_Bit_Direction;`	Direction of the Chip Select pin.	`sbit CanSpi_CS_Bit_Direction at DDRB.B0;`
`extern sfr sbit CanSpi_Rst_Bit_Direction;`	Direction of the Reset pin.	`sbit CanSpi_Rst_Bit_Direction at DDRB.B2;`

Library Routines

- CANSPISetOperationMode
- CANSPIGetOperationMode
- CANSPIInitialize
- CANSPISetBaudRate
- CANSPISetMask
- CANSPISetFilter
- CANSPIread
- CANSPIWrite

The following routines are for an internal use by the library only:

- RegsToCANSPIID
- CANSPIIDToRegs

Be sure to check CANSPI constants necessary for using some of the functions.

CANSPISetOperationMode

Prototype	`void CANSPISetOperationMode(char mode, char WAIT);`
Returns	Nothing.
Description	Sets the CANSPI module to requested mode. Parameters : - `mode`: CANSPI module operation mode. Valid values: `CANSPI_OP_MODE` constants (see CANSPI constants). - `WAIT`: CANSPI mode switching verification request. If `WAIT == 0`, the call is non-blocking. The function does not verify if the CANSPI module is switched to requested mode or not. Caller must use `CANSPIGetOperationMode` to verify correct operation mode before performing mode specific operation. If `WAIT != 0`, the call is blocking – the function won't "return" until the requested mode is set.
Requires	The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.
Example	`// set the CANSPI module into configuration mode (wait inside CANSPISetOperationMode until this mode is set)` `CANSPISetOperationMode(CANSPI_MODE_CONFIG, 0xFF);`

CANSPIGetOperationMode

Prototype	`char CANSPIGetOperationMode();`
Returns	Current operation mode.
Description	The function returns current operation mode of the CANSPI module. Check `CANSPI_OP_MODE` constants (see CANSPI constants) or device datasheet for operation mode codes.
Requires	The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	`// check whether the CANSPI module is in Normal mode and if it is do something.`
	`if (CANSPIGetOperationMode() == CANSPI_MODE_NORMAL) {`
	`  ...`
	`}`

CANSPIInitialize

Prototype	`void CANSPIInitialize( char SJW, char BRP, char PHSEG1, char PHSEG2, char PROPSEG, char CAN_CONFIG_FLAGS);`
Returns	Nothing.
Description	Initializes the CANSPI module. Stand-Alone CAN controller in the CANSPI module is set to: - Disable CAN capture - Continue CAN operation in Idle mode - Do not abort pending transmissions - Fcan clock : 4*Tcy (Fosc) - Baud rate is set according to given parameters - CAN mode : Normal - Filter and mask registers IDs are set to zero - Filter and mask message frame type is set according to `CAN_CONFIG_FLAGS` value `SAM`, `SEG2PHTS`, `WAKFIL` and `DBEN` bits are set according to `CAN_CONFIG_FLAGS` value. Parameters: - `SJW` as defined in CAN controller's datasheet - `BRP` as defined in CAN controller's datasheet - `PHSEG1` as defined in CAN controller's datasheet - `PHSEG2` as defined in CAN controller's datasheet - `PROPSEG` as defined in CAN controller's datasheet - `CAN_CONFIG_FLAGS` is formed from predefined constants (see CANSPI constants)
Requires	Global variables : - `CanSpi_CS`: Chip Select line - `CanSpi_Rst`: Reset line - `CanSpi_CS_Bit_Direction`: Direction of the Chip Select pin - `CanSpi_Rst_Bit_Direction`: Direction of the Reset pin must be defined before using this function. The CANSPI routines are supported only by MCUs with the SPI module. The SPI module needs to be initialized. See the Spi_Init and Spi_Init_Advanced routines. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	```// CANSPI module connections
	sbit CanSpi_CS at PORTB.B0;
	sbit CanSpi_CS_Direction at DDRB.B0;
	sbit CanSpi_Rst at PORTB.B2;
	sbit CanSpi_Rst_Direction at DDRB.B2;
	// End CANSPI module connections
	
	// initialize the CANSPI module with the appropriate baud rate
	and message acceptance flags along with the sampling rules
	char Can_Init_Flags;
	  ...
	  Can_Init_Flags = CAN_CONFIG_SAMPLE_THRICE & // form value to
	be used
	                   CAN_CONFIG_PHSEG2_PRG_ON & // with
	CANSPIInitialize
	                   CAN_CONFIG_XTD_MSG &
	                   CAN_CONFIG_DBL_BUFFER_ON &
	                   CAN_CONFIG_VALID_XTD_MSG;
	  ...
	  SPI1_Init(); // initialize
	SPI module
	  Spi_Rd_Ptr = SPI1_Read; // pass pointer
	to SPI Read function of used SPI module
	
	  CANSPIInitialize(1,3,3,3,1,Can_Init_Flags); // initialize
	external CANSPI module```

CANSPISetBaudRate

Prototype	`void CANSPISetBaudRate( char SJW, char BRP, char PHSEG1, char PHSEG2, char PROPSEG, char CAN_CONFIG_FLAGS);`
Returns	Nothing.
Description	Sets the CANSPI module baud rate. Due to complexity of the CAN protocol, you can not simply force a bps value. Instead, use this function when the CANSPI module is in Config mode. `SAM`, `SEG2PHTS` and `WAKFIL` bits are set according to `CAN_CONFIG_FLAGS` value. Refer to datasheet for details. Parameters: - `SJW` as defined in CAN controller's datasheet - `BRP` as defined in CAN controller's datasheet - `PHSEG1` as defined in CAN controller's datasheet - `PHSEG2` as defined in CAN controller's datasheet - `PROPSEG` as defined in CAN controller's datasheet - `CAN_CONFIG_FLAGS` is formed from predefined constants (see CANSPI constants)
Requires	The CANSPI module must be in Config mode, otherwise the function will be ignored. See CANSPISetOperationMode. The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	`// set required baud rate and sampling rules`
	`char can_config_flags;`
	`...`
	`CANSPISetOperationMode(CANSPI_MODE_CONFIG,0xFF); // set CONFIGURATION mode (CANSPI module mast be in config mode for baud rate settings)`
	`can_config_flags = CANSPI_CONFIG_SAMPLE_THRICE &`
	`CANSPI_CONFIG_PHSEG2_PRG_ON &`
	`CANSPI_CONFIG_STD_MSG &`
	`CANSPI_CONFIG_DBL_BUFFER_ON &`
	`CANSPI_CONFIG_VALID_XTD_MSG &`
	`CANSPI_CONFIG_LINE_FILTER_OFF;`
	`CANSPISetBaudRate(1, 1, 3, 3, 1, can_config_flags);`

CANSPISetMask

Prototype	`void CANSPISetMask(char CAN_MASK, long val, char CAN_CONFIG_FLAGS);`
Returns	Nothing.

Description	Configures mask for advanced filtering of messages. The parameter value is bit-adjusted to the appropriate mask registers.
	
	Parameters:
	
	- `CAN_MASK`: CANSPI module mask number. Valid values: `CANSPI_MASK` constants (see CANSPI constants)
	- `val`: mask register value
	- `CAN_CONFIG_FLAGS`: selects type of message to filter. Valid values:
	
	`CANSPI_CONFIG_ALL_VALID_MSG,`
	`CANSPI_CONFIG_MATCH_MSG_TYPE & CANSPI_CONFIG_STD_MSG,`
	`CANSPI_CONFIG_MATCH_MSG_TYPE & CANSPI_CONFIG_XTD_MSG.`
	
	(see CANSPI constants)

Requires	The CANSPI module must be in Config mode, otherwise the function will be ignored. See CANSPISetOperationMode. The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	`// set the appropriate filter mask and message type value`
	`CANSPISetOperationMode(CANSPI_MODE_CONFIG,0xFF);      // set CONFIGURATION mode (CANSPI module must be in config mode for mask settings)`
	
	`// Set all B1 mask bits to 1 (all filtered bits are relevant):`
	`// Note that -1 is just a cheaper way to write 0xFFFFFFFF.`
	`// Complement will do the trick and fill it up with ones.`
	`CANSPISetMask(CANSPI_MASK_B1, -1, CANSPI_CONFIG_MATCH_MSG_TYPE & CANSPI_CONFIG_XTD_MSG);`

CANSPISetFilter

Prototype	`void CANSPISetFilter(char CAN_FILTER, long val, char CAN_CONFIG_FLAGS);`
Returns	Nothing.

Description	Configures message filter. The parameter `value` is bit-adjusted to the appropriate filter registers.
	
	Parameters:
	
	- `CAN_FILTER`: CANSPI module filter number. Valid values: `CANSPI_FILTER` constants (see CANSPI constants)
	- `val`: filter register value
	- `CAN_CONFIG_FLAGS`: selects type of message to filter. Valid values:
	
	`CANSPI_CONFIG_ALL_VALID_MSG,`
	`CANSPI_CONFIG_MATCH_MSG_TYPE & CANSPI_CONFIG_STD_MSG,`
	`CANSPI_CONFIG_MATCH_MSG_TYPE & CANSPI_CONFIG_XTD_MSG.`
	
	(see CANSPI constants)

Requires	The CANSPI module must be in Config mode, otherwise the function will be ignored. See CANSPISetOperationMode. The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	`// set the appropriate filter value and message type`
	`CANSPISetOperationMode(CANSPI_MODE_CONFIG,0xFF);`
	`// set CONFIGURATION mode (CANSPI module must be in config mode for filter settings)`
	
	`/* Set id of filter B1_F1 to 3: */`
	`CANSPISetFilter(CANSPI_FILTER_B1_F1, 3, CANSPI_CONFIG_XTD_MSG);`

CANSPIRead

Prototype	`char CANSPIRead(long *id, char *rd_data, char *data_len, char *CAN_RX_MSG_FLAGS);`
Returns	- `0` if nothing is received - `0xFF` if one of the Receive Buffers is full (message received)
Description	If at least one full Receive Buffer is found, it will be processed in the following way: - Message ID is retrieved and stored to location provided by the `id` parameter - Message data is retrieved and stored to a buffer provided by the `rd_data` parameter - Message length is retrieved and stored to location provided by the `data_len` parameter - Message flags are retrieved and stored to location provided by the `CAN_RX_MSG_FLAGS` parameter Parameters: - `id:` message identifier storage address - `rd_data:` data buffer (an array of bytes up to 8 bytes in length) - `data_len:` data length storage address. - `CAN_RX_MSG_FLAGS`: message flags storage address
Requires	The CANSPI module must be in a mode in which receiving is possible. See CANSPISetOperationMode. The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	`// check the CANSPI module for received messages. If any was received do something.`
	`char msg_rcvd, rx_flags, data_len;`
	`char data[8];`
	`long msg_id;`
	`...`
	`CANSPISetOperationMode(CANSPI_MODE_NORMAL,0xFF);`
	`// set NORMAL mode (CANSPI module must be in mode in which receive is possible)`
	`...`
	`rx_flags = 0;`
	`// clear message flags`
	`if (msg_rcvd = CANSPIRead(msg_id, data, data_len, rx_flags)) {`
	`   ...`
	`}`

CANSPIWrite

Prototype	`char CANSPIWrite(long id, char *wr_data, char data_len, char CAN_TX_MSG_FLAGS);`
Returns	- `0` if all Transmit Buffers are busy - `0xFF` if at least one Transmit Buffer is available
Description	If at least one empty Transmit Buffer is found, the function sends message in the queue for transmission. Parameters: - `id:`CAN message identifier. Valid values: 11 or 29 bit values, depending on message type (standard or extended) - `wr_data:` data to be sent (an array of bytes up to 8 bytes in length) - `data_len:` data length. Valid values: 1 to 8 - `CAN_RX_MSG_FLAGS:` message flags
Requires	The CANSPI module must be in mode in which transmission is possible. See CANSPISetOperationMode. The CANSPI routines are supported only by MCUs with the SPI module. MCU has to be properly connected to mikroElektronika's CANSPI Extra Board or similar hardware. See connection example at the bottom of this page.

Example	`// send message extended CAN message with the appropriate ID and data`
	`char tx_flags;`
	`char data[ 8] ;`
	`long msg_id;`
	`...`
	`CANSPISetOperationMode(CAN_MODE_NORMAL,0xFF);`
	`// set NORMAL mode (CANSPI must be in mode in which transmission is possible)`
	
	`tx_flags = CANSPI_TX_PRIORITY_0 & CANSPI_TX_XTD_FRAME;`
	`// set message flags`
	`CANSPIWrite(msg_id, data, 2, tx_flags);`

CANSPI Constants

There is a number of constants predefined in the CANSPI library. You need to be familiar with them in order to be able to use the library effectively. Check the example at the end of the chapter.

CANSPI_OP_MODE

The CANSPI_OP_MODE constants define CANSPI operation mode. Function CANSPISetOperationMode expects one of these as it's argument:

```
const char
    CANSPI_MODE_BITS    = 0xE0,    // Use this to access opmode  bits
    CANSPI_MODE_NORMAL  = 0x00,
    CANSPI_MODE_SLEEP   = 0x20,
    CANSPI_MODE_LOOP    = 0x40,
    CANSPI_MODE_LISTEN  = 0x60,
    CANSPI_MODE_CONFIG  = 0x80;
```

CANSPI_CONFIG_FLAGS

The CANSPI_CONFIG_FLAGS constants define flags related to the CANSPI module configuration. The functions CANSPIInitialize, CANSPISetBaudRate, CANSPISetMask and CANSPISetFilter expect one of these (or a bitwise combination) as their argument:

```
const char
    CANSPI_CONFIG_DEFAULT          = 0xFF,    // 11111111

    CANSPI_CONFIG_PHSEG2_PRG_BIT   = 0x01,
    CANSPI_CONFIG_PHSEG2_PRG_ON    = 0xFF,    // XXXXXXX1
    CANSPI_CONFIG_PHSEG2_PRG_OFF   = 0xFE,    // XXXXXXX0

    CANSPI_CONFIG_LINE_FILTER_BIT  = 0x02,
    CANSPI_CONFIG_LINE_FILTER_ON   = 0xFF,    // XXXXXX1X
    CANSPI_CONFIG_LINE_FILTER_OFF  = 0xFD,    // XXXXXX0X

    CANSPI_CONFIG_SAMPLE_BIT       = 0x04,
    CANSPI_CONFIG_SAMPLE_ONCE      = 0xFF,    // XXXXX1XX
    CANSPI_CONFIG_SAMPLE_THRICE    = 0xFB,    // XXXXX0XX

    CANSPI_CONFIG_MSG_TYPE_BIT     = 0x08,
    CANSPI_CONFIG_STD_MSG          = 0xFF,    // XXXX1XXX
    CANSPI_CONFIG_XTD_MSG          = 0xF7,    // XXXX0XXX
```

```
    CANSPI_CONFIG_DBL_BUFFER_BIT   = 0x10,
    CANSPI_CONFIG_DBL_BUFFER_ON    = 0xFF,    // XXX1XXXX
    CANSPI_CONFIG_DBL_BUFFER_OFF   = 0xEF,    // XXX0XXXX

    CANSPI_CONFIG_MSG_BITS          = 0x60,
    CANSPI_CONFIG_ALL_MSG           = 0xFF,    // X11XXXXX
    CANSPI_CONFIG_VALID_XTD_MSG    = 0xDF,    // X10XXXXX
    CANSPI_CONFIG_VALID_STD_MSG    = 0xBF,    // X01XXXXX
    CANSPI_CONFIG_ALL_VALID_MSG    = 0x9F;    // X00XXXXX
```

You may use bitwise AND (&) to form config byte out of these values. For example:

```
init = CANSPI_CONFIG_SAMPLE_THRICE &
        CANSPI_CONFIG_PHSEG2_PRG_ON &
        CANSPI_CONFIG_STD_MSG        &
        CANSPI_CONFIG_DBL_BUFFER_ON &
        CANSPI_CONFIG_VALID_XTD_MSG &
        CANSPI_CONFIG_LINE_FILTER_OFF;
...
CANSPIInitialize(1, 1, 3, 3, 1, init);    // initialize CANSPI
```

CANSPI_TX_MSG_FLAGS

CANSPI_TX_MSG_FLAGS are flags related to transmission of a CAN message:

```
const char
    CANSPI_TX_PRIORITY_BITS = 0x03,
    CANSPI_TX_PRIORITY_0     = 0xFC,    // XXXXXX00
    CANSPI_TX_PRIORITY_1     = 0xFD,    // XXXXXX01
    CANSPI_TX_PRIORITY_2     = 0xFE,    // XXXXXX10
    CANSPI_TX_PRIORITY_3     = 0xFF,    // XXXXXX11

    CANSPI_TX_FRAME_BIT     = 0x08,
    CANSPI_TX_STD_FRAME     = 0xFF,     // XXXXX1XX
    CANSPI_TX_XTD_FRAME     = 0xF7,     // XXXXX0XX

    CANSPI_TX_RTR_BIT       = 0x40,
    CANSPI_TX_NO_RTR_FRAME = 0xFF,     // X1XXXXXX
    CANSPI_TX_RTR_FRAME     = 0xBF;     // X0XXXXXX
```

You may use bitwise AND (&) to adjust the appropriate flags. For example:

```
/*  form value to be used as sending message flag : */
send_config = CANSPI_TX_PRIORITY_0 &
               CANSPI_TX_XTD_FRAME   &
               CANSPI_TX_NO_RTR_FRAME;
...
CANSPIWrite(id, data, 1, send_config);
```

CANSPI_RX_MSG_FLAGS

CANSPI_RX_MSG_FLAGS are flags related to reception of CAN message. If a particular bit is set then corresponding meaning is TRUE or else it will be FALSE.

```
const char
    CANSPI_RX_FILTER_BITS = 0x07,// Use this to access filter bits
    CANSPI_RX_FILTER_1     = 0x00,
    CANSPI_RX_FILTER_2     = 0x01,
    CANSPI_RX_FILTER_3     = 0x02,
    CANSPI_RX_FILTER_4     = 0x03,
    CANSPI_RX_FILTER_5     = 0x04,
    CANSPI_RX_FILTER_6     = 0x05,

    CANSPI_RX_OVERFLOW     = 0x08,// Set if Overflowed else cleared
    CANSPI_RX_INVALID_MSG = 0x10, // Set if invalid else cleared
    CANSPI_RX_XTD_FRAME    = 0x20,//Set if XTD message else cleared
    CANSPI_RX_RTR_FRAME    = 0x40,//Set if RTR message else cleared
    CANSPI_RX_DBL_BUFFERED = 0x80;  // Set if this message was
hardware double-buffered
```

You may use bitwise AND (&) to adjust the appropriate flags. For example:

```
if (MsgFlag & CANSPI_RX_OVERFLOW != 0) {
  ...
  // Receiver overflow has occurred.
  // We have lost our previous message.
}
```

CANSPI_MASK

The CANSPI_MASK constants define mask codes. Function CANSPISetMask expects one of these as it's argument:

```
const char
    CANSPI_MASK_B1 = 0,
    CANSPI_MASK_B2 = 1;
```

CANSPI_FILTER

The CANSPI_FILTER constants define filter codes. Functions CANSPISetFilter expects one of these as it's argument:

```
const char
    CANSPI_FILTER_B1_F1 = 0,
    CANSPI_FILTER_B1_F2 = 1,
    CANSPI_FILTER_B2_F1 = 2,
    CANSPI_FILTER_B2_F2 = 3,
    CANSPI_FILTER_B2_F3 = 4,
    CANSPI_FILTER_B2_F4 = 5;
```

Library Example

This is a simple demonstration of CANSPI Library routines usage. First node initiates the communication with the second node by sending some data to its address. The second node responds by sending back the data incremented by 1. First node then does the same and sends incremented data back to second node, etc.

Code for the first CANSPI node:

```
unsigned char Can_Init_Flags, Can_Send_Flags, Can_Rcv_Flags; // can
flags
unsigned char Rx_Data_Len;        // received data length in bytes
char RxTx_Data[8];                 // can rx/tx data buffer
char Msg_Rcvd;                      // reception flag
long Tx_ID, Rx_ID;                   // can rx and tx ID

// CANSPI module connections
sbit CanSpi_CS  at  PORTB.B0;
sbit CanSpi_CS_Direction  at  DDRB.B0;
sbit CanSpi_Rst at  PORTB.B2;
sbit CanSpi_Rst_Direction at  DDRB.B2;
// End CANSPI module connections



void main() {
  ADCSRA.B7 = 0;                        // set AN pins to Digital I/O
  PORTC = 0;                                    // clear PORTC
  DDRC = 255;

  Can_Init_Flags = 0;                                   //
  Can_Send_Flags = 0;                                 // clear flags
  Can_Rcv_Flags  = 0;                                 //
```

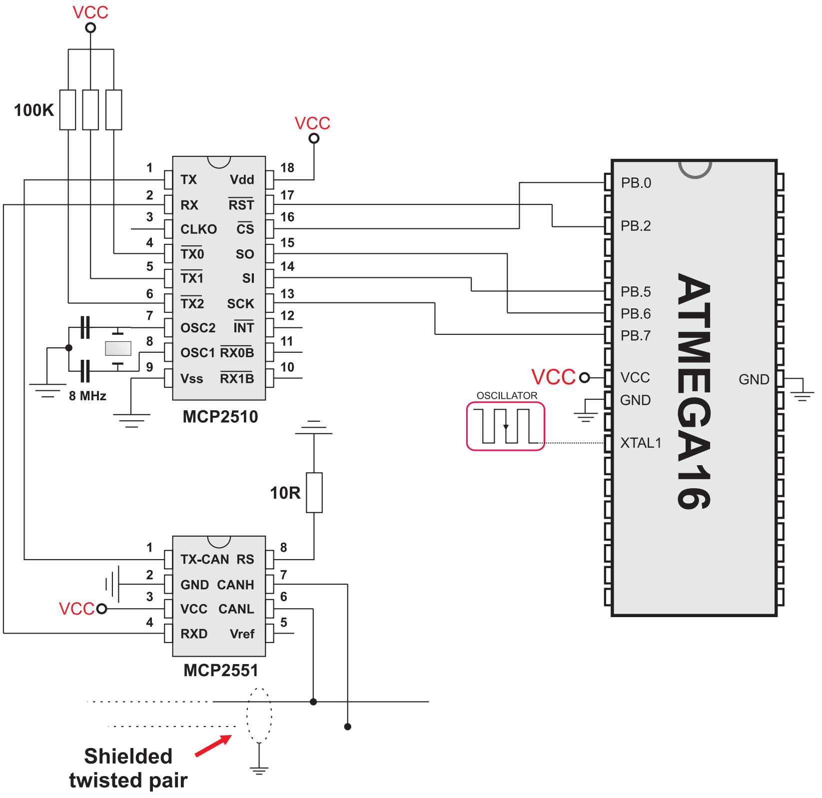
```
  Can_Send_Flags = _CANSPI_TX_PRIORITY_0 &  // form value to be used
                   _CANSPI_TX_XTD_FRAME &      //     with CANSPIWrite
                     _CANSPI_TX_NO_RTR_FRAME;

  Can_Init_Flags = _CANSPI_CONFIG_SAMPLE_THRICE &            // form
value to be used
                    _CANSPI_CONFIG_PHSEG2_PRG_ON &// with CANSPIInit
                    _CANSPI_CONFIG_XTD_MSG &
                    _CANSPI_CONFIG_DBL_BUFFER_ON &
                    _CANSPI_CONFIG_VALID_XTD_MSG;

  SPI1_Init();
  Spi_Rd_Ptr = SPI1_Read;                                        //
pass pointer to SPI Read function of used SPI module
  SPI1_Init();                              // initialize SPI1 module
  CANSPIInitialize(1,3,3,3,1,Can_Init_Flags);                    //
initialize external CANSPI module
  CANSPISetOperationMode(_CANSPI_MODE_CONFIG,0xFF);              //
set CONFIGURATION mode
          CANSPISetMask(_CANSPI_MASK_B1,-1,_CANSPI_CONFIG_XTD_MSG);
// set all mask1 bits to ones
          CANSPISetMask(_CANSPI_MASK_B2,-1,_CANSPI_CONFIG_XTD_MSG);
// set all mask2 bits to ones
      CANSPISetFilter(_CANSPI_FILTER_B2_F4,3,_CANSPI_CONFIG_XTD_MSG);
// set id of filter B1_F1 to 3
  CANSPISetOperationMode(_CANSPI_MODE_NORMAL,0xFF);              //
set NORMAL mode
  RxTx_Data[0] = 9;                   // set initial data to be sent
  Tx_ID = 12111;                              // set transmit ID
  CANSPIWrite(Tx_ID, RxTx_Data, 1, Can_Send_Flags);              //
send initial message

                                       while(1)                  {
// endless loop
       Msg_Rcvd  =  CANSPIRead(&Rx_ID  ,  RxTx_Data  ,  &Rx_Data_Len,
&Can_Rcv_Flags);   // receive message
             if    ((Rx_ID    ==    3u)    &&    Msg_Rcvd)    {
// if message received check id
                                 PORTC      =      RxTx_Data[0];
// id correct, output data at PORTC
                                       RxTx_Data[0]++        ;
// increment received data
       Delay_ms(10);
             CANSPIWrite(Tx_ID,  RxTx_Data,  1,  Can_Send_Flags);
// send incremented data back
    }
  }
}
```

Code for the second CANSPI node:

```
unsigned char Can_Init_Flags, Can_Send_Flags, Can_Rcv_Flags;  // can
flags
unsigned char Rx_Data_Len;          // received data length in bytes
char RxTx_Data[8];                   // can rx/tx data buffer
char Msg_Rcvd;                       // reception flag
long Tx_ID, Rx_ID;                   // can rx and tx ID

// CANSPI module connections
sbit CanSpi_CS  at  PORTB.B0;
sbit CanSpi_CS_Direction  at  DDRB.B0;
sbit CanSpi_Rst at  PORTB.B2;
sbit CanSpi_Rst_Direction at  DDRB.B2;
// End CANSPI module connections


void main() {

  PORTC = 0;                                  // clear PORTC
  DDRC = 255;                                  // set PORTC as output

  Can_Init_Flags = 0;                                              //
  Can_Send_Flags = 0;                                    // clear flags
  Can_Rcv_Flags  = 0;                                              //

  Can_Send_Flags = _CANSPI_TX_PRIORITY_0 &  // form value to be used
                   _CANSPI_TX_XTD_FRAME &      //  with CANSPIWrite
                   _CANSPI_TX_NO_RTR_FRAME;

  Can_Init_Flags = _CANSPI_CONFIG_SAMPLE_THRICE &//orm value to be used
                  _CANSPI_CONFIG_PHSEG2_PRG_ON & //  with CANSPIInit
                   _CANSPI_CONFIG_XTD_MSG &
                   _CANSPI_CONFIG_DBL_BUFFER_ON &
                   _CANSPI_CONFIG_VALID_XTD_MSG &
                   _CANSPI_CONFIG_LINE_FILTER_OFF;
SPI1_Init();
Spi_Rd_Ptr = SPI1_Read; // pass pointer to SPI Read function of used
SPI module
SPI1_Init();                         // initialize SPI1 module
  CANSPIInitialize(1,3,3,3,1,Can_Init_Flags);  // initialize exter-
nal CANSPI module
   CANSPISetOperationMode(_CANSPI_MODE_CONFIG,0xFF);//set  CONFIGURA-
TION mode
CANSPISetMask(_CANSPI_MASK_B1,-1,_CANSPI_CONFIG_XTD_MSG);
// set all mask1 bits to ones
CANSPISetMask(_CANSPI_MASK_B2,-1,_CANSPI_CONFIG_XTD_MSG);
// set all mask2 bits to ones
```

```
CANSPISetFilter(_CANSPI_FILTER_B2_F3,12111,_CANSPI_CONFIG_XTD_MSG);
// set id of filter B1_F1 to 3
CANSPISetOperationMode(_CANSPI_MODE_NORMAL,0xFF); // set NORMAL mode
  Tx_ID = 3;                                       // set tx ID

while (1) {                                     // endless loop
       Msg_Rcvd  =  CANSPIRead(&Rx_ID  ,  RxTx_Data  ,  &Rx_Data_Len,
&Can_Rcv_Flags);  // receive message
if ((Rx_ID == 12111u) && Msg_Rcvd) {                    // if message
received check id
PORTC = RxTx_Data[0];          // id correct, output data at PORTC
RxTx_Data[0]++ ;                           // increment received data
CANSPIWrite(Tx_ID, RxTx_Data, 1, Can_Send_Flags);     // send incre-
mented data back
    }
  }
}
```

HW Connection



Example of interfacing CAN transceiver MCP2510 with MCU via SPI interface

COMPACT FLASH LIBRARY

The Compact Flash Library provides routines for accessing data on Compact Flash card (abbr. CF further in text). CF cards are widely used memory elements, commonly used with digital cameras. Great capacity and excellent access time of only a few microseconds make them very attractive for microcontroller applications.

In CF card, data is divided into sectors. One sector usually comprises 512 bytes. Routines for file handling, the Cf_Fat routines, are not performed directly but successively through 512B buffer.

Note: Routines for file handling can be used only with FAT16 file system.

Note: Library functions create and read files from the root directory only.

Note: Library functions populate both FAT1 and FAT2 tables when writing to files, but the file data is being read from the FAT1 table only; i.e. there is no recovery if the FAT1 table gets corrupted.

Note: If MMC/SD card has Master Boot Record (MBR), the library will work with the first available primary (logical) partition that has non-zero size. If MMC/SD card has Volume Boot Record (i.e. there is only one logical partition and no MBRs), the library works with entire card as a single partition. For more information on MBR, physical and logical drives, primary/secondary partitions and partition tables, please consult other resources, e.g. Wikipedia and similar.

Note: Before writing operation, make sure not to overwrite boot or FAT sector as it could make your card on PC or digital camera unreadable. Drive mapping tools, such as Winhex, can be of great assistance.

External dependencies of Compact Flash Library

The following variables must be defined in all projects using Compact Flash Library:	Description:	Example :
`extern sfr char CF_Data_Port;`	Compact Flash Data Port.	`sfr char CF_Data_Port at PORTD;`
`extern sfr char CF_Data_Port_Direction;`	Direction of the Compact Flash Data Port.	`sfr char CF_Data_Port_Direction at DDRD;`
`extern sfr sbit CF_RDY;`	Ready signal line.	`sbit CF_RDY at PINB.B7;`
`extern sfr sbit CF_WE;`	Write Enable signal line.	`sbit CF_WE at PORTB.B6;`
`extern sfr sbit CF_OE;`	Output Enable signal line.	`sbit CF_OE at PORTB.B5;`
`extern sfr sbit CF_CD1;`	Chip Detect signal line.	`sbit CF_CD1 at PINB.B4;`
`extern sfr sbit CF_CE1;`	Chip Enable signal line.	`sbit CF_CE1 at PORTB.B3;`
`extern sfr sbit CF_A2;`	Address pin 2.	`sbit CF_A2 at PORTB.B2;`
`extern sfr sbit CF_A1;`	Address pin 1.	`sbit CF_A1 at PORTB.B1;`
`extern sfr sbit CF_A0;`	Address pin 0.	`sbit CF_A0 at PORTB.B0;`
`extern sfr sbit CF_RDY_direction;`	Direction of the Ready pin.	`sbit CF_RDY_direction at DDRB.B7;`
`extern sfr sbit CF_WE_direction;`	Direction of the Write Enable pin.	`sbit CF_WE_direction at DDRB.B6;`
`extern sfr sbit CF_OE_direction;`	Direction of the Output Enable pin.	`sbit CF_OE_direction at DDRB.B5;`
`extern sfr sbit CF_CD1_direction;`	Direction of the Chip Detect pin.	`sbit CF_CD1_direction at DDRB.B4;`
`extern sfr sbit CF_CE1_direction;`	Direction of the Chip Enable pin.	`sbit CF_CE1_direction at DDRB.B3;`
`extern sfr sbit CF_A2_direction;`	Direction of the Address 2 pin.	`sbit CF_A2_direction at DDRB.B2;`

`extern sfr sbit CF_A1_direction;`	Direction of the Address 1 pin.	`sbit CF_A1_direction at DDRB.B1;`
`extern sfr sbit CF_A0_direction;`	Direction of the Address 0 pin.	`sbit CF_A0_direction at DDRB.B0;`

Library Routines

- Cf_Init
- Cf_Detect
- Cf_Enable
- Cf_Disable
- Cf_Read_Init
- Cf_Read_Byte
- Cf_Write_Init
- Cf_Write_Byte
- Cf_Read_Sector
- Cf_Write_Sector

Routines for file handling:

- Cf_Fat_Init
- Cf_Fat_QuickFormat
- Cf_Fat_Assign
- Cf_Fat_Reset
- Cf_Fat_Read
- Cf_Fat_Rewrite
- Cf_Fat_Append
- Cf_Fat_Delete
- Cf_Fat_Write
- Cf_Fat_Set_File_Date
- Cf_Fat_Get_File_Date
- Cf_Fat_Get_File_Size
- Cf_Fat_Get_Swap_File

The following routine is for the internal use by compiler only:

- Cf_Issue_ID_Command

Cf_Init

Prototype	`void Cf_Init();`
Returns	Nothing.
Description	Initializes ports appropriately for communication with CF card.
Requires	Global variables : - `CF_Data_Port` : Compact Flash data port - `CF_RDY` : Ready signal line - `CF_WE` : Write enable signal line - `CF_OE` : Output enable signal line - `CF_CD1` : Chip detect signal line - `CF_CE1` : Enable signal line - `CF_A2` : Address pin 2 - `CF_A1` : Address pin 1 - `CF_A0` : Address pin 0 - `CF_Data_Port_direction` : Direction of the Compact Flash data direction port - `CF_RDY_direction` : Direction of the Ready pin - `CF_WE_direction` : Direction of the Write enable pin - `CF_OE_direction` : Direction of the Output enable pin - `CF_CD1_direction` : Direction of the Chip detect pin - `CF_CE1_direction` : Direction of the Chip enable pin - `CF_A2_direction` : Direction of the Address 2 pin - `CF_A1_direction` : Direction of the Address 1 pin - `CF_A0_direction` : Direction of the Address 0 pin must be defined before using this function.
Example	`...` `Cf_Init();       // initialize CF`

Cf_Detect

Prototype	`unsigned short Cf_Detect(void);`
Returns	- `1` - if CF card was detected - `0` - otherwise
Description	Checks for presence of CF card by reading the `chip detect` pin.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.

Example	`// Wait until CF card is inserted:`
	`do`
	`   asm nop;`
	`while (!Cf_Detect());`

Cf_Enable

Prototype	`void Cf_Enable(void);`
Returns	Nothing.
Description	Enables the device. Routine needs to be called only if you have disabled the device by means of the Cf_Disable routine. These two routines in conjunction allow you to free/occupy data line when working with multiple devices.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.
Example	`// enable compact flash` `Cf_Enable();`

Cf_Disable

Prototype	`void Cf_Disable(void);`
Returns	Nothing.
Description	Routine disables the device and frees the data lines for other devices. To enable the device again, call Cf_Enable. These two routines in conjunction allow you to free/occupy data line when working with multiple devices.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.
Example	`// disable compact flash` `Cf_Disable();`

Cf_Read_Init

Prototype	`void Cf_Read_Init(unsigned long address, unsigned short sector_count);`
Returns	Nothing.
Description	Initializes CF card for reading. Parameters : - `address`: the first sector to be prepared for reading operation. - `sector_count`: number of sectors to be prepared for reading operation.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.
Example	`// initialize compact flash for reading from sector 590` `Cf_Read_Init(590, 1);`

Cf_Read_Byte

Prototype	`unsigned short Cf_Read_Byte(void);`
Returns	Returns a byte read from Compact Flash sector buffer. **Note**: Higher byte of the `unsigned` return value is cleared.
Description	Reads one byte from Compact Flash sector buffer location currently pointed to by internal read pointers. These pointers will be autoicremented upon reading.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init. CF card must be initialized for reading operation. See Cf_Read_Init.

Example	`// Read a byte from compact flash:`
	`char data;`
	`...`
	`data = Cf_Read_Byte();`

Cf_Write_Init

Prototype	`void Cf_Write_Init(unsigned long address, unsigned short sectcnt);`
Returns	Nothing.
Description	Initializes CF card for writing. Parameters : - `address`: the first sector to be prepared for writing operation. - `sectcnt`: number of sectors to be prepared for writing operation.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.
Example	`// initialize compact flash for writing to sector 590` `Cf_Write_Init(590, 1);`

Cf_Write_Byte

Prototype	`void Cf_Write_Byte(unsigned short data_);`
Returns	Nothing.
Description	Writes a byte to Compact Flash sector buffer location currently pointed to by writing pointers. These pointers will be autoicremented upon reading. When sector buffer is full, its contents will be transfered to appropriate flash memory sector. Parameters : - `data_`: byte to be written.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init. CF card must be initialized for writing operation. See Cf_Write_Init.

Example	`char data = 0xAA;`
	`...`
	`Cf_Write_Byte(data);`

Cf_Read_Sector

Prototype	`void Cf_Read_Sector(unsigned long sector_number, unsigned short *buffer);`
Returns	Nothing.
Description	Reads one sector (512 bytes). Read data is stored into buffer provided by the `buffer` parameter. Parameters : - `sector_number`: sector to be read. - `buffer`: data buffer of at least 512 bytes in length.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.

Example	`// read sector 22`
	`unsigned short data[ 512] ;`
	`...`
	`Cf_Read_Sector(22, data);`

Cf_Write_Sector

Prototype	`void Cf_Write_Sector(unsigned long sector_number, unsigned short *buffer);`
Returns	Nothing.
Description	Writes 512 bytes of data provided by the `buffer` parameter to one CF sector. Parameters : - `sector_number`: sector to be written to. - `buffer`: data buffer of 512 bytes in length.
Requires	The corresponding MCU ports must be appropriately initialized for CF card. See Cf_Init.

Example	`// write to sector 22`
	`unsigned short data[ 512] ;`
	`...`
	`Cf_Write_Sector(22, data);`

Cf_Fat_Init

Prototype	`unsigned short Cf_Fat_Init();`
Returns	- `0` - if CF card was detected and successfully initialized - `1` - if FAT16 boot sector was not found - `255` - if card was not detected
Description	Initializes CF card, reads CF FAT16 boot sector and extracts necessary data needed by the library.
Requires	Nothing.

Example	`// Init the FAT library`
	`if (!Cf_Fat_Init()) {  // Init the FAT library`
	`...`
	`}`

Cf_Fat_QuickFormat

Prototype	`unsigned char Cf_Fat_QuickFormat(char *cf_fat_label);`
Returns	- `0` - if CF card was detected, successfully formated and initialized - `1` - if FAT16 format was unseccessful - `255` - if card was not detected
Description	Formats to FAT16 and initializes CF card. Parameters : - `cf_fat_label`: volume label (11 characters in length). If less than 11 characters are provided, the label will be padded with spaces. If null string is passed, the volume will not be labeled. **Note**: This routine can be used instead or in conjunction with Cf_Fat_Init routine. **Note**: If CF card already contains a valid boot sector, it will remain unchanged (except volume label field) and only FAT and ROOT tables will be erased. Also, the new volume label will be set.
Requires	Nothing.

Example	`//--- format and initialize the FAT library -`
	`if (!Cf_Fat_QuickFormat(&cf_fat_label)) {`
	`...`
	`}`

Cf_Fat_Assign

<table>
<tr><td>Prototype</td><td><code>unsigned short Cf_Fat_Assign(char *filename, char file_cre_attr);</code></td></tr>
<tr><td>Returns</td><td>- <code>0</code> if file does not exist and no new file is created.
- <code>1</code> if file already exists or file does not exist but a new file is created.</td></tr>
<tr><td>Description</td><td>Assigns file for file operations (read, write, delete...). All subsequent file operations will be applied over the assigned file.

Parameters :

- <code>filename</code>: name of the file that should be assigned for file operations. The file name should be in DOS 8.3 (file_name.extension) format. The file name and extension will be automatically padded with spaces by the library if they have less than length required (i.e. "mikro.tx" -> "mikro .tx "), so the user does not have to take care of that. The file name and extension are case insensitive. The library will convert them to proper case automatically, so the user does not have to take care of that.
Also, in order to keep backward compatibility with the first version of this library, file names can be entered as UPPERCASE string of 11 bytes in length with no dot character between the file name and extension (i.e. "MIKROELETXT" -> MIKROELE.TXT). In this case the last 3 characters of the string are considered to be file extension.

- <code>file_cre_attr</code>: file creation and attributs flags. Each bit corresponds to the appropriate file attribut:
<table>
<tr><th>Bit</th><th>Mask</th><th>Description</th></tr>
<tr><td>0</td><td>0x01</td><td>Read Only</td></tr>
<tr><td>1</td><td>0x02</td><td>Hidden</td></tr>
<tr><td>2</td><td>0x04</td><td>System</td></tr>
<tr><td>3</td><td>0x08</td><td>Volume Label</td></tr>
<tr><td>4</td><td>0x10</td><td>Subdirectory</td></tr>
<tr><td>5</td><td>0x20</td><td>Archive</td></tr>
<tr><td>6</td><td>0x40</td><td>Device (internal use only, never found on disk)</td></tr>
<tr><td>7</td><td>0x80</td><td>File creation flag. If the file does not exist and this flag is set, a new file with specified name will be created.</td></tr>
</table>
Note: Long File Names (LFN) are not supported.</td></tr>
<tr><td>Requires</td><td>CF card and CF library must be initialized for file operations. See Cf_Fat_Init.</td></tr>
<tr><td>Example</td><td><code>// create file with archive attributes if it does not already exist
Cf_Fat_Assign("MIKRO007.TXT",0xA0);</code></td></tr>
</table>

Cf_Fat_Reset

Prototype	`void Cf_Fat_Reset(unsigned long *size);`
Returns	Nothing.
Description	Opens currently assigned file for reading. Parameters : size: buffer to store file size to. After file has been open for reading its size is returned through this parameter.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign.

Example	`unsigned long size;`
	`...`
	`Cf_Fat_Reset(size);`

Cf_Fat_Read

Prototype	`void Cf_Fat_Read(unsigned short *bdata);`
Returns	Nothing.
Description	Reads a byte from currently assigned file opened for reading. Upon function execution file pointers will be set to the next character in the file. Parameters : - `bdata`: buffer to store read byte to. Upon this function execution read byte is returned through this parameter.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign. File must be open for reading. See Cf_Fat_Reset.

Example	`char character;`
	`...`
	`Cf_Fat_Read(&character);`

Cf_Fat_Rewrite

Prototype	`void Cf_Fat_Rewrite();`
Returns	Nothing.
Description	Opens currently assigned file for writing. If the file is not empty its content will be erased.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. The file must be previously assigned. See Cf_Fat_Assign.
Example	`// open file for writing` `Cf_Fat_Rewrite();`

Cf_Fat_Append

Prototype	`void Cf_Fat_Append();`
Returns	Nothing.
Description	Opens currently assigned file for appending. Upon this function execution file pointers will be positioned after the last byte in the file, so any subsequent file writing operation will start from there.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign.
Example	`// open file for appending` `Cf_Fat_Append();`

Cf_Fat_Delete

Prototype	`void Cf_Fat_Delete();`
Returns	Nothing.
Description	Deletes currently assigned file from CF card.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign.
Example	`// delete current file` `Cf_Fat_Delete();`

Cf_Fat_Write

Prototype	`void Cf_Fat_Write(char *fdata, unsigned data_len);`
Returns	Nothing.
Description	Writes requested number of bytes to currently assigned file opened for writing. Parameters : - `fdata`: data to be written. - `data_len`: number of bytes to be written.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign. File must be open for writing. See Cf_Fat_Rewrite or Cf_Fat_Append.

Example	`char file_contents[42];`
	`...`
	`Cf_Fat_Write(file_contents, 42); // write data to the assigned file`

Cf_Fat_Set_File_Date

Prototype	`void Cf_Fat_Set_File_Date(unsigned int year, unsigned short month, unsigned short day, unsigned short hours, unsigned short mins, unsigned short seconds);`
Returns	Nothing.
Description	Sets the date/time stamp. Any subsequent file writing operation will write this stamp to currently assigned file's time/date attributs. Parameters : - `year`: year attribute. Valid values: 1980-2107 - `month`: month attribute. Valid values: 1-12 - `day`: day attribute. Valid values: 1-31 - `hours`: hours attribute. Valid values: 0-23 - `mins`: minutes attribute. Valid values: 0-59 - `seconds`: seconds attribute. Valid values: 0-59
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign. File must be open for writing. See Cf_Fat_Rewrite or Cf_Fat_Append.
Example	`Cf_Fat_Set_File_Date(2005,9,30,17,41,0);`

Cf_Fat_Get_File_Date

Prototype	`void Cf_Fat_Get_File_Date(unsigned int *year, unsigned short *month, unsigned short *day, unsigned short *hours, unsigned short *mins);`
Returns	Nothing.
Description	Reads time/date attributes of currently assigned file. Parameters : - `year`: buffer to store year attribute to. Upon function execution year attribute is returned through this parameter. - `month`: buffer to store month attribute to. Upon function execution month attribute is returned through this parameter. - `day`: buffer to store day attribute to. Upon function execution day attribute is returned through this parameter. - `hours`: buffer to store hours attribute to. Upon function execution hours attribute is returned through this parameter. - `mins`: buffer to store minutes attribute to. Upon function execution minutes attribute is returned through this parameter.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign.

Example	`unsigned year;`
	`char month, day, hours, mins;`
	`...`
	`Cf_Fat_Get_File_Date(&year, &month, &day, &hours, &mins);`

Cf_Fat_Get_File_Size

Prototype	`unsigned long Cf_Fat_Get_File_Size();`
Returns	Size of the currently assigned file in bytes.
Description	This function reads size of currently assigned file in bytes.
Requires	CF card and CF library must be initialized for file operations. See Cf_Fat_Init. File must be previously assigned. See Cf_Fat_Assign.

Example	`unsigned long my_file_size;`
	`...`
	`my_file_size = Cf_Fat_Get_File_Size();`

Cf_Fat_Get_Swap_File

Prototype	`unsigned long Cf_Fat_Get_Swap_File(unsigned long sectors_cnt, char *filename, char file_attr);`
Returns	- Number of the start sector for the newly created swap file, if there was enough free space on CF card to create file of required size. - `0` - otherwise.
Description	This function is used to create a swap file of predefined name and size on the CF media. If a file with specified name already exists on the media, search for consecutive sectors will ignore sectors occupied by this file. Therefore, it is recommended to erase such file if it exists before calling this function. If it is not erased and there is still enough space for a new swap file, this function will delete it after allocating new memory space for a new swap file. The purpose of the swap file is to make reading and writing to CF media as fast as possible, by using the Cf_Read_Sector() and Cf_Write_Sector() functions directly, without potentially damaging the FAT system. Swap file can be considered as a "window" on the media where the user can freely write/read data. It's main purpose in the mikroC's library is to be used for fast data acquisition; when the time-critical acquisition has finished, the data can be re-written into a "normal" file, and formatted in the most suitable way. Parameters: - `sectors_cnt`: number of consecutive sectors that user wants the swap file to have. - `filename`: name of the file that should be assigned for file operations. The file name should be in DOS 8.3 (file_name.extension) format. The file name and extension will be automatically padded with spaces by the library if they have less than length required (i.e. "mikro.tx" -> "mikro .tx "), so the user does not have to take care of that. The file name and extension are case insensitive. The library will convert them to proper case automatically, so the user does not have to take care of that. Also, in order to keep backward compatibility with the first version of this library, file names can be entered as UPPERCASE string of 11 bytes in length with no dot character between the file name and exten sion (i.e. "MIKROELETXT" -> MIKROELE.TXT). In this case the last 3 characters of the string are considered to be file extension. - `file_attr`: file creation and attributs flags. Each bit corresponds to the appropriate file attribut:

Description

Bit	Mask	Description
0	0x01	Read Only
1	0x02	Hidden
2	0x04	System
3	0x08	Volume Label
4	0x10	Subdirectory
5	0x20	Archive
6	0x40	Device (internal use only, never found on disk)
7	0x80	Not used

Note: Long File Names (LFN) are not supported.

Requires

CF card and CF library must be initialized for file operations. See Cf_Fat_Init.

Example

```
//-------------- Try to create a swap file with archive atribute, whose size will be at least 1000 sectors.
//               If it succeeds, it sends the No. of start sector over UART
unsigned long size;
...
size = Cf_Fat_Get_Swap_File(1000, "mikroE.txt", 0x20);
if (size) {
  UART_Write(0xAA);
  UART_Write(Lo(size));
  UART_Write(Hi(size));
  UART_Write(Higher(size));
  UART_Write(Highest(size));
  UART_Write(0xAA);
} //~
```

Library Example

The following example is a simple demonstration of CF(Compact Flash) Library which shows how to use CF card data accessing routines.

```
#include "built_in.h"

// set compact flash pinout
sfr char Cf_Data_Port at PORTD;
sfr char Cf_Data_Port_Direction at DDRD;

sfr CF_RDY at PINB.B7;
sfr CF_WE  at PORTB.B6;
sfr CF_OE  at PORTB.B5;
sfr CF_CD1 at PINB.B4;
sfr CF_CE1 at PORTB.B3;
sfr CF_A2  at PORTB.B2;
sfr CF_A1  at PORTB.B1;
sfr CF_A0  at PORTB.B0;

sfr CF_RDY_direction at DDRB.B7;
sfr CF_WE_direction  at DDRB.B6;
sfr CF_OE_direction  at DDRB.B5;
sfr CF_CD1_direction at DDRB.B4;
sfr CF_CE1_direction at DDRB.B3;
sfr CF_A2_direction  at DDRB.B2;
sfr CF_A1_direction  at DDRB.B1;
sfr CF_A0_direction  at DDRB.B0;
// end of cf pinout

char
 fat_txt[20] = "FAT16 not found",
 file_contents[50] = "XX CF FAT16 library by Anton Rieckertn";

char
 filename[14] = "MIKRO00xTXT";           // File names
unsigned short
 tmp, caracter, loop, loop2;
unsigned long
 i, size;

char Buffer[512];

//-------------- Writes string to USART
void I_Write_Str(char *ostr) {
  unsigned short i;
```

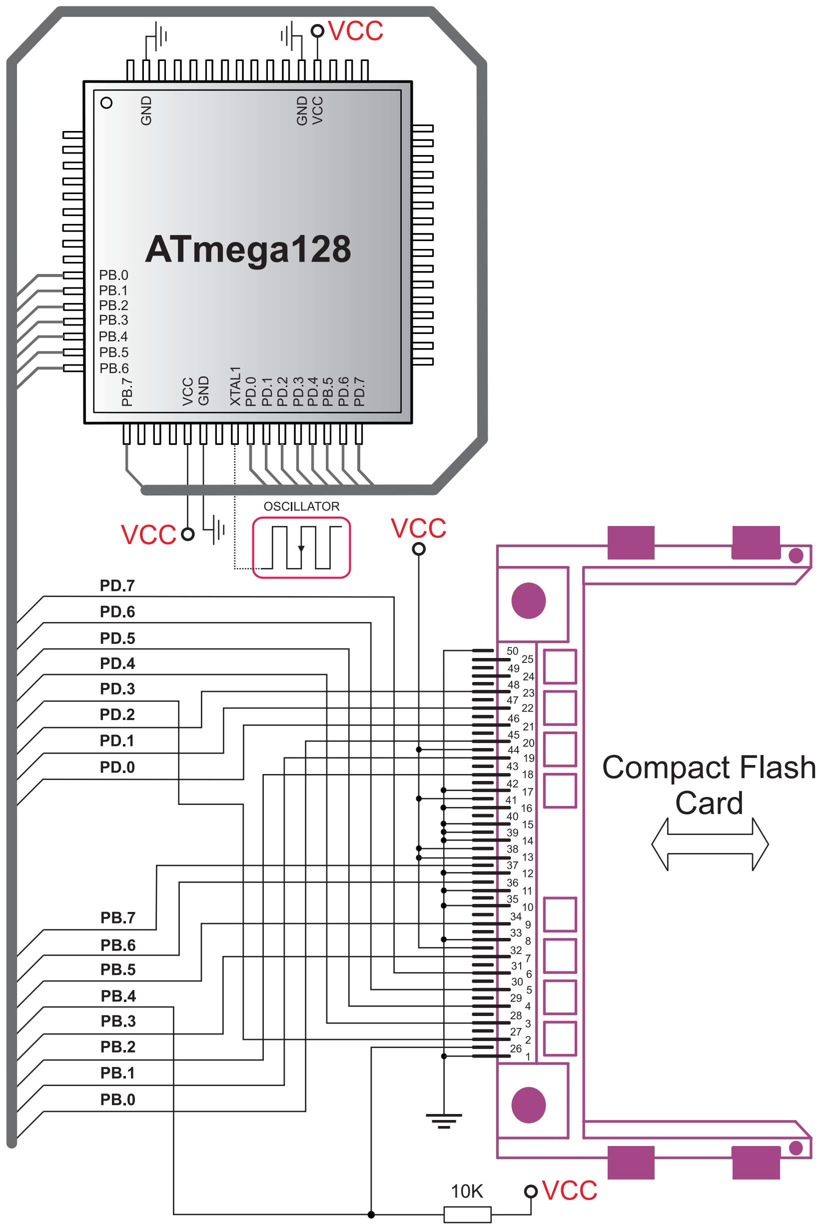
```
i = 0;
  while (ostr[ i] ) {
    UART1_Write(ostr[ i++] );
  }
  UART1_Write(0x0A);
}


//-------------- Creates new file and writes some data to it
    void M_Create_New_File() {
  filename[ 7] = 'A';
  Cf_Fat_Assign(&filename, 0x80);      // Will not find file and then
create file
  Cf_Fat_Rewrite();                      // To clear file and start
with new data
  for(loop = 1; loop <= 99; loop++) {   //  We want 5 files on the
MMC card
    file_contents[ 0] = loop / 10 + 48;
    file_contents[ 1] = loop % 10 + 48;
    Cf_Fat_Write(file_contents, 38); // write data to the assigned
file
    UART1_Write('.');
  }
}

//-------------- Creates many new files and writes data to them
void M_Create_Multiple_Files() {
  for(loop2 = 'B'; loop2 <= 'Z'; loop2++) {
    UART1_Write(loop2);
    filename[ 7] = loop2;              // set filename
    Cf_Fat_Assign(&filename, 0xA0);   // find existing file or cre-
ate a new one
    Cf_Fat_Rewrite();                    // To clear file and start
with new data
    for(loop = 1; loop <= 44; loop++) {
      file_contents[ 0] = loop / 10 + 48;
      file_contents[ 1] = loop % 10 + 48;
      Cf_Fat_Write(file_contents, 38); // write data to the assigned
file
    }
  }
}

//-------------- Opens an existing file and rewrites it
void M_Open_File_Rewrite() {
```

```
filename[ 7]  = 'C';
  Cf_Fat_Assign(&filename, 0);
  Cf_Fat_Rewrite();
  for(loop = 1; loop <= 55; loop++) {
    file_contents[ 0]  = loop / 10 + 64;
    file_contents[ 1]  = loop % 10 + 64;
    Cf_Fat_Write(file_contents, 38); // write data to the assigned
file
  }
}

//-------------- Opens an existing file and appends data to it
//                  (and alters the date/time stamp)
void M_Open_File_Append() {

      filename[ 7]  = 'B';
      Cf_Fat_Assign(&filename, 0);
      Cf_Fat_Set_File_Date(2005,6,21,10,35,0);
     Cf_Fat_Append();                                       // Prepare
file for append
     Cf_Fat_Write(" for mikroElektronika 2005n", 27);   // Write data
to assigned file
}

//-------------- Opens an existing file, reads data from it and puts
it to USART
void M_Open_File_Read() {

  filename[ 7]  = 'B';
  Cf_Fat_Assign(&filename, 0);
  Cf_Fat_Reset(&size);            // To read file, procedure returns
size of file
  for (i = 1; i <= size; i++) {
    Cf_Fat_Read(&caracter);
    UART1_Write(caracter);          // Write data to USART
  }
}

//-------------- Deletes a file. If file doesn't exist, it will first
be created
//                  and then deleted.
void M_Delete_File() {
  filename[ 7]  = 'F';
  Cf_Fat_Assign(filename, 0);
  Cf_Fat_Delete();
}
```

```
//-------------- Tests whether file exists, and if so sends its cre-
ation date
//                  and file size via USART
void M_Test_File_Exist() {
  unsigned long fsize;
  unsigned int year;
  unsigned short month, day, hour, minute;
  unsigned char outstr[12];

  filename[7] = 'B';         //uncomment this line to search for file
that DOES exists
//  filename[7] = 'F';        //uncomment this line to search for file
that DOES NOT exist
  if (Cf_Fat_Assign(filename, 0)) {
    //--- file has been found - get its date
    Cf_Fat_Get_File_Date(&year, &month, &day, &hour, &minute);
    WordToStr(year, outstr);
    I_Write_Str(outstr);
    ByteToStr(month, outstr);
    I_Write_Str(outstr);
    WordToStr(day, outstr);
    I_Write_Str(outstr);
    WordToStr(hour, outstr);
    I_Write_Str(outstr);
    WordToStr(minute, outstr);
    I_Write_Str(outstr);
    //--- get file size
    fsize = Cf_Fat_Get_File_Size();
    LongToStr((signed long)fsize, outstr);
    I_Write_Str(outstr);
  }
  else {
    //--- file was not found - signal it
    UART1_Write(0x55);
    Delay_ms(1000);
    UART1_Write(0x55);
  }
}

//-------------- Tries to create a swap file, whose size will be at
least 100
//                  sectors (see Help for details)
void M_Create_Swap_File() {
  unsigned int i;

  for(i=0; i<512; i++)
    Buffer[i] = i;
```

```
 size = Cf_Fat_Get_Swap_File(5000, "mikroE.txt", 0x20);   // see help
on this function for details

  if (size) {
    LongToStr((signed long)size, fat_txt);
    I_Write_Str(fat_txt);

    for(i=0; i<5000; i++) {
      Cf_Write_Sector(size++, Buffer);
      UART1_Write('.');
    }
  }
}


//-------------- Main. Uncomment the function(s) to test the desired
operation(s)
void main() {
    // we will use PORTC to signal test end
    DDRC   = 0xFF;
    PORTC = 0;
    //--- set up USART for the file read
    UART1_Init(19200);
    Delay_ms(100);
    // use fat16 quick format instead of init routine if a format-
ting is needed
    if(!Cf_Fat_Init()) {     // Init the FAT library
      //--- Test start
      UART1_Write('s');
      M_Create_New_File();
      M_Create_Multiple_Files();
      M_Open_File_Rewrite();
      M_Open_File_Append();
      M_Open_File_Read();
      M_Delete_File();
      M_Test_File_Exist();
      M_Create_Swap_File();
      //--- Test termination
      UART1_Write('e');
    }
    else {
     I_Write_Str(fat_txt);
    }
    //--- Test termination
    PORTC = 0x0F;
}
```

HW Connection



Pin diagram of CF memory card

EEPROM LIBRARY

EEPROM data memory is available with a number of AVR family. The mikroC PRO for AVR includes a library for comfortable work with MCU's internal EEPROM.

Note: EEPROM Library functions implementation is MCU dependent, consult the appropriate MCU datasheet for details about available EEPROM size and constrains.

Library Routines

- EEPROM_Read
- EEPROM_Write

EEPROM_Read

Prototype	`unsigned short EEPROM_Read(unsigned int address);`
Returns	Byte from the specified address.
Description	Reads data from specified `address`. Parameters : - `address`: address of the EEPROM memory location to be read.
Requires	Nothing.

Example	`unsigned int address = 2;`
	`unsigned short temp;`
	`...`
	`temp = EEPROM_Read(address);`

EEPROM_Write

Prototype	`void EEPROM_Write(unsigned address, unsigned short dData);`
Returns	Nothing.
Description	Writes wrdata to specified address. Parameters : - `address`: address of the EEPROM memory location to be written. - `wrdata`: data to be written. **Note**: Specified memory location will be erased before writing starts.
Requires	Nothing.

Example	`unsigned address = 0x732;`
	`unsigned short dData = 0x55;`
	`...`
	`EEPROM_Write(address, dData);`

Library Example

This example demonstrates using the EEPROM Library with ATMEGA16 MCU.

First, some data is written to EEPROM in byte and block mode; then the data is read from the same locations and displayed on PORTA, PORTB and PORTC.

```
char dat[32], ii;                          // Data buffer, loop variable

void main(){
   DDRA = 0xFF;                              // set PORTA as output
   DDRB = 0xFF;                              // set PORTB as output
   DDRC = 0xFF;                              // set PORTC as output

   for(ii = 31; dat[ii] = ii; ii--)      // Fill data buffer
     ;

   EEPROM_Write(2,0xAA);              // Write some data at address 2
   EEPROM_Write(0x732,0x55);      // Write some data at address 0x732
   EEPROM_Write_Block(0x100,dat);        // Write 32 bytes block at
address 0x100

   Delay_ms(1000);                       // Blink PORTA and PORTB diodes
   PORTA = 0xFF;                         //   to indicate reading start
   PORTB = 0xFF;
   Delay_ms(1000);
   PORTA = 0x00;
   PORTB = 0x00;
   Delay_ms(1000);

   PORTA = EEPROM_Read(2);                 // Read data from address 2
and display it on PORTA
   PORTB = EEPROM_Read(0x732);              // Read data from address
0x732 and display it on PORTB
   Delay_ms(1000);

   for(ii = 0; ii < 32; ii++) {            // Read 32 bytes block from
address 0x100
     PORTC = EEPROM_Read(0x100+ii);     //   and display data on PORTC
      Delay_ms(100);
     }
}
```

FLASH MEMORY LIBRARY

This library provides routines for accessing microcontroller Flash memory. Note that prototypes differ for MCU to MCU due to the amount of Flash memory.

Note: Due to the AVR family flash specifics, flash library is MCU dependent. Since some AVR MCU's have more or less than 64kb of Flash memory, prototypes may be different from chip to chip.
Please refer to datasheet before using flash library.

Note: Currently, Write operations are not supported. See mikroC PRO for AVR specifics for details.

Library Routines

- FLASH_Read_Byte
- FLASH_Read_Bytes
- FLASH_Read_Word
- FLASH_Read_Words

FLASH_Read_Byte

Prototype	`// for MCUs with 64kb of Flash memory or less`
	`char FLASH_Read_Byte(unsigned int address);`
	
	`// for MCUs with Flash memory larger than 64kb`
	`char FLASH_Read_Byte(unsigned long address);`

Returns	Returns data byte from Flash memory.
Description	Reads data from the specified `address` in Flash memory.
Requires	Nothing.

Example	`// for MCUs with Flash memory larger than 64kb`
	`unsigned long tmp;`
	`...`
	`tmp = Flash_Read(0x0D00);`
	`...`

FLASH_Read_Bytes

Prototype	`// for MCUs with 64kb of Flash memory or less`
	`void FLASH_Read_Bytes(unsigned int address, char *buffer, unsigned NoBytes);`
	
	`// for MCUs with Flash memory larger than 64kb`
	`void FLASH_Read_Bytes(unsigned long address, char *buffer, unsigned NoBytes);`

Returns	Nothing.
Description	Reads number of data bytes defined by `NoBytes` parameter from the specified `address` in Flash memory to varibale pointed by `buffer`.
Requires	Nothing.

Example	`// for MCUs with Flash memory larger than 64kb`
	`const long F_ADDRESS = 0x200;`
	`unsigned int dat_buff[32];`
	`...`
	`FLASH_Read_Bytes(F_ADDRESS,dat_buff, 64);`

FLASH_Read_Word

Prototype	`// for MCUs with 64kb of Flash memory or less`
	`char FLASH_Read_Word(unsigned int address);`
	
	`// for MCUs with Flash memory larger than 64kb`
	`char FLASH_Read_Word(unsigned long address);`

Returns	Returns data word from Flash memory.
Description	Reads data from the specified address in Flash memory.
Requires	Nothing.

Example	`// for MCUs with Flash memory larger than 64kb`
	`unsigned long tmp;`
	`...`
	`tmp = Flash_Read(0x0D00);`
	`...`

FLASH_Read_Words

Prototype	`// for MCUs with 64kb of Flash memory or less`
	`void FLASH_Read_wWrds(unsigned int address, char *buffer, unsigned NoWords);`
	
	`// for MCUs with Flash memory larger than 64kb`
	`void FLASH_Read_Words(unsigned long address, char *buffer, unsigned NoWords);`

Returns	Nothing.
Description	Reads number of data words defined by NoWords parameter from the specified address in Flash memory to varibale pointed by buffer.
Requires	Nothing.

Example	`// for MCUs with Flash memory larger than 64kb`
	`const long F_ADDRESS = 0x200;`
	`unsigned int dat_buff[32];`
	`...`
	`FLASH_Read_Words(F_ADDRESS,dat_buff, 32);`

Library Example

The example demonstrates simple write to the flash memory for AVR, then reads the data and displays it on PORTB and PORTD.

```
const long F_ADDRESS = 0x200;


const unsigned int data_[32] = {                    // constant table
  0x0000,0x0001,0x0002,0x0003,0x0004,0x0005,0x0006,0x0007,
  0x0008,0x0009,0x000A,0x000B,0x000C,0x000D,0x000E,0x000F,
  0x0000,0x0100,0x0200,0x0300,0x0400,0x0500,0x0600,0x0700,
  0x0800,0x0900,0x0A00,0x0B00,0x0C00,0x0D00,0x0E00,0x0F00,
 } absolute 0x200;

char i;
unsigned int word;
unsigned int dat_buff[32];

void main() {
  DDRD = 0xFF;                        // set direction to be output
  DDRB = 0xFF;                        // set direction to be output
  word = data_[0];                           //  link const table
```

```
  for (i = 0; i<64 ; i+=2)             // reading 32 words in loop
    {
      word  = FLASH_Read_Word(F_ADDRESS + i);    //  demonstration of reading single word
       PORTD = word;                        //  output low byte to PORTD
      PORTB = word >> 8;              //  output higher byte to PORTB
       Delay_ms(200);
    }
  i = 0;
  while ( i < 64 )                    //  reading 64 bytes in loop
    {
       PORTD = FLASH_Read_Byte(F_ADDRESS + i++);    //  demonstration of reading single byte
       PORTB = FLASH_Read_Byte(F_ADDRESS + i++);    //  demonstration of reading single byte
       Delay_ms(200);
    }

  FLASH_Read_Bytes(F_ADDRESS,dat_buff, 64);     //  demonstration of reading 64 bytes
  for (i = 0; i<32 ; i++)
    {

       PORTD = dat_buff[ i] ;              //  output low byte to PORTD
      PORTB = dat_buff[ i]  >> 8;       //  output higher byte to PORTB
       Delay_ms(200);
    }

 FLASH_Read_Words(F_ADDRESS,dat_buff, 32);      //  demonstration of reading 64 bytes
 for (i = 0; i<32 ; i++)
  {
    PORTD = dat_buff[ i] ;                 //  output low byte to PORTD
    PORTB = dat_buff[ i]  >> 8;         //  output higher byte to PORTB
    Delay_ms(200);
  }
}
```

GRAPHIC LCD LIBRARY

The mikroC PRO for AVR provides a library for operating Graphic LCD 128x64 (with commonly used Samsung KS108/KS107 controller).

For creating a custom set of Glcd images use Glcd Bitmap Editor Tool.

External dependencies of Graphic LCD Library

The following variables must be defined in all projects using Graphic LCD Library:	Description :	Example :
`extern sfr char GLCD_DataPort;`	Glcd Data Port.	`char GLCD_DataPort at PORTC;`
`extern sfr char GLCD_DataPort_Direction;`	Direction of the Glcd Data Port.	`char GLCD_DataPort_Direction at DDRC;`
`extern sfr sbit GLCD_CS1;`	Chip Select 1 line.	`sbit GLCD_CS1 at PORTD.B2;`
`extern sfr sbit GLCD_CS2;`	Chip Select 2 line.	`sbit GLCD_CS2 at PORTD.B3;`
`extern sfr sbit GLCD_RS;`	Register select line.	`sbit GLCD_RS at PORTD.B4;`
`extern sfr sbit GLCD_RW;`	Read/Write line.	`sbit GLCD_RW at PORTD.B5;`
`extern sfr sbit GLCD_EN;`	Enable line.	`sbit GLCD_EN at PORTD.B6;`
`extern sfr sbit GLCD_RST;`	Reset line.	`sbit GLCD_RST at PORTD.B7;`
`extern sfr sbit GLCD_CS1_Direction;`	Direction of the Chip Select 1 pin.	`sbit LCD_CS1_Direction at DDRD.B2;`
`extern sfr sbit GLCD_CS2_Direction;`	Direction of the Chip Select 2 pin.	`sbit LCD_CS2_Direction at DDRD.B3;`
`extern sfr sbit GLCD_RS_Direction;`	Direction of the Register select pin.	`sbit GLCD_RS_Direction at DDRD.B4;`
`extern sfr sbit GLCD_RW_Direction;`	Direction of the Read/Write pin.	`sbit GLCD_RW_Direction at DDRD.B5;`
`extern sfr sbit GLCD_EN_Direction;`	Direction of the Enable pin.	`sbit GLCD_EN_Direction at DDRD.B6;`
`extern sfr sbit GLCD_RST_Direction;`	Direction of the Reset pin.	`sbit LCD_RST_Direction at DDRD.B7;`

Library Routines

Basic routines:

- Glcd_Init
- Glcd_Set_Side
- Glcd_Set_X
- Glcd_Set_Page
- Glcd_Read_Data
- Glcd_Write_Data

Advanced routines:

- Glcd_Fill
- Glcd_Dot
- Glcd_Line
- Glcd_V_Line
- Glcd_H_Line
- Glcd_Rectangle
- Glcd_Box
- Glcd_Circle
- Glcd_Set_Font
- Glcd_Write_Char
- Glcd_Write_Text
- Glcd_Image

Glcd_Init

Prototype	`void Glcd_Init();`
Returns	Nothing.
Description	Initializes the Glcd module. Each of the control lines is both port and pin configurable, while data lines must be on a single port (pins <0:7>).
Requires	Global variables : - `GLCD_CS1` : Chip select 1 signal pin - `GLCD_CS2` : Chip select 2 signal pin - `GLCD_RS` : Register select signal pin - `GLCD_RW` : Read/Write Signal pin - `GLCD_EN` : Enable signal pin - `GLCD_RST` : Reset signal pin - `GLCD_DataPort` : Data port - `GLCD_CS1_Direction` : Direction of the Chip select 1 pin - `GLCD_CS2_Direction` : Direction of the Chip select 2 pin - `GLCD_RS_Direction` : Direction of the Register select signal pin - `GLCD_RW_Direction` : Direction of the Read/Write signal pin - `GLCD_EN_Direction` : Direction of the Enable signal pin - `GLCD_RST_Direction` : Direction of the Reset signal pin - `GLCD_DataPort_Direction` : Direction of the Data port must be defined before using this function.
Example	see below

Example

```
// glcd pinout settings
char GLCD_DataPort at PORTC;
char GLCD_DataPort_Direction at DDRC;

sbit GLCD_CS1 at PORTD.B2;
sbit GLCD_CS2 at PORTD.B3;
sbit GLCD_RS  at PORTD.B4;
sbit GLCD_RW  at PORTD.B5;
sbit GLCD_RST at PORTD.B6;
sbit GLCD_EN  at PORTD.B7;

sbit GLCD_CS1_Direction at DDRD.B2;
sbit GLCD_CS2_Direction at DDRD.B3;
sbit GLCD_RS_Direction at DDRD.B4;
sbit GLCD_RW_Direction at DDRD.B5;
sbit GLCD_EN_Direction at DDRD.B6;
sbit GLCD_RST_Direction at DDRD.B7;
...

Glcd_Init();
```

Glcd_Set_Side

Prototype	`void Glcd_Set_Side(unsigned short x_pos);`
Returns	Nothing.
Description	Selects Glcd side. Refer to the Glcd datasheet for detailed explaination. Parameters : - `x_pos`: position on x-axis. Valid values: 0..127 The parameter `x_pos` specifies the Glcd side: values from 0 to 63 specify the left side, values from 64 to 127 specify the right side. **Note**: For side, x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized, see Glcd_Init routine.

Example	The following two lines are equivalent, and both of them select the left side of Glcd:
	
	`Glcd_Select_Side(0);`
	`Glcd_Select_Side(10);`

Glcd_Set_X

Prototype	`void Glcd_Set_X(unsigned short x_pos);`
Returns	Nothing.
Description	Sets x-axis position to `x_pos` dots from the left border of Glcd within the selected side. Parameters : - `x_pos`: position on x-axis. Valid values: 0..63 **Note**: For side, x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`Glcd_Set_X(25);`

Glcd_Set_Page

Prototype	`void Glcd_Set_Page(unsigned short page);`
Returns	Nothing.
Description	Selects page of the Glcd. Parameters : - `page`: page number. Valid values: 0..7 **Note**: For side, x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`Glcd_Set_Page(5);`

Glcd_Read_Data

Prototype	`unsigned short Glcd_Read_Data();`
Returns	One byte from Glcd memory.
Description	Reads data from from the current location of Glcd memory and moves to the next location.
Requires	Glcd needs to be initialized, see Glcd_Init routine. Glcd side, x-axis position and page should be set first. See functions Glcd_Set_Side, Glcd_Set_X, and Glcd_Set_Page.

Example	`unsigned short data;`
	`...`
	`data = Glcd_Read_Data();`

Glcd_Write_Data

Prototype	`void Glcd_Write_Data(unsigned short ddata);`
Returns	Nothing.
Description	Writes one byte to the current location in Glcd memory and moves to the next location. Parameters : - `ddata`: data to be written
Requires	Glcd needs to be initialized, see Glcd_Init routine. Glcd side, x-axis position and page should be set first. See functions Glcd_Set_Side, Glcd_Set_X, and Glcd_Set_Page.

Example	`unsigned short data;`
	`...`
	`Glcd_Write_Data(data);`

Glcd_Fill

Prototype	`void Glcd_Fill(unsigned short pattern);`
Returns	Nothing.
Description	Fills Glcd memory with the byte `pattern`. Parameters : - `pattern`: byte to fill Glcd memory with To clear the Glcd screen, use `Glcd_Fill(0)`. To fill the screen completely, use `Glcd_Fill(0xFF)`.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Clear screen` `Glcd_Fill(0);`

Glcd_Dot

Prototype	`void Glcd_Dot(unsigned short x_pos, unsigned short y_pos, unsigned short color);`
Returns	Nothing.
Description	Draws a dot on Glcd at coordinates (`x_pos, y_pos`). Parameters : - `x_pos`: x position. Valid values: 0..127 - `y_pos`: y position. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines a dot state: 0 clears dot, 1 puts a dot, and 2 inverts dot state. **Note**: For x and y axis layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Invert the dot in the upper left corner` `Glcd_Dot(0, 0, 2);`

Glcd_Line

Prototype	`void Glcd_Line(int x_start, int y_start, int x_end, int y_end, unsigned short color);`
Returns	Nothing.
Description	Draws a line on Glcd. Parameters : - `x_start`: x coordinate of the line start. Valid values: 0..127 - `y_start`: y coordinate of the line start. Valid values: 0..63 - `x_end`: x coordinate of the line end. Valid values: 0..127 - `y_end`: y coordinate of the line end. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the line color: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw a line between dots (0,0) and (20,30)` `Glcd_Line(0, 0, 20, 30, 1);`

Glcd_V_Line

Prototype	`void Glcd_V_Line(unsigned short y_start, unsigned short y_end, unsigned short x_pos, unsigned short color);`
Returns	Nothing.
Description	Draws a vertical line on Glcd. Parameters : - `y_start`: y coordinate of the line start. Valid values: 0..63 - `y_end`: y coordinate of the line end. Valid values: 0..63 - `x_pos`: x coordinate of vertical line. Valid values: 0..127 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the line color: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw a vertical line between dots (10,5) and (10,25)` `Glcd_V_Line(5, 25, 10, 1);`

Glcd_H_Line

Prototype	`void Glcd_H_Line(unsigned short x_start, unsigned short x_end, unsigned short y_pos, unsigned short color);`
Returns	Nothing.
Description	Draws a horizontal line on Glcd. Parameters : - `x_start`: x coordinate of the line start. Valid values: 0..127 - `x_end`: x coordinate of the line end. Valid values: 0..127 - `y_pos`: y coordinate of horizontal line. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the line color: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw a horizontal line between dots (10,20) and (50,20)` `Glcd_H_Line(10, 50, 20, 1);`

Glcd_Rectangle

Prototype	`void Glcd_Rectangle(unsigned short x_upper_left, unsigned short y_upper_left, unsigned short x_bottom_right, unsigned short y_bottom_right, unsigned short color);`
Returns	Nothing.
Description	Draws a rectangle on Glcd. Parameters : - `x_upper_left`: x coordinate of the upper left rectangle corner. Valid values: 0..127 - `y_upper_left`: y coordinate of the upper left rectangle corner. Valid values: 0..63 - `x_bottom_right`: x coordinate of the lower right rectangle corner. Valid values: 0..127 - `y_bottom_right`: y coordinate of the lower right rectangle corner. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the rectangle border: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw a rectangle between dots (5,5) and (40,40)` `Glcd_Rectangle(5, 5, 40, 40, 1);`

Glcd_Box

Prototype	`void Glcd_Box(unsigned short x_upper_left, unsigned short y_upper_left, unsigned short x_bottom_right, unsigned short y_bottom_right, unsigned short color);`
Returns	Nothing.
Description	Draws a box on Glcd. Parameters : - `x_upper_left`: x coordinate of the upper left box corner. Valid values: 0..127 - `y_upper_left`: y coordinate of the upper left box corner. Valid values: 0..63 - `x_bottom_right`: x coordinate of the lower right box corner. Valid values: 0..127 - `y_bottom_right`: y coordinate of the lower right box corner. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the box fill: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw a box between dots (5,15) and (20,40)` `Glcd_Box(5, 15, 20, 40, 1);`

Glcd_Circle

Prototype	`void Glcd_Circle(int x_center, int y_center, int radius, unsigned short color);`
Returns	Nothing.
Description	Draws a circle on Glcd. Parameters : - `x_center`: x coordinate of the circle center. Valid values: 0..127 - `y_center`: y coordinate of the circle center. Valid values: 0..63 - `radius`: radius size - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the circle line: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw a circle with center in (50,50) and radius=10` `Glcd_Circle(50, 50, 10, 1);`

Glcd_Set_Font

Prototype	`void Glcd_Set_Font(const char *activeFont, unsigned short aFontWidth, unsigned short aFontHeight, unsigned int aFontOffs);`
Returns	Nothing.
Description	Sets font that will be used with Glcd_Write_Char and Glcd_Write_Text routines. Parameters : - `activeFont`: font to be set. Needs to be formatted as an array of char - `aFontWidth`: width of the font characters in dots. - `aFontHeight`: height of the font characters in dots. - `aFontOffs`: number that represents difference between the mikroC PRO for AVR character set and regular ASCII set (eg. if 'A' is 65 in ASCII character, and 'A' is 45 in the mikroC PRO for AVR character set, aFontOffs is 20). Demo fonts supplied with the library have an offset of 32, which means that they start with space. The user can use fonts given in the file "__Lib_GLCDFonts" file located in the Uses folder or create his own fonts.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Use the custom 5x7 font "myfont" which starts with space (32):` `Glcd_Set_Font(myfont, 5, 7, 32);`

Glcd_Write_Char

Prototype	`void Glcd_Write_Char(unsigned short chr, unsigned short x_pos, unsigned short page_num, unsigned short color);`
Returns	Nothing.
Description	Prints character on the Glcd. Parameters : - `chr`: character to be written - `x_pos`: character starting position on x-axis. Valid values: 0..(127-FontWidth) - `page_num`: the number of the page on which character will be written. Valid values: 0..7 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the character: 0 white, 1 black, and 2 inverts each dot. **Note**: For x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized, see Glcd_Init routine. Use Glcd_Set_Font to specify the font for display; if no font is specified, then default 5x8 font supplied with the library will be used.
Example	`// Write character 'C' on the position 10 inside the page 2:` `Glcd_Write_Char('C', 10, 2, 1);`

Glcd_Write_Text

Prototype	`void Glcd_Write_Text(char *text, unsigned short x_pos, unsigned short page_num, unsigned short color);`
Returns	Nothing.
Description	Prints text on Glcd. Parameters : - `text`: text to be written - `x_pos`: text starting position on x-axis. - `page_num`: the number of the page on which text will be written. Valid values: 0..7 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the text: 0 white, 1 black, and 2 inverts each dot. **Note**: For x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized, see Glcd_Init routine. Use Glcd_Set_Font to specify the font for display; if no font is specified, then default 5x8 font supplied with the library will be used.
Example	`// Write text "Hello world!" on the position 10 inside the page 2:` `Glcd_Write_Text("Hello world!", 10, 2, 1);`

Glcd_Image

Prototype	`void Glcd_Image(code const unsigned short *image);`
Returns	Nothing.
Description	Displays bitmap on Glcd. Parameters : - `image`: image to be displayed. Bitmap array must be located in code memory. Use the mikroC PRO for AVR integrated Glcd Bitmap Editor to convert image to a constant array suitable for displaying on Glcd.
Requires	Glcd needs to be initialized, see Glcd_Init routine.
Example	`// Draw image my_image on Glcd` `Glcd_Image(my_image);`

Library Example

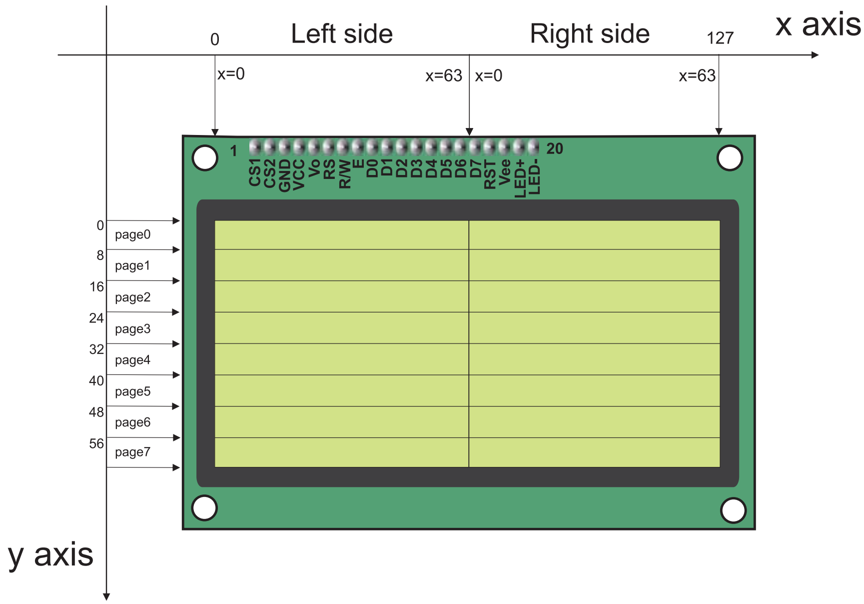
The following example demonstrates routines of the Glcd library: initialization, clear(pattern fill), image displaying, drawing lines, circles, boxes and rectangles, text displaying and handling.

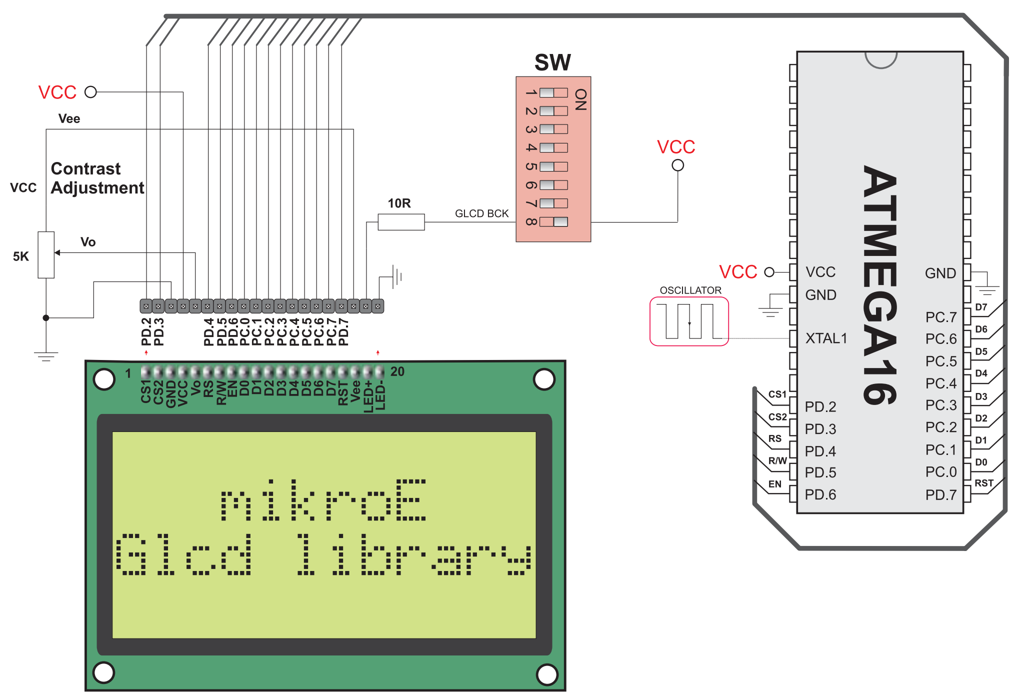
```
//Declarations------------------------------------------------------------------
-const code char truck_bmp[1024];
//---------------------------------------------------------------------end-declara-
tions

// Glcd module connections
char GLCD_DataPort at PORTC;
char GLCD_DataPort_Direction at DDRC;

sbit GLCD_CS1 at PORTD.B2;
sbit GLCD_CS2 at PORTD.B3;
sbit GLCD_RS  at PORTD.B4;
sbit GLCD_RW  at PORTD.B5;
sbit GLCD_EN  at PORTD.B6;
sbit GLCD_RST at PORTD.B7;

sbit GLCD_CS1_Direction at DDRD.B2;
sbit GLCD_CS2_Direction at DDRD.B3;
sbit GLCD_RS_Direction  at DDRD.B4;
sbit GLCD_RW_Direction  at DDRD.B5;
sbit GLCD_EN_Direction  at DDRD.B6;
sbit GLCD_RST_Direction at DDRD.B7;
// End Glcd module connections
```

```
void delay2S(){                             // 2 seconds delay function
  Delay_ms(2000);
}

void main() {
  unsigned short ii;
  char *someText;

  Glcd_Init();                                  // Initialize Glcd
  Glcd_Fill(0x00);                              // Clear Glcd

  while(1) {
    Glcd_Image(truck_bmp);                      // Draw image
    delay2S(); delay2S();

    Glcd_Fill(0x00);                            // Clear Glcd

    Glcd_Box(62,40,124,56,1);                   // Draw box
    Glcd_Rectangle(5,5,84,35,1);                // Draw rectangle
    Glcd_Line(0, 0, 127, 63, 1);                // Draw line
    delay2S();

    for(ii = 5; ii < 60; ii+=5 ){               // Draw horizontal and
vertical lines
      Delay_ms(250);
      Glcd_V_Line(2, 54, ii, 1);
      Glcd_H_Line(2, 120, ii, 1);
    }

    delay2S();

    Glcd_Fill(0x00);                            // Clear Glcd

     Glcd_Set_Font(Character8x7, 8, 7, 32);     // Choose font, see
__Lib_GLCDFonts.c in Uses folder
    Glcd_Write_Text("mikroE", 1, 7, 2);        // Write string

    for (ii = 1; ii <= 10; ii++)                // Draw circles
      Glcd_Circle(63,32, 3*ii, 1);
    delay2S();

    Glcd_Box(12,20, 70,57, 2);                  // Draw box
    delay2S();

    Glcd_Fill(0xFF);                            // Fill Glcd
```

```
    Glcd_Set_Font(Character8x7, 8, 7, 32);   // Change font
    someText = "8x7 Font";
    Glcd_Write_Text(someText, 5, 0, 2);      // Write string
    Glcd_Write_Text(someText, 5, 1, 2);      // Write string
    delay2S();

    Glcd_Set_Font(System3x5, 3, 5, 32);      // Change font
    someText = "3X5 CAPITALS ONLY";
    Glcd_Write_Text(someText, 60, 5, 2);     // Write string
    Glcd_Write_Text(someText, 60, 6, 2);     // Write string
    delay2S();

    Glcd_Set_Font(font5x7, 5, 7, 32);        // Change font
    someText = "5x7 Font";
    Glcd_Write_Text(someText, 5, 5, 2);      // Write string
    Glcd_Write_Text(someText, 5, 6, 2);      // Write string
    delay2S();

    Glcd_Set_Font(FontSystem5x7_v2, 5, 7, 32); // Change font
    someText = "5x7 Font (v2)";
    Glcd_Write_Text(someText, 5, 3, 2);      // Write string
    Glcd_Write_Text(someText, 5, 2, 2);      // Write string
    delay2S();
  }
}
```

HW Connection





Glcd HW connection

KEYPAD LIBRARY

The mikroC PRO for AVR provides a library for working with 4x4 keypad. The library routines can also be used with 4x1, 4x2, or 4x3 keypad. For connections explanation see schematic at the bottom of this page.

Note: Since sampling lines for AVR MCUs are activated by logical zero Keypad Library can not be used with hardwares that have protective diodes connected with anode to MCU side, such as mikroElektronika's Keypad extra board HW.Rev v1.20

External dependencies of Keypad Library

The following variable must be defined in all projects using Keypad Library:	Description :	Example :
`extern sfr char keypadPort;`	Keypad Port.	`sfr char keypadPort at PORTB;`
`extern sfr char keypadPort_Direction;`	Direction of the Keypad Port.	`sfr char keypadPort_Direction at DDRB;`

Library Routines

- Keypad_Init
- Keypad_Key_Press
- Keypad_Key_Click

Keypad_Init

<table>
<tr><td>Prototype</td><td><code>void Keypad_Init(void);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initializes port for working with keypad.</td></tr>
<tr><td>Requires</td><td>Global variables :
keypadPort - Keypad port
keypadPort_Direction - Direction of the Keypad port
must be defined before using this function.</td></tr>
<tr><td>Example</td><td><pre>
// Initialize PORTB for communication with keypad
sfr char keypadPort at PORTB;

// Port direction
sfr char keypadPort_Direction at DDRB;

// LCD module connections
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;
sbit LCD_D4 at PORTD.B4;
sbit LCD_D5 at PORTD.B5;
sbit LCD_D6 at PORTD.B6;
sbit LCD_D7 at PORTD.B7;

sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D4_Direction at DDRD.B4;
sbit LCD_D5_Direction at DDRD.B5;
sbit LCD_D6_Direction at DDRD.B6;
sbit LCD_D7_Direction at DDRD.B7;
// End LCD module connections
...
Keypad_Init();
</pre></td></tr>
</table>

Keypad_Key_Press

Prototype	`char Keypad_Key_Press(void);`
Returns	The code of a pressed key (1..16). If no key is pressed, returns 0.
Description	Reads the key from keypad when key gets pressed.
Requires	Port needs to be initialized for working with the Keypad library, see Keypad_Init.

Example	`char kp;`
	`...`
	`kp = Keypad_Key_Press();`

Keypad_Key_Click

Prototype	`char Keypad_Key_Click(void);`
Returns	The code of a clicked key (1..16). If no key is clicked, returns 0.
Description	Call to `Keypad_Key_Click` is a blocking call: the function waits until some key is pressed and released. When released, the function returns 1 to 16, depending on the key. If more than one key is pressed simultaneously the function will wait until all pressed keys are released. After that the function will return the code of the first pressed key.
Requires	Port needs to be initialized for working with the Keypad library, see Keypad_Init.

Example	`char kp;`
	`...`
	`kp = Keypad_Key_Click();`

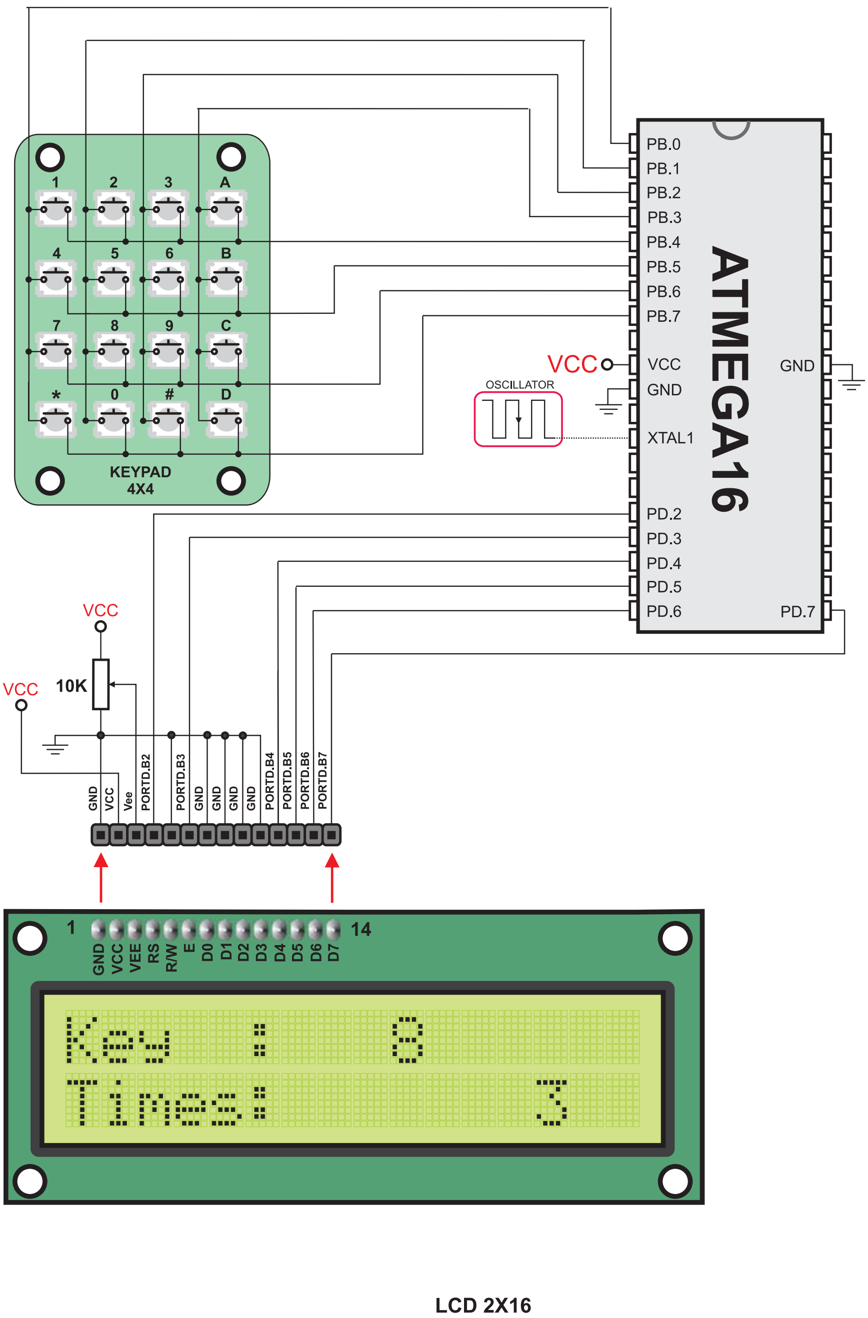
Library Example

This is a simple example of using the Keypad Library. It supports keypads with 1..4 rows and 1..4 columns. The code being returned by Keypad_Key_Click() function is in range from 1..16. In this example, the code returned is transformed into ASCII codes [0..9,A..F] and displayed on LCD. In addition, a small single-byte counter displays in the second LCD row number of key presses.

```
unsigned short kp, cnt, oldstate = 0;
char txt[ 6] ;

// Keypad module connections
sfr char  keypadPort at PORTB;
sfr char  keypadPort_Direction at DDRB;
// End Keypad module connections

// LCD module connections
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;
sbit LCD_D4 at PORTD.B4;
sbit LCD_D5 at PORTD.B5;
sbit LCD_D6 at PORTD.B6;
sbit LCD_D7 at PORTD.B7;

sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D4_Direction at DDRD.B4;
sbit LCD_D5_Direction at DDRD.B5;
sbit LCD_D6_Direction at DDRD.B6;
sbit LCD_D7_Direction at DDRD.B7;
// End LCD module connections

void main() {
  cnt = 0;                                       // Reset counter
  Keypad_Init();                                // Initialize Keypad
  Lcd_Init();                                    // Initialize LCD
  Lcd_Cmd(LCD_CLEAR);                           // Clear display
  Lcd_Cmd(LCD_CURSOR_OFF);                     // Cursor off
  Lcd_Out(1, 1, "1");
  Lcd_Out(1, 1, "Key  :");              // Write message text on LCD
  Lcd_Out(2, 1, "Times:");

  do {
    kp = 0;                                // Reset key code variable
    // Wait for key to be pressed and released
    do
      //kp = Keypad_Key_Press();    // Store key code in kp variable
      kp = Keypad_Key_Click();     // Store key code in kp variable
    while  (!kp);
   // Prepare value for output, transform key to it's ASCII value
    switch (kp) {
    switch (kp) {
      //case 10: kp = 42; break;  // '*'    // Uncomment this block
for keypad4x3
      //case 11: kp = 48; break;  // '0'
      //case 12: kp = 35; break;  // '#'
      //default: kp += 48;
```

```
      case  1: kp = 49; break; // 1         // Uncomment this block
for keypad4x4
      case  2: kp = 50; break; // 2
      case  3: kp = 51; break; // 3
      case  4: kp = 65; break; // A
      case  5: kp = 52; break; // 4
      case  6: kp = 53; break; // 5
      case  7: kp = 54; break; // 6
      case  8: kp = 66; break; // B
      case  9: kp = 55; break; // 7
      case 10: kp = 56; break; // 8
      case 11: kp = 57; break; // 9
      case 12: kp = 67; break; // C
      case 13: kp = 42; break; // *
      case 14: kp = 48; break; // 0
      case 15: kp = 35; break; // #
      case 16: kp = 68; break; // D

    }

    if (kp != oldstate) {       // Pressed key differs from previous
      cnt = 1;
      oldstate = kp;
      }
    else {                      // Pressed key is same as previous
      cnt++;
      }

    Lcd_Chr(1, 10, kp);          // Print key ASCII value on LCD

    if (cnt == 255) {            // If counter varialble overflow
      cnt = 0;
      Lcd_Out(2, 10, "   ");
      }

    WordToStr(cnt, txt);        // Transform counter value to string
    Lcd_Out(2, 10, txt);           // Display counter value on LCD
  } while (1);
}
```

HW Connection



4x4 Keypad connection scheme

LCD LIBRARY

The mikroC PRO for AVR provides a library for communication with Lcds (with HD44780 compliant controllers) through the 4-bit interface. An example of Lcd connections is given on the schematic at the bottom of this page.

For creating a set of custom Lcd characters use Lcd Custom Character Tool.

External dependencies of Lcd Library

The following variables must be defined in all projects using Lcd Library :	Description :	Example :
`extern sfr sbit LCD_RS:`	Register Select line.	`sbit LCD_RS at PORTD.B2;`
`extern sfr sbit LCD_EN:`	Enable line.	`sbit LCD_EN at PORTD.B3;`
`extern sfr sbit LCD_D7;`	Data 7 line.	`sbit LCD_D7 at PORTD.B4;`
`extern sfr sbit LCD_D6;`	Data 6 line.	`sbit LCD_D6 at PORTD.B5;`
`extern sfr sbit LCD_D5;`	Data 5 line.	`sbit LCD_D5 at PORTD.B6;`
`extern sfr sbit LCD_D4;`	Data 4 line.	`sbit LCD_D4 at PORTD.B7;`
`extern sfr sbit LCD_RS_Direction;`	Register Select direction pin.	`sbit LCD_RS_Direction at DDRD.B2;`
`extern sfr sbit LCD_EN_Direction;`	Enable direction pin.	`sbit LCD_EN_Direction at DDRD.B3;`
`extern sfr sbit LCD_D7_Direction;`	Data 7 direction pin.	`sbit LCD_D7_Direction at DDRD.B4;`
`extern sfr sbit LCD_D6_Direction;`	Data 6 direction pin.	`sbit LCD_D6_Direction at DDRD.B5;`
`extern sfr sbit LCD_D5_Direction;`	Data 5 direction pin.	`sbit LCD_D5_Direction at DDRD.B6;`
`extern sfr sbit LCD_D4_Direction;`	Data 4 direction pin.	`sbit LCD_D4_Direction at DDRD.B7;`

Library Routines

- Lcd_Init
- Lcd_Out
- Lcd_Out_Cp
- Lcd_Chr
- Lcd_Chr_Cp
- Lcd_Cmd

Lcd_Init

Prototype	`void Lcd_Init();`
Returns	Nothing.
Description	Initializes Lcd module.
Requires	Global variables: - `LCD_D7`: Data bit 7 - `LCD_D6`: Data bit 6 - `LCD_D5`: Data bit 5 - `LCD_D4`: Data bit 4 - `LCD_RS`: Register Select (data/instruction) signal pin - `LCD_EN`: Enable signal pin - `LCD_D7_Direction`: Direction of the Data 7 pin - `LCD_D6_Direction`: Direction of the Data 6 pin - `LCD_D5_Direction`: Direction of the Data 5 pin - `LCD_D4_Direction`: Direction of the Data 4 pin - `LCD_RS_Direction`: Direction of the Register Select pin - `LCD_EN_Direction`: Direction of the Enable signal pin must be defined before using this function.
Example	see below

```
// Lcd pinout settings
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;
sbit LCD_D7 at PORTD.B4;
sbit LCD_D6 at PORTD.B5;
sbit LCD_D5 at PORTD.B6;
sbit LCD_D4 at PORTD.B7;

// Pin direction
sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D7_Direction at DDRD.B4;
sbit LCD_D6_Direction at DDRD.B5;
sbit LCD_D5_Direction at DDRD.B6;
sbit LCD_D4_Direction at DDRD.B7;
...

Lcd_Init();
```

Lcd_Out

Prototype	`void Lcd_Out(char row, char column, char *text);`
Returns	Nothing.
Description	Prints text on Lcd starting from specified position. Both string variables and literals can be passed as a text. Parameters : - `row`: starting position row number - `column`: starting position column number - `text`: text to be written
Requires	The Lcd module needs to be initialized. See Lcd_Init routine.
Example	`// Write text "Hello!" on Lcd starting from row 1, column 3:` `Lcd_Out(1, 3, "Hello!");`

Lcd_Out_Cp

Prototype	`void Lcd_Out_Cp(char *text);`
Returns	Nothing.
Description	Prints text on Lcd at current cursor position. Both string variables and literals can be passed as a text. Parameters : - `text`: text to be written
Requires	The Lcd module needs to be initialized. See Lcd_Init routine.
Example	`// Write text "Here!" at current cursor position:` `Lcd_Out_Cp("Here!");`

Lcd_Chr

Prototype	`void Lcd_Chr(char row, char column, char out_char);`
Returns	Nothing.
Description	Prints character on Lcd at specified position. Both variables and literals can be passed as a character. Parameters : - `row`: writing position row number - `column`: writing position column number - `out_char`: character to be written
Requires	The Lcd module needs to be initialized. See Lcd_Init routine.
Example	`// Write character "i" at row 2, column 3:` `Lcd_Chr(2, 3, 'i');`

Lcd_Chr_Cp

Prototype	`void Lcd_Chr_Cp(char out_char);`
Returns	Nothing.
Description	Prints character on Lcd at current cursor position. Both variables and literals can be passed as a character. Parameters : - `out_char`: character to be written
Requires	The Lcd module needs to be initialized. See Lcd_Init routine.
Example	`// Write character "e" at current cursor position:` `Lcd_Chr_Cp('e');`

Lcd_Cmd

Prototype	`void Lcd_Cmd(char out_char);`
Returns	Nothing.
Description	Sends command to Lcd. Parameters : - `out_char`: command to be sent **Note**: Predefined constants can be passed to the function, see Available Lcd Commands.
Requires	The Lcd module needs to be initialized. See Lcd_Init table.
Example	`// Clear Lcd display:` `Lcd_Cmd(LCD_CLEAR);`

Available Lcd Commands

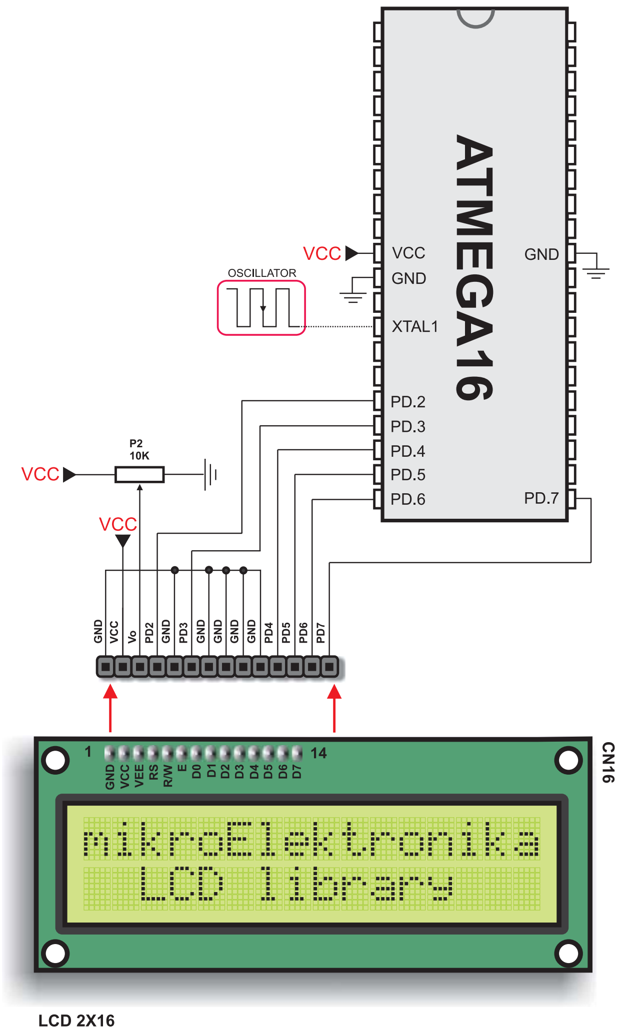
Lcd Command	Purpose
`LCD_FIRST_ROW`	Move cursor to the 1st row
`LCD_SECOND_ROW`	Move cursor to the 2nd row
`LCD_THIRD_ROW`	Move cursor to the 3rd row
`LCD_FOURTH_ROW`	Move cursor to the 4th row
`LCD_CLEAR`	Clear display
`LCD_RETURN_HOME`	Return cursor to home position, returns a shifted display to its original position. Display data RAM is unaffected.
`LCD_CURSOR_OFF`	Turn off cursor
`LCD_UNDERLINE_ON`	Underline cursor on
`LCD_BLINK_CURSOR_ON`	Blink cursor on
`LCD_MOVE_CURSOR_LEFT`	Move cursor left without changing display data RAM
`LCD_MOVE_CURSOR_RIGHT`	Move cursor right without changing display data RAM
`LCD_TURN_ON`	Turn Lcd display on
`LCD_TURN_OFF`	Turn Lcd display off
`LCD_SHIFT_LEFT`	Shift display left without changing display data RAM
`LCD_SHIFT_RIGHT`	Shift display right without changing display data RAM

Library Example

The following code demonstrates usage of the Lcd Library routines:

```
// Lcd module connections
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;
sbit LCD_D4 at PORTD.B4;
sbit LCD_D5 at PORTD.B5;
sbit LCD_D6 at PORTD.B6;
sbit LCD_D7 at PORTD.B7;

sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D4_Direction at DDRD.B4;
sbit LCD_D5_Direction at DDRD.B5;
sbit LCD_D6_Direction at DDRD.B6;
sbit LCD_D7_Direction at DDRD.B7;
// End LCD module connections

char txt1[] = "mikroElektronika";
char txt2[] = "EasyAVR5A";
char txt3[] = "Lcd4bit";
char txt4[] = "example";

char i;                              // Loop variable

void Move_Delay() {                  // Function used for text moving
  Delay_ms(500);               // You can change the moving speed here
}

void main(){
  Lcd_Init();                        // Initialize Lcd
  Lcd_Cmd(LCD_CLEAR);               // Clear display
  Lcd_Cmd(LCD_CURSOR_OFF);          // Cursor off

  Lcd_Out(1,6,txt3);                // Write text in first row
  Lcd_Out(2,6,txt4);                // Write text in second row
  Delay_ms(2000);
  Lcd_Cmd(LCD_CLEAR);               // Clear display

  Lcd_Out(1,1,txt1);                // Write text in first row
  Lcd_Out(2,4,txt2);                // Write text in second row
  Delay_ms(2000);

// Moving text
  for(i=0; i<4; i++) {            // Move text to the right 4 times
    Lcd_Cmd(LCD_SHIFT_RIGHT);
    Move_Delay();
  }
```

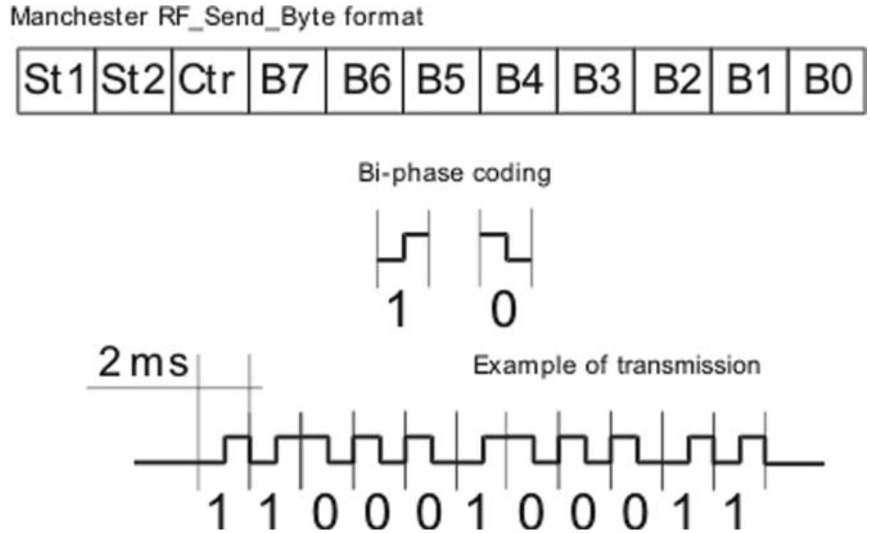
```
  while(1) {                          // Endless loop
    for(i=0; i<7; i++) {              // Move text to the left 7 times
      Lcd_Cmd(LCD_SHIFT_LEFT);
      Move_Delay();
    }

    for(i=0; i<7; i++) {              // Move text to the right 7 times
      Lcd_Cmd(LCD_SHIFT_RIGHT);
      Move_Delay();
    }

  }
}
```



Lcd HW connection

MANCHESTER CODE LIBRARY

The mikroC PRO for AVR provides a library for handling Manchester coded signals. The Manchester code is a code in which data and clock signals are combined to form a single self-synchronizing data stream; each encoded bit contains a transition at the midpoint of a bit period, the direction of transition determines whether the bit is 0 or 1; the second half is the true bit value and the first half is the complement of the true bit value (as shown in the figure below).



Notes: The Manchester receive routines are blocking calls (`Man_Receive_Init` and `Man_Synchro`). This means that MCU will wait until the task has been performed (e.g. byte is received, synchronization achieved, etc).

Note: Manchester code library implements time-based activities, so interrupts need to be disabled when using it.

External dependencies of Manchester Code Library

The following variables must be defined in all projects using Manchester Code Library:	Description:	Example:
`extern sfr sbit MANRXPIN;`	Receive line.	`sbit MANRXPIN at PINB.B0;`
`extern sfr sbit MANTXPIN;`	Transmit line.	`sbit MANTXPIN at PORTB.B1;`
`extern sfr sbit MANRXPIN_Direction;`	Direction of the Receive pin.	`sbit MANRXPIN_Direction at DDRB.B0;`
`extern sfr sbit MANTXPIN_Direction;`	Direction of the Transmit pin.	`sbit MANTXPIN_Direction at DDRB.B1;`

Library Routines

- Man_Receive_Init
- Man_Receive
- Man_Send_Init
- Man_Send
- Man_Synchro
- Man_Break

The following routines are for the internal use by compiler only:

- Manchester_0
- Manchester_1
- Manchester_Out

Man_Receive_Init

Prototype	`unsigned int Man_Receive_Init();`
Returns	- `0` - if initialization and synchronization were successful. - `1` - upon unsuccessful synchronization. - `255` - upon user abort.
Description	The function configures Receiver pin and performs synchronization procedure in order to retrieve baud rate out of the incoming signal. **Note**: In case of multiple persistent errors on reception, the user should call this routine once again or Man_Synchro routine to enable synchronization.
Requires	Global variables : - `MANRXPIN` : Receive line - `MANRXPIN_Direction` : Direction of the receive pin must be defined before using this function.

Example	`// Initialize Receiver`
	`sbit MANRXPIN at PORTB.B0;`
	`sbit MANRXPIN_Direction at DDRB.B0;`
	`...`
	`Man_Receive_Init();`

Man_Receive

Prototype	`unsigned char Man_Receive(unsigned char *error);`
Returns	A byte read from the incoming signal.
Description	The function extracts one byte from incoming signal. Parameters : - `error`: error flag. If signal format does not match the expected, the `error` flag will be set to non-zero.
Requires	To use this function, the user must prepare the MCU for receiving. See Man_Receive_Init.

Example	`unsigned char data = 0, error = 0;`
	`...`
	`data = Man_Receive(&error);`
	`if (error)`
	`  { /* error handling */ }`

Man_Send_Init

Prototype	`void Man_Send_Init();`
Returns	Nothing.
Description	The function configures Transmitter pin.
Requires	Global variables : - `MANTXPIN` : Transmit line - `MANTXPIN_Direction` : Direction of the transmit pin must be defined before using this function.

Example	`// Initialize Transmitter:`
	`sbit MANTXPIN at PORTB.B1;`
	`sbit MANTXPIN_Direction at DDRB.B1;`
	`...`
	`Man_Send_Init();`

Man_Send

Prototype	`void Man_Send(unsigned char tr_data);`
Returns	Nothing.
Description	Sends one byte. Parameters : - `tr_data`: data to be sent **Note**: Baud rate used is 500 bps.
Requires	To use this function, the user must prepare the MCU for sending. See Man_Send_Init.

Example	`unsigned char msg;`
	`...`
	`Man_Send(msg);`

Man_Synchro

Prototype	`unsigned char Man_Synchro();`
Returns	- `255` - if synchronization was not successful. - Half of the manchester bit length, given in multiples of 10us - upon successful synchronization.
Description	Measures half of the manchester bit length with 10us resolution.
Requires	To use this function, you must first prepare the MCU for receiving. See Man_Receive_Init.

Example	`unsigned int man__half_bit_len;`
	`...`
	`man__half_bit_len = Man_Synchro();`

Man_Break

Prototype	`void Man_Break();`
Returns	Nothing.
Description	Man_Receive is blocking routine and it can block the program flow. Call this routine from interrupt to unblock the program execution. This mechanism is similar to WDT. **Note**: Interrupts should be disabled before using Manchester routines again (see note at the top of this page).
Requires	Nothing.
Example	(see code below)

```
char data1, error, counter = 0;

void Timer0Overflow_ISR() org 0x12 {

  if (counter >= 20) {
    Man_Break();
    counter = 0;                      // reset counter
  }
  else
    counter++;                        // increment counter
}

void main() {

  TOIE0_bit  = 1;                     // Timer0 overflow interrupt
enable
  TCCR0_bit  = 5;                     // Start timer with 1024
prescaler

  SREG_I = 0;                         // Interrupt disable

  ...

  Man_Receive_Init();

  ...

  // try Man_Receive with blocking prevention mechanism

  SREG_I = 1;                         // Interrupt enable
  data1 = Man_Receive(&error);
  SREG_I = 0;                         // Interrupt disable

  ...

}
```

Library Example

The following code is code for the Manchester receiver, it shows how to use the Manchester Library for receiving data:

```
// LCD module connections
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;
sbit LCD_D4 at PORTD.B4;
sbit LCD_D5 at PORTD.B5;
sbit LCD_D6 at PORTD.B6;
sbit LCD_D7 at PORTD.B7;

sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D4_Direction at DDRD.B4;
sbit LCD_D5_Direction at DDRD.B5;
sbit LCD_D6_Direction at DDRD.B6;
sbit LCD_D7_Direction at DDRD.B7;
// End LCD module connections

// Manchester module connections
sfr sbit MANRXPIN at PINB.B0;
sfr sbit MANRXPIN_Direction at DDRB.B0;
sfr sbit MANTXPIN at PORTB.B1;
sfr sbit MANTXPIN_Direction at DDRB.B1;
// End Manchester module connections

char error, ErrorCount, temp;

void main() {
  ErrorCount = 0;
  Manchester_Stop();

  Lcd_Init();                                   // Initialize LCD
  Lcd_Cmd(LCD_CLEAR);                           // Clear LCD display

  Man_Receive_Init();                           // Initialize Receiver

  while (1) {                                   // Endless loop

      Lcd_Cmd(LCD_FIRST_ROW);           // Move cursor to the 1st row

     while (1) {                       // Wait for the "start" byte
        temp = Man_Receive(&error);          // Attempt byte receive
        if (temp == 0x0B)  // "Start" byte, see Transmitter example
          break;                     // We got the starting sequence
        if (error)                 // Exit so we do not loop forever
          break;
        }
```

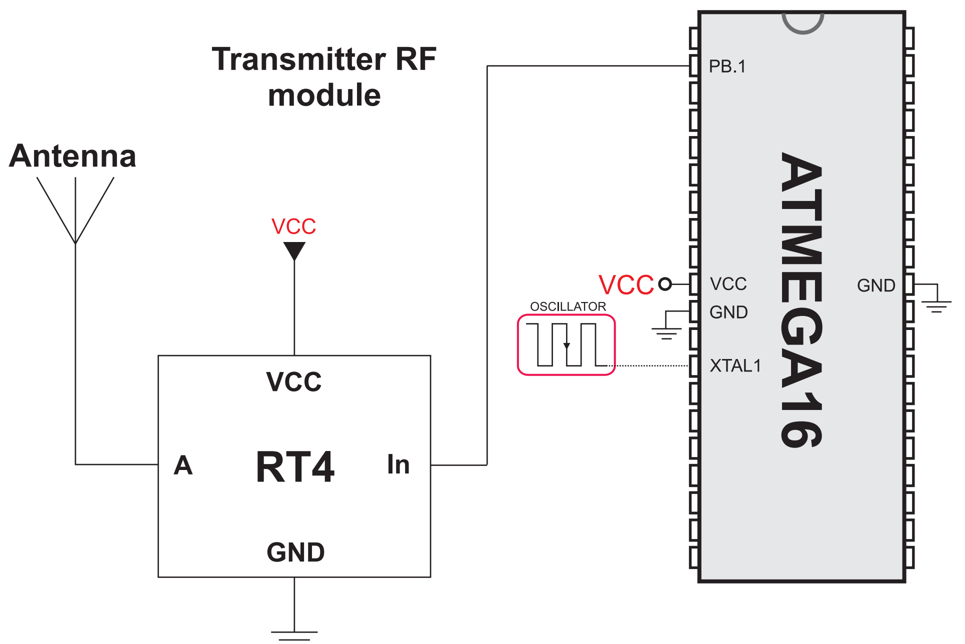
```
do
        {
          temp = Man_Receive(&error);        // Attempt byte receive
          if (error) {                            // If error occured
            Lcd_Chr_CP('?');           // Write question mark on LCD
            ErrorCount++;                   // Update error counter
           if (ErrorCount > 20) {      // In case of multiple errors
              temp = Man_Synchro();    // Try to synchronize again
              //Man_Receive_Init();                // Alternative,
try to Initialize Receiver again
              ErrorCount = 0;                // Reset error counter
              }
            }
          else {                               // No error occured
              if (temp != 0x0E)                 // If "End" byte was
received(see Transmitter example)
              Lcd_Chr_CP(temp);          //   do not write received
byte on LCD
              }
          Delay_ms(25);
        }
     while (temp != 0x0E) ;          // If "End" byte was received
exit do loop
   }
}
```

The following code is code for the Manchester transmitter, it shows how to use the Manchester Library for transmitting data:

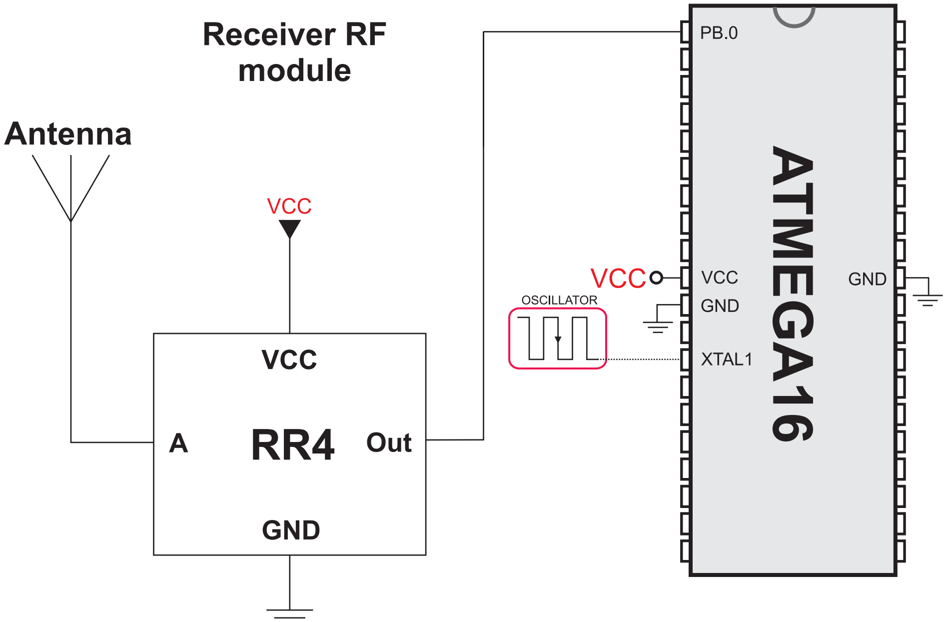
```
// Manchester module connections
sbit MANRXPIN at PORTB.B0;
sbit MANRXPIN_Direction at DDRB.B0;
sbit MANTXPIN at PORTB.B1;
sbit MANTXPIN_Direction at DDRB.B1;
// End Manchester module connections

char index, character;
char s1[] = "mikroElektronika";

void main() {

  Man_Send_Init();                   // Initialize transmitter

  while (1) {                         // Endless loop
    Man_Send(0x0B);                  // Send "start" byte
    Delay_ms(100);                   // Wait for a while
```

```
      character = s1[0];              // Take first char from string
      index = 0;                       // Initialize index variable
      while (character) {             // String ends with zero
        Man_Send(character);          // Send character
        Delay_ms(90);                 // Wait for a while
        index++;                       // Increment index variable
        character = s1[index];        // Take next char from string
        }
      Man_Send(0x0E);                 // Send "end" byte
      Delay_ms(1000);
    }
}
```

Connection Example



Simple Transmitter connection



Simple Receiver connection

MULTI MEDIA CARD LIBRARY

The Multi Media Card (MMC) is a flash memory card standard. MMC cards are currently available in sizes up to and including 1 GB, and are used in cell phones, mp3 players, digital cameras, and PDA's.
mikroC PRO for AVR provides a library for accessing data on Multi Media Card via SPI communication.This library also supports SD(Secure Digital) memory cards.

Secure Digital Card

Secure Digital (SD) is a flash memory card standard, based on the older Multi Media Card (MMC) format.
SD cards are currently available in sizes of up to and including 2 GB, and are used in cell phones, mp3 players, digital cameras, and PDAs.

Notes:

- Routines for file handling can be used only with FAT16 file system.
- Library functions create and read files from the root directory only;
- Library functions populate both FAT1 and FAT2 tables when writing to files, but the file data is being read from the FAT1 table only; i.e. there is no recovery if FAT1 table is corrupted.
- Prior to calling any of this library routines, Spi_Rd_Ptr needs to be initialized with the appropriate SPI_Read routine.

External dependecies of MMC Library

The following variables must be defined in all projects using Manchester Code Library:	Description:	Example:
`extern sfr sbit Mmc_Chip_Select;`	Chip select pin.	`sbit Mmc_Chip_Select at PORTG.B1;`
`extern sfr sbit Mmc_Chip_Select_Direction;`	Direction of the chip select pin.	`sbit Mmc_Chip_Select_Direction at DDRG.B1;`

Library Routines

- Mmc_Init
- Mmc_Read_Sector
- Mmc_Write_Sector
- Mmc_Read_Cid
- Mmc_Read_Csd

Routines for file handling:

- Mmc_Fat_Init
- Mmc_Fat_QuickFormat
- Mmc_Fat_Assign
- Mmc_Fat_Reset
- Mmc_Fat_Read
- Mmc_Fat_Rewrite
- Mmc_Fat_Append
- Mmc_Fat_Delete
- Mmc_Fat_Write
- Mmc_Fat_Set_File_Date
- Mmc_Fat_Get_File_Date
- Mmc_Fat_Get_File_Size
- Mmc_Fat_Get_Swap_File

Mmc_Init

Prototype	`unsigned char Mmc_Init();`
Returns	- `1` - if MMC/SD card was detected and successfully initialized - `0` - otherwise
Description	Initializes hardware SPI communication; The function returns 1 if MMC card is present and successfully initialized, otherwise returns 0. Mmc_Init needs to be called before using other functions of this library.
Requires	Global variables : - `Mmc_Chip_Select`: Chip Select line - `Mmc_Chip_Select_Direction`: Direction of the Chip Select pin must be defined before using this function.

Example	`// MMC module connections`
	`sfr sbit Mmc_Chip_Select at PORTG.B1;`
	`sfr sbit Mmc_Chip_Select_Direction at DDRG.B1;`
	`// MMC module connections`
	
	`SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV2, _SPI_CLK_LO_LEAD-ING);`
	`Spi_Rd_Ptr = SPI1_Read;`
	
	`error = Mmc_Init();  // Init with CS line at PORTB.B2`

Mmc_Read_Sector

Prototype	`unsigned char Mmc_Read_Sector(unsigned long sector, char* dbuff);`
Returns	Returns 0 if read was successful, or 1 if an error occurred.
Description	Function reads one sector (512 bytes) from MMC card at sector address `sector`. Read data is stored in the array `data`. Function returns 0 if read was successful, or 1 if an error occurred.
Requires	Library needs to be initialized, see Mmc_Init.
Example	`error = Mmc_Read_Sector(sector, data);`

Mmc_Write_Sector

Prototype	`unsigned char Mmc_Write_Sector(unsigned long sector, char *dbuff);`
Returns	Returns 0 if write was successful; returns 1 if there was an error in sending write command; returns 2 if there was an error in writing.
Description	Function writes 512 bytes of `data` to MMC card at sector address `sector`. Function returns 0 if write was successful, or 1 if there was an error in sending write command, or 2 if there was an error in writing.
Requires	Library needs to be initialized, see Mmc_Init.
Example	`error := Mmc_Write_Sector(sector, data);`

Mmc_Read_Cid

Prototype	`unsigned char Mmc_Read_Cid(char * data_for_registers);`
Returns	Returns 0 if read was successful, or 1 if an error occurred.
Description	Function reads CID register and returns 16 bytes of content into `data_for_registers`.
Requires	Library needs to be initialized, see Mmc_Init.
Example	`error = Mmc_Read_Cid(data);`

Mmc_Read_Csd

Prototype	`unsigned char Mmc_Read_Csd(char * data_for_registers);`
Returns	Returns 0 if read was successful, or 1 if an error occurred.
Description	Function reads CSD register and returns 16 bytes of content into `data_for_registers`.
Requires	Library needs to be initialized, see Mmc_Init.
Example	`error = Mmc_Read_Csd(data);`

Mmc_Fat_Init

Prototype	`unsigned short Mmc_Fat_Init();`
Returns	- `0` - if MMC/SD card was detected and successfully initialized - `1` - if FAT16 boot sector was not found - `255` - if MMC/SD card was not detected
Description	Initializes MMC/SD card, reads MMC/SD FAT16 boot sector and extracts necessary data needed by the library. **Note**: MMC/SD card has to be formatted to FAT16 file system.
Requires	Global variables : - `Mmc_Chip_Select`: Chip Select line - `Mmc_Chip_Select_Direction`: Direction of the Chip Select pin must be defined before using this function. The appropriate hardware SPI module must be previously initialized. See the SPI1_Init, SPI1_Init_Advanced routines.

Example	`// MMC module connections`
	`sfr sbit Mmc_Chip_Select at PORTG.B1;`
	`sfr sbit Mmc_Chip_Select_Direction at DDRG.B1;`
	`// MMC module connections`
	
	`// Pointer to appropriate SPI Read function`
	`SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV128, _SPI_CLK_LO_LEADING);`
	`Spi_Rd_Ptr = SPI1_Read;`
	
	`// use fat16 quick format instead of init routine if a formatting is needed`
	`if (!Mmc_Fat_Init()) {`
	`// reinitialize spi at higher speed`
	`SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV2, _SPI_CLK_LO_LEADING);`
	`...`
	`}`

Mmc_Fat_QuickFormat

Prototype	`unsigned char Mmc_Fat_QuickFormat(unsigned char *port, unsigned char pin, char * mmc_fat_label)`
Returns	- `0` - if MMC/SD card was detected, successfully formated and initialized - `1` - if FAT16 format was unseccessful - `255` - if MMC/SD card was not detected
Description	Formats to FAT16 and initializes MMC/SD card. Parameters: - `port`: chip select signal port address. - `pin`: chip select pin. - `mmc_fat_label`: volume label (11 characters in length). If less than 11 characters are provided, the label will be padded with spaces. If null string is passed volume will not be labeled **Note**: This routine can be used instead or in conjunction with Mmc_Fat_Init routine. **Note**: If MMC/SD card already contains a valid boot sector, it will remain unchanged (except volume label field) and only FAT and ROOT tables will be erased. Also, the new volume label will be set.
Requires	The appropriate hardware SPI module must be previously initialized.

Example	`// Pointer to appropriate SPI Read function`
	
	`SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV128, _SPI_CLK_LO_LEADING);`
	`Spi_Rd_Ptr = SPI1_Read;`
	`// Format and initialize MMC/SD card and MMC_FAT16 library globals`
	`if (!Mmc_Fat_QuickFormat(&mmc_fat_label)) {`
	
	`// Reinitialize the SPI module at higher speed (change primary prescaler).`
	`SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV2, _SPI_CLK_LO_LEADING);`
	`...`
	`}`

Mmc_Fat_Assign

<table>
<tr><td>Prototype</td><td><code>unsigned short Mmc_Fat_Assign(char * filename, char file_cre_attr);</code></td></tr>
<tr><td>Returns</td><td>- <code>1</code> - if file already exists or file does not exist but new file is created.
- <code>0</code> - if file does not exist and no new file is created.</td></tr>
<tr><td>Description</td><td>Assigns file for file operations (read, write, delete...). All subsequent file operations will be applied over the assigned file.

Parameters:

- <code>filename</code>: name of the file that should be assigned for file operations. File name should be in DOS 8.3 (file_name.extension) format. The file name and extension will be automatically padded with spaces by the library if they have less than length required (i.e. "mikro.tx" -> "mikro .tx "), so the user does no have to take care of that. The file name and extension are case insensitive. The library will convert them to proper case automatically, so the user does not have to take care of that. Also, in order to keep backward compatibility with first version of this library, file names can be entered as UPPERCASE string of 11 bytes in length with no dot character between file name and extension (i.e. "MIKROELETXT" -> MIKROELE.TXT). In this case last 3 characters of the string are considered to be file extension.

- <code>file_cre_attr</code>: file creation and attributs flags. Each bit corresponds to appropriate file attribut:
<table>
<tr><th>Bit</th><th>Mask</th><th>Description</th></tr>
<tr><td>0</td><td>0x01</td><td>Read Only</td></tr>
<tr><td>1</td><td>0x02</td><td>Hidden</td></tr>
<tr><td>2</td><td>0x04</td><td>System</td></tr>
<tr><td>3</td><td>0x08</td><td>Volume Label</td></tr>
<tr><td>4</td><td>0x10</td><td>Subdirectory</td></tr>
<tr><td>5</td><td>0x20</td><td>Archive</td></tr>
<tr><td>6</td><td>0x40</td><td>Device (internal use only, never found on disk)</td></tr>
<tr><td>7</td><td>0x80</td><td>File creation flag. If the file does not exist and this flag is set, a new file with specified name will be created.</td></tr>
</table>
Note: Long File Names (LFN) are not supported.</td></tr>
</table>

Requires	MMC/SD card and MMC library must be initialized for file operations. See Mmc_Fat_Init.
Example	`//Create file with archive attribut if it does not already exists` `Mmc_Fat_Assign('MIKROELE.TXT',0xA0);`

Mmc_Fat_Reset

Prototype	`void Mmc_Fat_Reset(unsigned long * size);`
Returns	Nothing.
Description	Procedure resets the file pointer (moves it to the start of the file) of the assigned file, so that the file can be read. Parameter `size` stores the size of the assigned file, in bytes.
Requires	The file must be assigned, see Mmc_Fat_Assign.
Example	`Mmc_Fat_Reset(size);`

Mmc_Fat_Rewrite

Prototype	`void Mmc_Fat_Rewrite();`
Returns	Nothing.
Description	Procedure resets the file pointer and clears the assigned file, so that new data can be written into the file.
Requires	The file must be assigned, see Mmc_Fat_Assign.
Example	`Mmc_Fat_Rewrite;`

Mmc_Fat_Append

Prototype	`void Mmc_Fat_Append();`
Returns	Nothing.
Description	The procedure moves the file pointer to the end of the assigned file, so that data can be appended to the file.
Requires	The file must be assigned, see Mmc_Fat_Assign.
Example	`Mmc_Fat_Append;`

Mmc_Fat_Read

Prototype	`void Mmc_Fat_Read(unsigned short * bdata);`
Returns	Nothing.
Description	Procedure reads the byte at which the file pointer points to and stores data into parameter data. The file pointer automatically increments with each call of `Mmc_Fat_Read`.
Requires	The file must be assigned, see Mmc_Fat_Assign. Also, file pointer must be initialized; see Mmc_Fat_Reset.
Example	`Mmc_Fat_Read(mydata);`

Mmc_Fat_Delete

Prototype	`void Mmc_Fat_Delete();`
Returns	Nothing.
Description	Deletes currently assigned file from MMC/SD card.
Requires	MMC/SD card and MMC library must be initialized for file operations. See Mmc_Fat_Init. The file must be previously assigned. See Mmc_Fat_Assign.
Example	`// delete current file` `Mmc_Fat_Delete();`

Mmc_Fat_Write

Prototype	`void Mmc_Fat_Write(char * fdata, unsigned data_len);`
Returns	Nothing.
Description	Procedure writes a chunk of bytes (`fdata`) to the currently assigned file, at the position of the file pointer.
Requires	The file must be assigned, see Mmc_Fat_Assign. Also, file pointer must be initialized; see Mmc_Fat_Append or Mmc_Fat_Rewrite.
Example	`Mmc_Fat_Write(txt,255);` `Mmc_Fat_Write('Hello world',255);`

Mmc_Fat_Set_File_Date

Prototype	`void Mmc_Fat_Set_File_Date(unsigned int year, unsigned short month, unsigned short day, unsigned short hours, unsigned short mins, unsigned short seconds);`
Returns	Nothing.
Description	Writes system timestamp to a file. Use this routine before each writing to file; otherwise, the file will be appended an unknown timestamp.
Requires	The file must be assigned, see Mmc_Fat_Assign. Also, file pointer must be initialized; see Mmc_Fat_Reset.
Example	`// April 1st 2005, 18:07:00` `Mmc_Fat_Set_File_Date(2005, 4, 1, 18, 7, 0);`

Mmc_Fat_Get_File_Date

Prototype	`void Mmc_Fat_Get_File_Date(unsigned int *year, unsigned short *month, unsigned short *day, unsigned short *hours, unsigned short *mins);`
Returns	Nothing.
Description	Retrieves date and time for the currently selected file. Seconds are not being retrieved since they are written in 2-sec increments.
Requires	The file must be assigned, see Mmc_Fat_Assign.

Example	`// get Date/time of file`
	`unsigned yr;`
	`char mnth, dat, hrs, mins;`
	`...`
	`file_Name = "MYFILEABTXT";`
	`Mmc_Fat_Assign(file_Name);`
	`Mmc_Fat_Get_File_Date(yr, mnth, dat, hrs, mins);`

Mmc_Fat_Get_File_Size

Prototype	`unsigned long Mmc_Fat_Get_File_Size();`
Returns	This function returns size of active file (in bytes).
Description	Retrieves size for currently selected file.
Requires	The file must be assigned, see Mmc_Fat_Assign.

Example	`// get Date/time of file`
	`unsigned yr;`
	`char mnth, dat, hrs, mins;`
	`...`
	`file_name = "MYFILEXXTXT";`
	`Mmc_Fat_Assign(file_name);`
	`mmc_size = Mmc_Fat_Get_File_Size;`

Mmc_Fat_Get_Swap_File

Prototype	`unsigned long Mmc_Fat_Get_Swap_File(unsigned long sectors_cnt, char* filename, char file_attr);`
Returns	- Number of the start sector for the newly created swap file, if there was enough free space on the MMC/SD card to create file of required size. - 0 - otherwise.
Description	This function is used to create a swap file of predefined name and size on the MMC/SD media. If a file with specified name already exists on the media, search for consecutive sectors will ignore sectors occupied by this file. Therefore, it is recomended to erase such file if it exists before calling this function. If it is not erased and there is still enough space for new swap file, this function will delete it after allocating new memory space for new swap file. The purpose of the swap file is to make reading and writing to MMC/SD media as fast as possible, by using the Mmc_Read_Sector() and Mmc_Write_Sector() functions directly, without potentially damaging the FAT system. Swap file can be considered as a "window" on the media where user can freely write/read the data. It's main purpose in mikroC's library is to be used for fast data acquisition; when the time-critical acquisition has finished, the data can be re-written into a "normal" file, and formatted in the most suitable way. Parameters: - `sectors_cnt`: number of consecutive sectors that user wants the swap file to have. - `filename`: name of the file that should be assigned for file operations. File name should be in DOS 8.3 (file_name.extension) format. The file name and extension will be automatically padded with spaces by the library if they have less than length required (i.e. "mikro.tx" -> "mikro .tx "), so the user does no have to take care of that. The file name and extension are case insensitive. The library will convert them to proper case automatically, so the user does not have to take care of that. Also, in order to keep backward compatibility with first version of this library, file names can be entered as UPPERCASE string of 11 bytes in length with no dot character between file name and extension (i.e. "MIKROELETXT" -> MIKROELE.TXT). In this case last 3 charac ters of the string are considered to be file extension. - `file_attr`: file creation and attributs flags. Each bit corresponds to appropriate file attribut:

Description

Bit	Mask	Description
0	0x01	Read Only
1	0x02	Hidden
2	0x04	System
3	0x08	Volume Label
4	0x10	Subdirectory
5	0x20	Archive
6	0x40	Device (internal use only, never found on disk)
7	0x80	Not used

Note: Long File Names (LFN) are not supported.

Requires

MMC/SD card and MMC library must be initialized for file operations. See Mmc_Fat_Init.

Example

```
//-------------- Tries to create a swap file, whose size will be
at least 100 sectors.
//If it succeeds, it sends the No. of start sector over UART
void M_Create_Swap_File(){
  size = Mmc_Fat_Get_Swap_File(100);
  if (size <> 0) {
    UART_Write(0xAA);
    UART_Write(Lo(size));
    UART_Write(Hi(size));
    UART_Write(Higher(size));
    UART_Write(Highest(size));
    UART_Write(0xAA);
  }
}
```

Library Example

MMC library test. Upon flashing, insert a MMC/SD card into the module, when you should receive the "Init-OK" message. Then, you can experiment with MMC read and write functions, and observe the results through the terminal Receive Panel window.

```
// if defined, we have a debug messages on PC terminal
#define RS232_debug 1

sbit Mmc_Chip_Select at PORTG.B1;
sbit Mmc_Chip_Select_Direction at DDRG.B1;

// universal variables
unsigned int  px, k; // universal for loops and other stuff

// Variables for MMC routines
unsigned char dData[512]; // Buffer for MMC sector reading/writing
unsigned char data_for_registers[16]; // buffer for CID and CSD reg-
isters

// RS232 communication variables
unsigned char received_character;
unsigned long sector_address;
unsigned char first_byte, second_byte, third_byte, fourth_byte;
unsigned char serial_buffer[2];
unsigned char serial_pointer;


// Display byte in hex
void printhex(unsigned char i) {
  unsigned char hi,lo;
  hi = i & 0xF0;                // High nibble
  hi = hi >> 4;
  hi = hi + '0';
  if (hi>'9') hi = hi + 7;
  lo = (i & 0x0F) + '0';        // Low nibble
  if (lo>'9') lo=lo+7;
  UART1_Write(hi);
  UART1_Write(lo);

}

char (*Spi_Rd_Ptr)(char) = SPI1_Read;

void main()
{
  unsigned int i;

  PORTC = 0;
  #ifdef RS232_debug
    UART1_Init(19200);
  #endif

  Delay_ms(10);
```

```
#ifdef RS232_debug
    UART1_Write_Text("PIC-Started"); // If PIC present report
    UART1_Write(13);
    UART1_Write(10);
  #endif

  // Before all, we must initialize a MMC card
   SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV2, _SPI_CLK_LO_LEAD-
ING);
  Spi_Rd_Ptr = SPI1_Read;
  i = Mmc_Init();
  #ifdef RS232_debug
    if(i == 0)
    {
      UART1_Write_Text("MMC Init-OK"); // If MMC present report
      UART1_Write(13);
      UART1_Write(10);
    }
    if(i)
    {
      UART1_Write_Text("MMC Init-error"); // If error report
      UART1_Write(13);
      UART1_Write(10);
    }
  #endif

  for(i=0; i<=511; i++)
    dData[i] = 'E'; // Fill MMC buffer with same characters
  i = Mmc_Write_Sector(55, dData);

  #ifdef RS232_debug
    if(i == 0)
    {
      UART1_Write_Text("Write-OK");
    }
    else  // if there are errors.....
    {
      UART1_Write_Text("Write-Error");
    }
    UART1_Write(13);
    UART1_Write(10);
  #endif
 // Reading of CID and CSD register on MMC card.....
  #ifdef RS232_debug
    i = Mmc_Read_Cid(data_for_registers);
    if(i == 0)
    {
      for(k=0; k<=15; k++)
      {
        printhex(data_for_registers[k]);
        if(k!=15) UART1_Write('-');
      }
```

```
    UART1_Write(13);
      }
      else
      {
        UART1_Write_Text("CID-error");
      }
      i == Mmc_Read_Csd(data_for_registers);
      if(i == 0)
      {
        for(k=0; k<=15; k++)
        {
          printhex(data_for_registers[k]);
          if(k!=15) UART1_Write('-');
        }
        UART1_Write(13);
        UART1_Write(10);
      }
      else
      {
        UART1_Write_Text("CSD-error");
      }
    #endif

    // Variables initialisation
    serial_pointer = 0;

    // MAIN loop
    while(1)
    {
      if (UART1_Data_Ready())
      {
         serial_buffer[serial_pointer] = UART1_Read();     // Get the
  received character
        serial_pointer++;
        if(serial_pointer>1)
        {
    serial_pointer = 0;
          // Collecting four bytes of the address!
          if(serial_buffer[0] == 'S') first_byte  = serial_buffer[1];
          if(serial_buffer[0] == 's') second_byte = serial_buffer[1];
          if(serial_buffer[0] == 'E') third_byte  = serial_buffer[1];
          if(serial_buffer[0] == 'e') fourth_byte = serial_buffer[1];
          if(serial_buffer[0] == 'R') // Command: Read memmory
          {
            if(serial_buffer[1] == 'r')
            {
  sector_address = ((long)first_byte << 24) + ((long)second_byte << 16)
  +
                                       ((long)third_byte << 8)   +
  ((long)fourth_byte);
              i = Mmc_Read_Sector(sector_address, dData);
              //UART1_Write(0x30 + i);  //
              if(i == 0)
```

```
                {
                  for(k=0; k<512; k++)
                 { //UART1_Write(dData[k]); // send 512 bytes from MMC
card via usart
                    printhex(dData[k]);
                    UART1_Write(' ');
                    if(((k+1) % 16)==0)
                    {
                      UART1_Write(' ');
                      //printhex(k);
                      for(px=(k-15); px<=k; px++)
                      {
                        if((dData[px]>33) && (dData[px]<126))
                        {
                          UART1_Write(dData[px]);
                        }
                        else
                        {
                          UART1_Write('.');
                        }
                      }
                      UART1_Write(13);
                    }
                  }
                  UART1_Write(13);
                  UART1_Write(10);
                }
                else
                {
                  UART1_Write_Text("Read-error");
                  UART1_Write(13);
                  UART1_Write(10);
                }
              }
            }
            if(serial_buffer[0] == 'W') // Command: Write
            {
              if(serial_buffer[1] == 'w')
              {
 // Generating 32-bit address of the sector out of four received bytes
                sector_address = ((long)first_byte << 24) + ((long)sec-
ond_byte << 16) +
                                                    ((long)third_byte << 8)   +
((long)fourth_byte);
                for(k=0; k<512; k++)
                  dData[k] = received_character;// fill RAM baffer
                 i = Mmc_Write_Sector(sector_address, dData); // write
buffer tou MMC
                if(i != 0)
```

```
{
              UART1_Write_Text("Write-error");
              UART1_Write(13);
              UART1_Write(10);
            }
            else
            {
              UART1_Write_Text("Write-Ok");
              UART1_Write(13);
              UART1_Write(10);
            }
          }
        }
        if(serial_buffer[0] == 'C')
        {
          received_character = serial_buffer[1];
        }
      }
    }
  }
}
```

The next program tests MMC FAT routines. First, we create 5 different files in the root of MMC card, and fill with some information. Then, we read the files and send them via UART for a check.

```
#include <built_in.h>

sbit Mmc_Chip_Select at PORTG.B1;
sbit Mmc_Chip_Select_Direction at DDRG.B1;

char
 fat_txt[20] = "FAT16 not found",
 file_contents[50] = "XX MMC/SD FAT16 library by Anton Rieckertn";

char
 filename[14] = "MIKRO00xTXT";           // File names
unsigned short
 tmp, caracter, loop, loop2;
unsigned long
 i, size;

char Buffer[512];

//I-I-I--------- Writes string to USART
void I_Write_Str(char *ostr) {
  unsigned short i;

 i = 0;
  while (ostr[i]) {
    UART1_Write(ostr[i++]);
  }
  UART1_Write(0x0A);
}

//M-M-M--------- Creates new file and writes some data to it
void M_Create_New_File() {
  filename[7] = 'A';
  Mmc_Fat_Assign(&filename, 0xA0);        // Will not find file and
then create file
  Mmc_Fat_Rewrite();                      // To clear file and start
with new data
  for(loop = 1; loop <= 99; loop++) {    //  We want 5 files on the
MMC card
    UART1_Write('.');
    file_contents[0] = loop / 10 + 48;
    file_contents[1] = loop % 10 + 48;
   Mmc_Fat_Write(file_contents, 42);   // write data to the assigned
file
  }
}
```

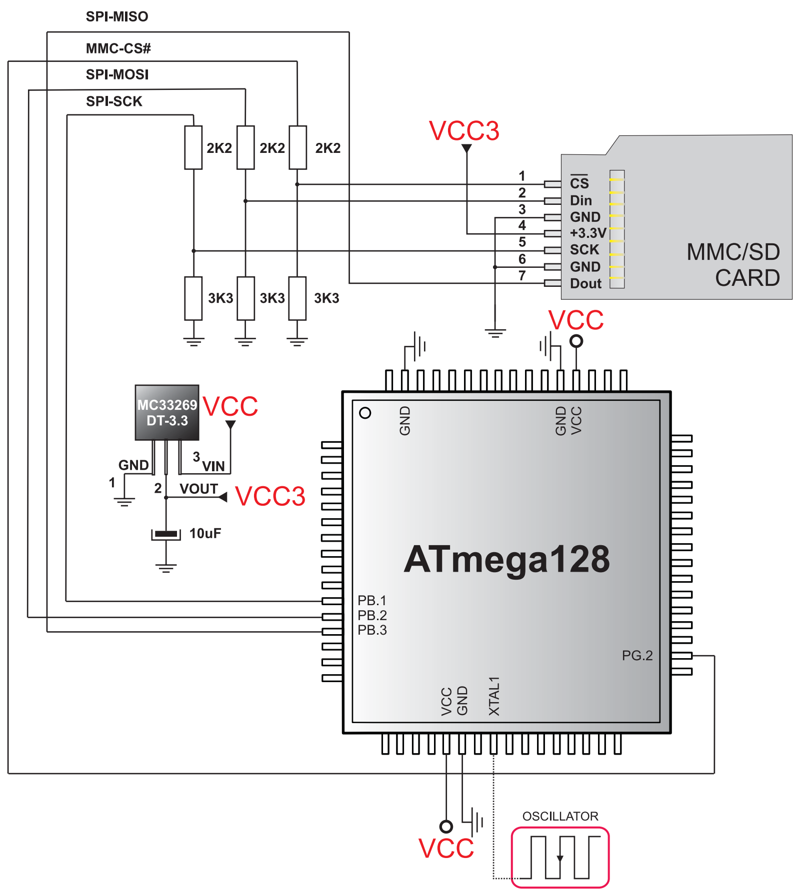
```
//M-M-M--------- Creates many new files and writes data to them
void M_Create_Multiple_Files() {
  for(loop2 = 'B'; loop2 <= 'Z'; loop2++) {
    UART1_Write(loop2);                 // signal the progress
    filename[7] = loop2;                      // set filename
    Mmc_Fat_Assign(&filename, 0xA0);        // find existing file or
create a new one
    Mmc_Fat_Rewrite();                      // To clear file and start
with new data
    for(loop = 1; loop <= 44; loop++) {
      file_contents[0] = loop / 10 + 48;
      file_contents[1] = loop % 10 + 48;
     Mmc_Fat_Write(file_contents, 42);  // write data to the assigned
file
    }
  }
}
//M-M-M--------- Opens an existing file and rewrites it
void M_Open_File_Rewrite() {
  filename[7] = 'C';
  Mmc_Fat_Assign(&filename, 0);
  Mmc_Fat_Rewrite();
for(loop = 1; loop <= 55; loop++) {
    file_contents[0] = loop / 10 + 64;
    file_contents[1] = loop % 10 + 64;
   Mmc_Fat_Write(file_contents, 42);   // write data to the assigned
file
  }
}

//M-M-M--------- Opens an existing file and appends data to it
//                 (and alters the date/time stamp)
void M_Open_File_Append() {
      filename[7] = 'B';
      Mmc_Fat_Assign(&filename, 0);
      Mmc_Fat_Set_File_Date(2005,6,21,10,35,0);
     Mmc_Fat_Append();                                      // Prepare
file for append
      Mmc_Fat_Write(" for mikroElektronika 2005n", 27);    // Write
data to assigned file
}//~

//M-M-M--------- Opens an existing file, reads data from it and puts
it to USART
void M_Open_File_Read() {
  filename[7] = 'B';
  Mmc_Fat_Assign(&filename, 0);
  Mmc_Fat_Reset(&size);                         // To read file, procedure
returns size of file
```

```
    for (i = 1; i <= size; i++) {
      Mmc_Fat_Read(&caracter);
      UART1_Write(caracter);          // Write data to USART
    }
}

//M-M-M--------- Deletes a file. If file doesn't exist, it will first
be created
//                and then deleted.
void M_Delete_File() {
  filename[ 7]  = 'F';
  Mmc_Fat_Assign(filename, 0);
  Mmc_Fat_Delete();
}

//M-M-M--------- Tests whether file exists, and if so sends its cre-
ation date
//                and file size via USART
void M_Test_File_Exist() {
  unsigned long fsize;
  unsigned int year;
  unsigned short month, day, hour, minute;
  unsigned char outstr[ 12] ;

filename[ 7]  = 'B';        //uncomment this line to search for file
that DOES exists
//  filename[ 7]  = 'F';       //uncomment this line to search for file
that DOES NOT exist
  if (Mmc_Fat_Assign(filename, 0)) {
    //--- file has been found - get its date
    Mmc_Fat_Get_File_Date(&year, &month, &day, &hour, &minute);

WordToStr(year, outstr);
    I_Write_Str(outstr);
    ByteToStr(month, outstr);
    I_Write_Str(outstr);
    WordToStr(day, outstr);
    I_Write_Str(outstr);
    WordToStr(hour, outstr);
    I_Write_Str(outstr);
    WordToStr(minute, outstr);
    I_Write_Str(outstr);
    //--- get file size
    fsize = Mmc_Fat_Get_File_Size();
    LongToStr((signed long)fsize, outstr);
    I_Write_Str(outstr);
  }
```

```
    else {
      //--- file was not found - signal it
      UART1_Write(0x55);
      Delay_ms(1000);
      UART1_Write(0x55);
    }
}


//-------------- Tries to create a swap file, whose size will be at
least 100
//                 sectors (see Help for details)
void M_Create_Swap_File() {
  unsigned int i;

  for(i=0; i<512; i++)
    Buffer[ i]  = i;

   size = Mmc_Fat_Get_Swap_File(5000, "mikroE.txt", 0x20);    // see
help on this function for details

  if (size) {
    LongToStr((signed long)size, fat_txt);
    I_Write_Str(fat_txt);

    for(i=0; i<5000; i++) {
      Mmc_Write_Sector(size++, Buffer);
      UART1_Write('.');
    }
  }
}

//-------------- Main. Uncomment the function(s) to test the desired
operation(s)
void main() {
     // we will use PORTC to signal test end
     DDRC   = 0xFF;
     PORTC = 0;

     Spi_Rd_Ptr = SPI1_Read;
     // use fat16 quick format instead of init routine if a format-
ting is needed
     if (!Mmc_Fat_Init()) {
       // reinitialize spi at higher speed
                 SPI1_Init_Advanced(_SPI_MASTER,   _SPI_FCY_DIV2,
_SPI_CLK_LO_LEADING);

       //--- Test start
       //--- Test routines. Uncomment them one-by-one to test cer-
tain features
```

```
      M_Create_New_File();
      M_Create_Multiple_Files();

      M_Open_File_Rewrite();
      M_Open_File_Append();
      M_Open_File_Read();
      M_Delete_File();
      M_Test_File_Exist();
      M_Create_Swap_File();
      UART1_Write('e');
    }
    else {
      I_Write_Str(fat_txt);
    }
    //--- Test termination
    PORTC = 0x0F;
}
```

HW Connection



MMC interface

MMC back view

ONEWIRE LIBRARY

The OneWire library provides routines for communication via the Dallas OneWire protocol, e.g. with DS18x20 digital thermometer. OneWire is a Master/Slave protocol, and all communication cabling required is a single wire. OneWire enabled devices should have open collector drivers (with single pull-up resistor) on the shared data line.

Slave devices on the OneWire bus can even get their power supply from data line. For detailed schematic see device datasheet.

Some basic characteristics of this protocol are:

- single master system,
- low cost,
- low transfer rates (up to 16 kbps),
- fairly long distances (up to 300 meters),
- small data transfer packages.

Each OneWire device has also a unique 64-bit registration number (8-bit device type, 48-bit serial number and 8-bit CRC), so multiple slaves can co-exist on the same bus.

Note: Oscillator frequency Fosc needs to be at least 8MHz in order to use the routines with Dallas digital thermometers.

External dependencies of OneWire Library

The following variables must be defined in all projects using Manchester Code Library:	Description:	Example:
`extern sfr sbit OW_Bit_Read;`	OneWire read line.	`sbit OW_Bit_Read at PINB.B2;`
`extern sfr sbit OW_Bit_Write;`	OneWire write line.	`sbit OW_Bit_Write at PORTB.B2;`
`extern sfr sbit OW_Bit_Direction;`	Direction of the OneWire pin.	`sbit OW_Bit_Direction at DDRB.B2;`

Library Routines

- Ow_Reset
- Ow_Read
- Ow_Write

Ow_Reset

Prototype	`unsigned short Ow_Reset();`
Returns	- `0` if the device is present - `1` if the device is not present
Description	Issues OneWire reset signal for DS18x20. Parameters : - None.
Requires	Devices compliant with the Dallas OneWire protocol. Global variables : - `OW_Bit_Read`: OneWire read line - `OW_Bit_Write`: OneWire write line. - `OW_Bit_Direction`: Direction of the OneWire pin must be defined before using this function.
Example	`// Issue Reset signal on One-Wire Bus` `Ow_Reset();`

Ow_Read

Prototype	`unsigned short Ow_Read();`
Returns	Data read from an external device over the OneWire bus.
Description	Reads one byte of data via the OneWire bus.
Requires	Devices compliant with the Dallas OneWire protocol. Global variables : - `OW_Bit_Read`: OneWire read line - `OW_Bit_Write`: OneWire write line. - `OW_Bit_Direction`: Direction of the OneWire pin must be defined before using this function.

Example	`// Read a byte from the One-Wire Bus`
	`unsigned short read_data;`
	`...`
	`read_data = Ow_Read();`

Ow_Write

Prototype	`void Ow_Write(char data_);`
Returns	Nothing.
Description	Writes one byte of data via the OneWire bus. Parameters : - `data_`: data to be written
Requires	Devices compliant with the Dallas OneWire protocol. Global variables : - `OW_Bit_Read`: OneWire read line - `OW_Bit_Write`: OneWire write line. - `OW_Bit_Direction`: Direction of the OneWire pin must be defined before using this function.
Example	`// Send a byte to the One-Wire Bus` `Ow_Write(0xCC);`

Library Example

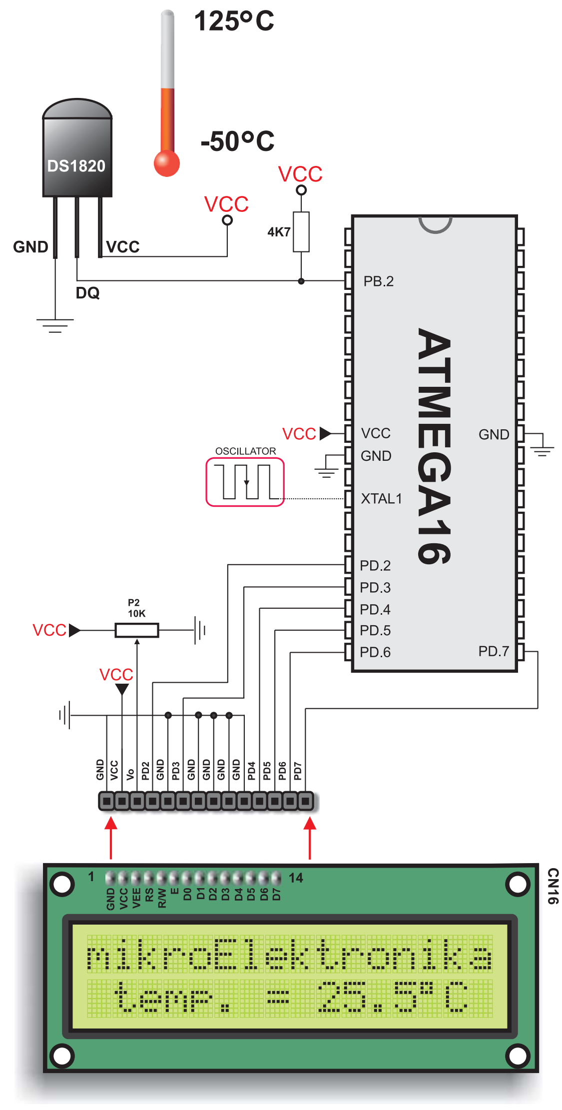
This example reads the temperature using DS18x20 connected to pin PORTB.2. After reset, MCU obtains temperature from the sensor and prints it on the LCD. Make sure to pull-up PORTB.2 line and to turn off the PORTB leds.

```
// LCD module connections
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;

sbit LCD_D4 at PORTD.B4;
sbit LCD_D5 at PORTD.B5;
sbit LCD_D6 at PORTD.B6;
sbit LCD_D7 at PORTD.B7;

sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D4_Direction at DDRD.B4;
sbit LCD_D5_Direction at DDRD.B5;
sbit LCD_D6_Direction at DDRD.B6;
sbit LCD_D7_Direction at DDRD.B7;
// End LCD module connections

// OneWire pinout
sbit OW_Bit_Write      at PORTB.B2;
sbit OW_Bit_Read       at PINB.B2;
sbit OW_Bit_Direction at DDRB.B2;
// end OneWire definition

//   Set  TEMP_RESOLUTION  to  the  corresponding  resolution  of  used
DS18x20 sensor:
//  18S20: 9  (default setting; can be 9,10,11,or 12)
//  18B20: 12
const unsigned short TEMP_RESOLUTION = 9;

char *text = "000.0000";
unsigned temp;

void Display_Temperature(unsigned int temp2write) {
  const unsigned short RES_SHIFT = TEMP_RESOLUTION - 8;
  char temp_whole;
  unsigned int temp_fraction;

// check if temperature is negative
  if (temp2write & 0x8000) {
     text[0] = '-';
     temp2write = ~temp2write + 1;
     }
```

```
   // extract temp_whole
    temp_whole = temp2write >> RES_SHIFT ;

    // convert temp_whole to characters
    if (temp_whole/100)
       text[0] = temp_whole/100  + 48;

    text[1] = (temp_whole/10)%10 + 48;             // Extract tens digit
    text[2] =  temp_whole%10     + 48;             // Extract ones digit

    // extract temp_fraction and convert it to unsigned int
    temp_fraction  = temp2write << (4-RES_SHIFT);
    temp_fraction &= 0x000F;
    temp_fraction *= 625;

    // convert temp_fraction to characters
    text[4] =  temp_fraction/1000    + 48;    // Extract thousands digit
    text[5] = (temp_fraction/100)%10 + 48;    // Extract hundreds digit
    text[6] = (temp_fraction/10)%10  + 48;         // Extract tens digit
    text[7] =  temp_fraction%10      + 48;         // Extract ones digit

    // print temperature on LCD
    Lcd_Out(2, 5, text);
  }

  void main() {

    Lcd_Init();                                        // Initialize LCD
    Lcd_Cmd(LCD_CLEAR);                                 // Clear LCD
    Lcd_Cmd(LCD_CURSOR_OFF);                          // Turn cursor off
    Lcd_Out(1, 1, " Temperature:   ");
    // Print degree character, 'C' for Centigrades
    Lcd_Chr(2,13,223);
    Lcd_Chr(2,14,'C');

    //--- main loop
    do {
      //--- perform temperature reading
      Ow_Reset();                                 // Onewire reset signal
      Ow_Write(0xCC);                            // Issue command SKIP_ROM
      Ow_Write(0x44);                           // Issue command CONVERT_T
      Delay_us(120);

    Ow_Reset();
      Ow_Write(0xCC);                            // Issue command SKIP_ROM
      Ow_Write(0xBE);                      // Issue command READ_SCRATCHPAD

      temp =  Ow_Read();
      temp = (Ow_Read() << 8) + temp;
```

```
        //--- Format and display result on Lcd
        Display_Temperature(temp);

        Delay_ms(500);
    } while (1);
}
```

HW Connection



Example of DS1820 connection

PORT EXPANDER LIBRARY

The mikroC PRO for AVR provides a library for communication with the Microchip's Port Expander MCP23S17 via SPI interface. Connections of the AVR compliant MCU and MCP23S17 is given on the schematic at the bottom of this page.

Note: Library uses the SPI module for communication. The user must initialize SPI module before using the Port Expander Library.

Note: Library does not use Port Expander interrupts.

External dependencies of Port Expander Library

The following variables must be defined in all projects using Manchester Code Library:	Description:	Example:
`extern sfr sbit SPExpanderRST;`	Reset line.	`sbit SPExpanderRST at PORTB.B0;`
`extern sfr sbit SPExpanderCS;`	Chip Select line.	`sbit SPExpanderCS at PORTB.B1;`
`extern sfr sbit SPExpanderRST_Direction;`	Direction of the Reset pin.	`sbit SPExpanderRST_Direction at DDRB.B0;`
`extern sfr sbit SPExpanderCS_Direction;`	Direction of the Chip Select pin.	`sbit SPExpanderCS_Direction at DDRB.B1;`

Library Routines

- Expander_Init
- Expander_Read_Byte
- Expander_Write_Byte
- Expander_Read_PortA
- Expander_Read_PortB
- Expander_Read_PortAB
- Expander_Write_PortA
- Expander_Write_PortB
- Expander_Write_PortAB
- Expander_Set_DirectionPortA
- Expander_Set_DirectionPortB
- Expander_Set_DirectionPortAB
- Expander_Set_PullUpsPortA
- Expander_Set_PullUpsPortB
- Expander_Set_PullUpsPortAB

Expander_Init

Prototype	`void Expander_Init(char ModuleAddress);`
Returns	Nothing.
Description	Initializes Port Expander using SPI communication. Port Expander module settings : - hardware addressing enabled - automatic address pointer incrementing disabled (byte mode) - BANK_0 register adressing - slew rate enabled Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page
Requires	Global variables : - `SPExpanderCS`: Chip Select line - `SPExpanderRST`: Reset line - `SPExpanderCS_Direction`: Direction of the Chip Select pin - `SPExpanderRST_Direction`: Direction of the Reset pin must be defined before using this function. SPI module needs to be initialized. See SPI_Init and SPI_Init_Advanced routines.
Example	see code below

```
// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS  at PORTB.B1;
sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections

// Pointer to appropriate SPI Read function
char (*SPI_Rd_Ptr)(char);

...

// If Port Expander Library uses SPI1 module
SPI_Rd_Ptr = &SPI1_Read;                    // Pass pointer to SPI 
Read function of used SPI module
SPI1_Init();                               // Initialize SPI module 
used with PortExpander
Expander_Init(0);                          // Initialize Port Expander
```

Expander_Read_Byte

Prototype	`char Expander_Read_Byte(char ModuleAddress, char RegAddress);`
Returns	Byte read.
Description	The function reads byte from Port Expander. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `RegAddress`: Port Expander's internal register address
Requires	Port Expander must be initialized. See Expander_Init.

Example	`// Read a byte from Port Expander's register`
	`char read_data;`
	`...`
	`read_data = Expander_Read_Byte(0,1);`

Expander_Write_Byte

Prototype	`void Expander_Write_Byte(char ModuleAddress,char RegAddress, char Data);`
Returns	Nothing.
Description	Routine writes a byte to Port Expander. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `RegAddress`: Port Expander's internal register address - `Data`: data to be written
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Write a byte to the Port Expander's register` `Expander_Write_Byte(0,1,$FF);`

Expander_Read_PortA

Prototype	`char Expander_Read_PortA(char ModuleAddress);`
Returns	Byte read.
Description	The function reads byte from Port Expander's PortA. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page
Requires	Port Expander must be initialized. See Expander_Init. Port Expander's PortA should be configured as input. See Expander_Set_DirectionPortA and Expander_Set_DirectionPortAB routines.

Example	`// Read a byte from Port Expander's PORTA`
	`char read_data;`
	`...`
	`Expander_Set_DirectionPortA(0,0xFF);        // set expander's porta to be input`
	`...`
	`read_data = Expander_Read_PortA(0);`

Expander_Read_PortB

Prototype	`char Expander_Read_PortB(char ModuleAddress);`
Returns	Byte read.
Description	The function reads byte from Port Expander's PortB. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page
Requires	Port Expander must be initialized. See Expander_Init. Port Expander's PortB should be configured as input. See Expander_Set_DirectionPortB and Expander_Set_DirectionPortAB routines.

Example	`// Read a byte from Port Expander's PORTB`
	`char read_data;`
	`...`
	`Expander_Set_DirectionPortB(0,0xFF);        // set expander's portb to be input`
	`...`
	`read_data = Expander_Read_PortB(0);`

Expander_Read_PortAB

Prototype	`unsigned int Expander_Read_PortAB(char ModuleAddress);`
Returns	Word read.
Description	The function reads word from Port Expander's ports. PortA readings are in the higher byte of the result. PortB readings are in the lower byte of the result. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page
Requires	Port Expander must be initialized. See Expander_Init. Port Expander's PortA and PortB should be configured as inputs. See Expander_Set_DirectionPortA, Expander_Set_DirectionPortB and Expander_Set_DirectionPortAB routines.

Example	`// Read a byte from Port Expander's PORTA and PORTB`
	`unsigned int read_data;`
	`...`
	`Expander_Set_DirectionPortAB(0,0xFFFF);        // set expander's porta and portb to be input`
	`...`
	`read_data = Expander_Read_PortAB(0);`

Expander_Write_PortA

Prototype	`void Expander_Write_PortA(char ModuleAddress, char Data);`
Returns	Nothing.
Description	The function writes byte to Port Expander's PortA. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data to be written
Requires	Port Expander must be initialized. See Expander_Init. Port Expander's PortA should be configured as output. See Expander_Set_DirectionPortA and Expander_Set_DirectionPortAB routines.

Example	`// Write a byte to Port Expander's PORTA`
	
	`...`
	`Expander_Set_DirectionPortA(0,0x00);         // set expander's porta to be output`
	`...`
	`Expander_Write_PortA(0, 0xAA);`

Expander_Write_PortB

Prototype	`void Expander_Write_PortB(char ModuleAddress, char Data);`
Returns	Nothing.
Description	The function writes byte to Port Expander's PortB. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data to be written
Requires	Port Expander must be initialized. See Expander_Init. Port Expander's PortB should be configured as output. See Expander_Set_DirectionPortB and Expander_Set_DirectionPortAB routines.

Example	`// Write a byte to Port Expander's PORTB`
	
	`...`
	`Expander_Set_DirectionPortB(0,0x00);        // set expander's portb to be output`
	`...`
	`Expander_Write_PortB(0, 0x55);`

Expander_Write_PortAB

Prototype	`void Expander_Write_PortAB(char ModuleAddress, unsigned int Data);`
Returns	Nothing.
Description	The function writes word to Port Expander's ports. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data to be written. Data to be written to PortA are passed in Data's higher byte. Data to be written to PortB are passed in Data's lower byte
Requires	Port Expander must be initialized. See Expander_Init. Port Expander's PortA and PortB should be configured as outputs. See Expander_Set_DirectionPortA, Expander_Set_DirectionPortB and Expander_Set_DirectionPortAB routines.

Example	`// Write a byte to Port Expander's PORTA and PORTB`
	
	`...`
	`Expander_Set_DirectionPortAB(0,0x0000);         // set expander's porta and portb to be output`
	`...`
	`Expander_Write_PortAB(0, 0xAA55);`

Expander_Set_DirectionPortA

Prototype	`void Expander_Set_DirectionPortA(char ModuleAddress, char Data);`
Returns	Nothing.
Description	The function sets Port Expander's PortA direction. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data to be written to the PortA direction register. Each bit corresponds to the appropriate pin of the PortA register. Set bit designates corresponding pin as input. Cleared bit designates corresponding pin as output.
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Set Port Expander's PORTA to be output` `Expander_Set_DirectionPortA(0,0x00);`

Expander_Set_DirectionPortB

Prototype	`void Expander_Set_DirectionPortB(char ModuleAddress, char Data);`
Returns	Nothing.
Description	The function sets Port Expander's PortB direction. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data to be written to the PortB direction register. Each bit corresponds to the appropriate pin of the PortB register. Set bit designates corresponding pin as input. Cleared bit designates corresponding pin as output.
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Set Port Expander's PORTB to be input` `Expander_Set_DirectionPortB(0,0xFF);`

Expander_Set_DirectionPortAB

Prototype	`void Expander_Set_DirectionPortAB(char ModuleAddress, unsigned int Direction);`
Returns	Nothing.
Description	The function sets Port Expander's PortA and PortB direction. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Direction`: data to be written to direction registers. Data to be written to the PortA direction register are passed in `Direction`'s higher byte. Data to be written to the PortB direction register are passed in `Direction`'s lower byte. Each bit corresponds to the appropriate pin of the PortA/PortB register. Set bit designates corresponding pin as input. Cleared bit designates corresponding pin as output.
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Set Port Expander's PORTA to be output and PORTB to be input` `Expander_Set_DirectionPortAB(0,0x00FF);`

Expander_Set_PullUpsPortA

Prototype	`void Expander_Set_PullUpsPortA(char ModuleAddress, char Data);`
Returns	Nothing.
Description	The function sets Port Expander's PortA pull up/down resistors. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data for choosing pull up/down resistors configuration. Each bit corresponds to the appropriate pin of the PortA register. Set bit enables pull-up for corresponding pin.
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Set Port Expander's PORTA pull-up resistors` `Expander_Set_PullUpsPortA(0, 0xFF);`

Expander_Set_PullUpsPortB

Prototype	`void Expander_Set_PullUpsPortB(char ModuleAddress, char Data);`
Returns	Nothing.
Description	The function sets Port Expander's PortB pull up/down resistors. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `Data`: data for choosing pull up/down resistors configuration. Each bit corresponds to the appropriate pin of the PortB register. Set bit enables pull-up for corresponding pin.
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Set Port Expander's PORTB pull-up resistors` `Expander_Set_PullUpsPortB(0, 0xFF);`

Expander_Set_PullUpsPortAB

Prototype	`void Expander_Set_PullUpsPortAB(char ModuleAddress, unsigned int PullUps);`
Returns	Nothing.
Description	The function sets Port Expander's PortA and PortB pull up/down resistors. Parameters : - `ModuleAddress`: Port Expander hardware address, see schematic at the bottom of this page - `PullUps`: data for choosing pull up/down resistors configuration. PortA pull up/down resistors configuration is passed in `PullUps`'s higher byte. PortB pull up/down resistors configuration is passed in `PullUps`'s lower byte. Each bit corresponds to the appropriate pin of the PortA/PortB register. Set bit enables pull-up for corresponding pin.
Requires	Port Expander must be initialized. See Expander_Init.
Example	`// Set Port Expander's PORTA and PORTB pull-up resistors` `Expander_Set_PullUpsPortAB(0, 0xFFFF);`

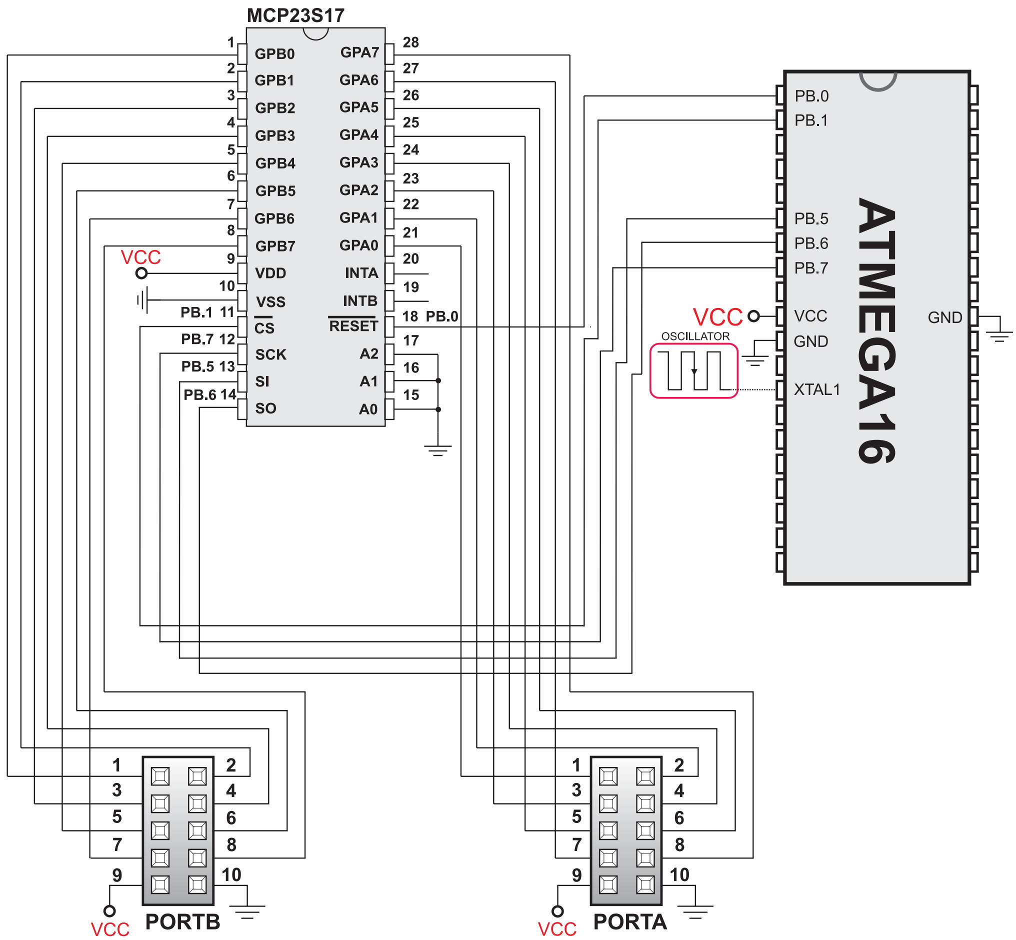
Library Example

The example demonstrates how to communicate with Port Expander MCP23S17.

Note that Port Expander pins A2 A1 A0 are connected to GND so Port Expander Hardware Address is `0`.

```
// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS  at PORTB.B1;
sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections

// Pointer to appropriate SPI Read function
char (*SPI_Rd_Ptr)(char);

unsigned char i = 0;

void main() {

  DDRC = 0xFF;                                    // Set PORTC as output

  // If Port Expander Library uses SPI1 module
  SPI1_Init();         // Initialize SPI module used with PortExpander
  SPI_Rd_Ptr = &SPI1_Read;      // Pass pointer to SPI Read function
of used SPI module

  //  // If Port Expander Library uses SPI2 module
  // SPI2_Init();      // Initialize SPI module used with PortExpander
  // SPI_Rd_Ptr = &SPI2_Read;   // Pass pointer to SPI Read function
of used SPI module

  Expander_Init(0);                            // Initialize Port Expander

  Expander_Set_DirectionPortA(0, 0x00);   // Set Expander's PORTA to
be output

  Expander_Set_DirectionPortB(0,0xFF);    // Set Expander's PORTB to
be input
  Expander_Set_PullUpsPortB(0,0xFF);       // Set pull-ups to all of
the Expander's PORTB pins

  while(1) {                                      // Endless loop
    Expander_Write_PortA(0, i++);       // Write i to expander's PORTA
     PORTC = Expander_Read_PortB(0);         // Read expander's PORTB
and write it to LEDs
     Delay_ms(100);
  }

}
```

HW Connection



Port Expander HW connection

PS/2 LIBRARY

The mikroC PRO for AVR provides a library for communication with the common PS/2 keyboard.

Note: The library does not utilize interrupts for data retrieval, and requires the oscillator clock to be at least 6MHz.

Note: The pins to which a PS/2 keyboard is attached should be connected to the pull-up resistors.

Note: Although PS/2 is a two-way communication bus, this library does not provide MCU-to-keyboard communication; e.g. pressing the Caps Lock key will not turn on the Caps Lock LED.

External dependencies of PS/2 Library

The following variables must be defined in all projects using Manchester Code Library:	Description:	Example:
`extern sfr sbit PS2_Data;`	PS/2 Data line.	`sbit PS2_Data at PINC.B0;`
`extern sfr sbit PS2_In_Clock;`	PS/2 Clock line in.	`sbit PS2_In_Clock at PINC.B1;`
`extern sfr sbit PS2_Out_Clock;`	PS/2 Clock line out.	`sbit PS2_Out_Clock at PORTC.B1;`
`extern sfr sbit PS2_Data_Direction;`	Direction of the PS/2 Data pin.	`sbit PS2_Data_Direction at DDRC.B0;`
`extern sfr sbit PS2_Clock_Direction;`	Direction of the PS/2 Clock pin.	`sbit PS2_Clock_Direction at DDRC.B0;`

Library Routines

- Ps2_Config
- Ps2_Key_Read

Ps2_Config

Prototype	`void Ps2_Config();`
Returns	Nothing.
Description	Initializes the MCU for work with the PS/2 keyboard.
Requires	Global variables : - `PS2_Data`: Data signal line - `PS2_In_Clock`: Clock signal line in - `PS2_Out_Clock`: Clock signal line out - `PS2_Data_Direction`: Direction of the Data pin - `PS2_Clock_Direction`: Direction of the Clock pin must be defined before using this function.

Example	`sbit PS2_Data at PINC.B0;`
	`sbit PS2_In_Clock at PINC.B1;`
	`sbit PS2_Out_Clock at PORTC.B1;`
	`sbit PS2_Data_Direction at DDRC.B0;`
	`sbit PS2_Clock_Direction at DDRC.B1;`
	`...`
	`Ps2_Config();          // Init PS/2 Keyboard`

Ps2_Key_Read

Prototype	`unsigned short Ps2_Key_Read(unsigned short *value, unsigned short *special, unsigned short *pressed);`
Returns	- `1` if reading of a key from the keyboard was successful - `0` if no key was pressed
Description	The function retrieves information on key pressed. Parameters : - `value`: holds the value of the key pressed. For characters, numerals, punctuation marks, and space `value` will store the appropriate ASCII code. Routine “recognizes” the function of Shift and Caps Lock, and behaves appropriately. For special function keys see Special Function Keys Table. - `special`: is a flag for special function keys (F1, Enter, Esc, etc). If key pressed is one of these, special will be set to 1, otherwise 0. - `pressed`: is set to 1 if the key is pressed, and 0 if it is released.
Requires	PS/2 keyboard needs to be initialized. See Ps2_Config routine.

Example	`unsigned short value, special, pressed;`
	`...`
	`// Press Enter to continue:`
	`do {`
	`  if (Ps2_Key_Read(&value, &special, &pressed)) {`
	`    if ((value == 13) && (special == 1)) break;`
	`  }`
	`} while (1);`

Special Function Keys

Key	Value returned
F1	1
F2	2
F3	3
F4	4
F5	5
F6	6
F7	7
F8	8
F9	9
F10	10
F11	11
F12	12
Enter	13
Page Up	14
Page Down	15
Backspace	16
Insert	17
Delete	18
Windows	19
Ctrl	20
Shift	21
Alt	22
Print Screen	23
Pause	24
Caps Lock	25
End	26
Home	27

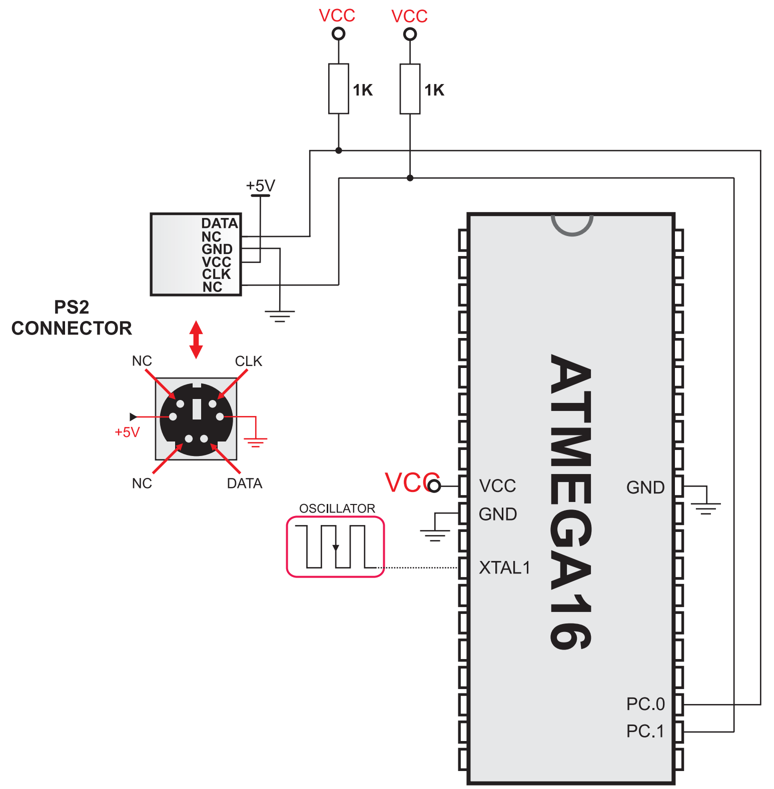
Scroll Lock	28
Num Lock	29
Left Arrow	30
Right Arrow	31
Up Arrow	32
Down Arrow	33
Escape	34
Tab	35

Library Example

This simple example reads values of the pressed keys on the PS/2 keyboard and sends them via UART.

```
unsigned short keydata = 0, special = 0, down = 0;

sbit PS2_Data at PINC.B0;
sbit PS2_In_Clock at PINC.B1;
sbit PS2_Out_Clock at PORTC.B1;

sbit PS2_Data_Direction at DDRC.B0;
sbit PS2_Clock_Direction at DDRC.B1;

void main() {
  ACSR.B7 = 1;                 // Disable analog comparators
  SREG.B7 = 0;                 // Disable all interrupts
  UART1_Init(19200);
  Ps2_Config();                // Init PS/2 Keyboard on PORTC
  Delay_ms(100);               // Wait for keyboard to finish
  UART1_Write('R');            // Ready

  do {
    if (Ps2_Key_Read(&keydata, &special, &down)) {
      if (down && (keydata == 16)) {         // Backspace
         UART1_Write(0x08);
      }
      else if (down && (keydata == 13)) {   // Enter
        UART1_Write('r');                    // send carriage return
to usart terminal
        //UART1_Write('n');                  // uncomment this line
if usart terminal also expects line feed
                                           // for new line transition
      }
      else if (down && !special && keydata) {
        UART1_Write(keydata);
      }
    }
    Delay_ms(10);               // debounce
  } while (1);
}
```

HW Connection



Example of PS2 keyboard connection

PWM LIBRARY

CMO module is available with a number of AVR MCUs. mikroC PRO for AVR provides library which simplifies using PWM HW Module.

Note: For better understanding of PWM module it would be best to start with the example provided in Examples folder of our mikroC PRO for AVR compiler. When you select a MCU, mikroC PRO for AVR automaticaly loads the correct PWM library (or libraries), which can be verified by looking at the Library Manager. PWM library handles and initializes the PWM module on the given AVR MCU, but it is up to user to set the correct pins as PWM output, this topic will be covered later in this section. mikroC PRO for AVR does not support enhanced PWM modules.

Library Routines

- PWM_Init
- PWM_Set_Duty
- PWM_Start
- PWM_Stop
- PWM1_Init
- PWM1_Set_Duty
- PWM1_Start
- PWM1_Stop

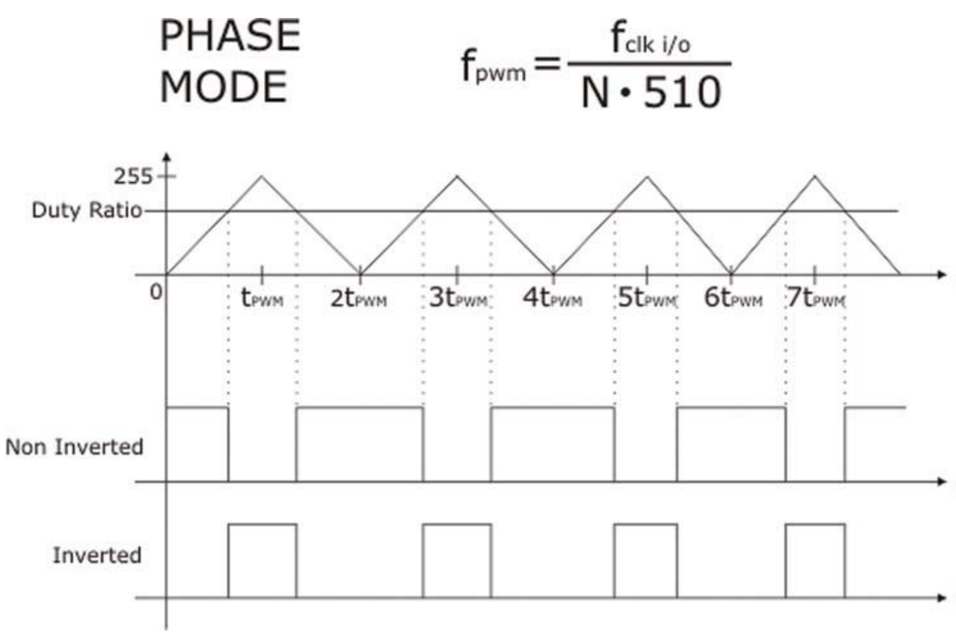
Predefined constants used in PWM library

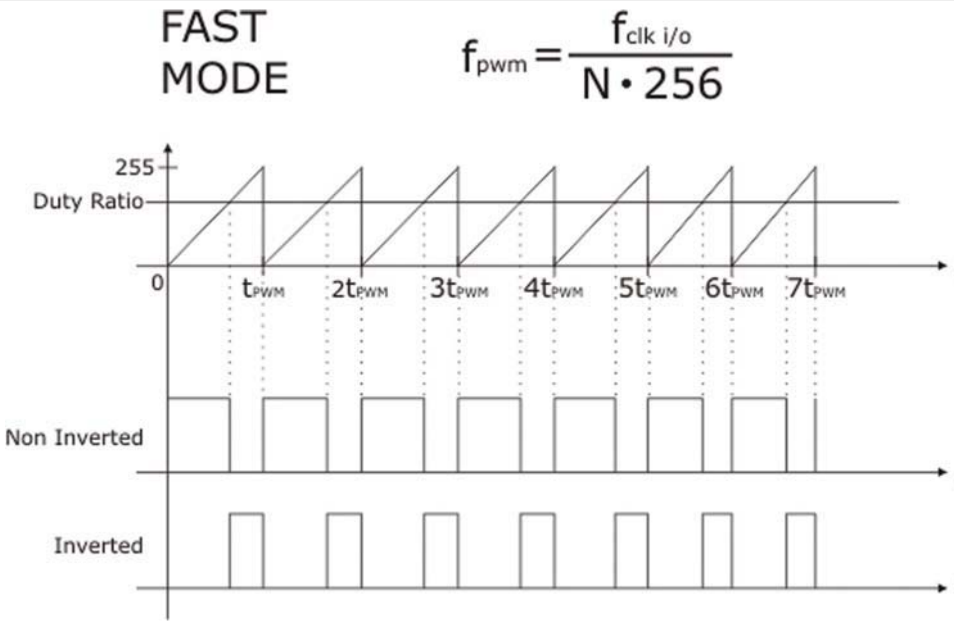
The following variables are used in PWM library functions:	Description:
`_PWM_PHASE_CORRECT_MODE`	Selects Phase Correct PWM mode on first PWM library.
`_PWM1_PHASE_CORRECT_MODE`	Selects Phase Correct PWM mode on second PWM library (if it exists in Library Manager.
`_PWM_FAST_MODE`	Selects Fast PWM mode on first PWM library.
`_PWM1_FAST_MODE`	Selects Fast PWM mode on second PWM library (if it exists in Library Manager.
`_PWM_PRESCALER_1`	Sets prescaler value to 1 (No prescaling).
`_PWM_PRESCALER_8`	Sets prescaler value to 8.

_PWM_PRESCALER_32	Sets prescaler value to 32 (this value is not available on every MCU. Please use Code Assistant to see if this value is available for the given MCU.
_PWM_PRESCALER_64	Sets prescaler value to 64.
_PWM_PRESCALER_128	Sets prescaler value to 128 (this value is not available on every MCU. Please use Code Assistant to see if this value is available for the given MCU.
_PWM_PRESCALER_256	Sets prescaler value to 256.
_PWM_PRESCALER_1024	Sets prescaler value to 1024.
_PWM1_PRESCALER_1	Sets prescaler value to 1 on second PWM library (if it exists in Library Manager).
_PWM1_PRESCALER_8	Sets prescaler value to 8 on second PWM library (if it exists in Library Manager).
_PWM1_PRESCALER_32	Sets prescaler value to 32 on second PWM library (if it exists in Library Manager). This value is not available on every MCU. Please use Code Assistant to see if this value is available for the given MCU.
_PWM1_PRESCALER_64	Sets prescaler value to 64 on second PWM library (if it exists in Library Manager).
_PWM1_PRESCALER_128	Sets prescaler value to 128 on second PWM library (if it exists in Library Manager). This value is not available on every MCU. Please use Code Assistant to see if this value is available for the given MCU.
_PWM1_PRESCALER_256	Sets prescaler value to 256 on second PWM library (if it exists in Library Manager).
_PWM1_PRESCALER_1024	Sets prescaler value to 1024 on second PWM library (if it exists in Library Manager).
_PWM_INVERTED	Selects the inverted PWM mode.
_PWM1_INVERTED	Selects the inverted PWM mode on second PWM library (if it exists in Library Manager).
_PWM_NON_INVERTED	Selects the normal (non inverted) PWM mode.
_PWM1_NON_INVERTED	Selects the normal (non inverted) PWM mode on second PWM library (if it exists in Library Manager).

Note: Not all of the MCUs have both PWM and PWM1 library included. Sometimes, like its the case with ATmega8515, MCU has only PWM library. Therefore constants that have in their name PWM1 are invalid (for ATmega8515) and will not be visible from Code Assistant. It is highly advisable to use this feature, since it handles all the constants (available) nad eliminates any chance of typing error.

PWM_Init

Prototype	`void PWM_Init(unsigned short wave_mode, unsigned short prescaler, unsigned short inverted, unsigned short duty);`
Returns	Nothing.
Description	Initializes the PWM module. Parameter `wave_mode` is a desired PWM mode. There are two modes: Phase Correct and Fast PWM. Parameter `prescaler` chooses prescale value N = 1,8,64,256 or 1024 (some modules support 32 and 128, but for this you will need to check the datasheet for the desired MCU). Paremeter `inverted` is for choosing between inverted and non inverted PWM signal. Parameter `duty` sets duty ratio from 0 to 255. PWM signal graphs and formulas are shown below.  The N variable represents the `prescaler` factor (1, 8, 64, 256, or 1024). Some modules also support 32 and 128 `prescaler` value, but for this you will need to check the datasheet for the desired MCU)

<table>
<tr><td>Description</td><td>
The N variable represents the <code>prescaler</code> factor (1, 8, 64, 256, or 1024). Some modules also support 32 and 128 <code>prescaler</code> value, but for this you will need to check the datasheet for the desired MCU)

PWM_Init must be called before using other functions from PWM Library.</td></tr>
<tr><td>Requires</td><td>You need a CMO on the given MCU (that supports PWM).

Before calling this routine you must set the output pin for the PWM (according to the datasheet):
<code>DDRB.3 = 1; // set PORTB pin 3 as output for the PWM</code>
This code oxample is for ATmega16, for different MCU please consult datasheet for the correct pinout of the PWM module or modules.</td></tr>
<tr><td>Example</td><td>Initialize PWM module:

<code>PWM_Init(_PWM_FAST_MODE, _PWM_PRESCALER_8, _PWM_NON_INVERTED, 127);</code></td></tr>
</table>

PWM_Set_Duty

Prototype	`void PWM_Set_Duty(unsigned short duty);`
Returns	Nothing.
Description	Changes PWM duty ratio. Parameter duty takes values from 0 to 255, where 0 is 0%, 127 is 50%, and 255 is 100% duty ratio. Other specific values for duty ratio can be calculated as `(Percent*255)/100`.
Requires	PWM module must to be initialised (PWM_Init) before using PWM_Set_Duty function.
Example	For example lets set duty ratio to 75%: `PWM_Set_Duty(192);`

PWM_Start

Prototype	`void PWM_Start();`
Returns	Nothing.
Description	Starts PWM.
Requires	MCU must have CMO module to use this library. PWM_Init must be called before using this routine.
Example	`PWM_Start();`

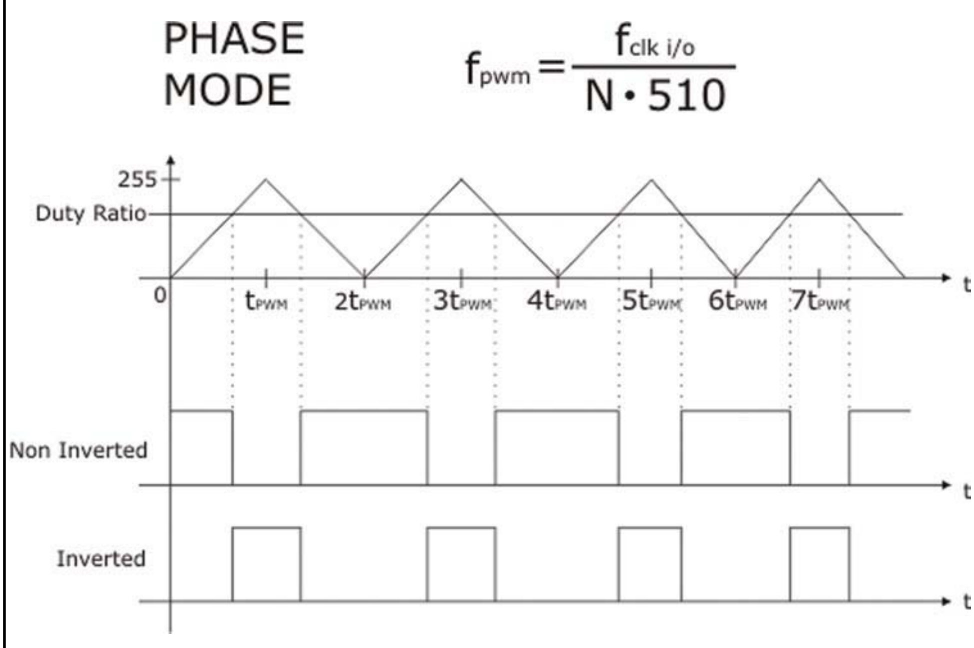
PWM_Stop

Prototype	`void PWM_Stop();`
Returns	Nothing.
Description	Stops the PWM.
Requires	MCU must have CMO module to use this library. PWM_Init and PWM_Start must be called before using this routine using this routine, otherwise it will have no effect as the PWM module is not running.
Example	`PWM_Stop();`

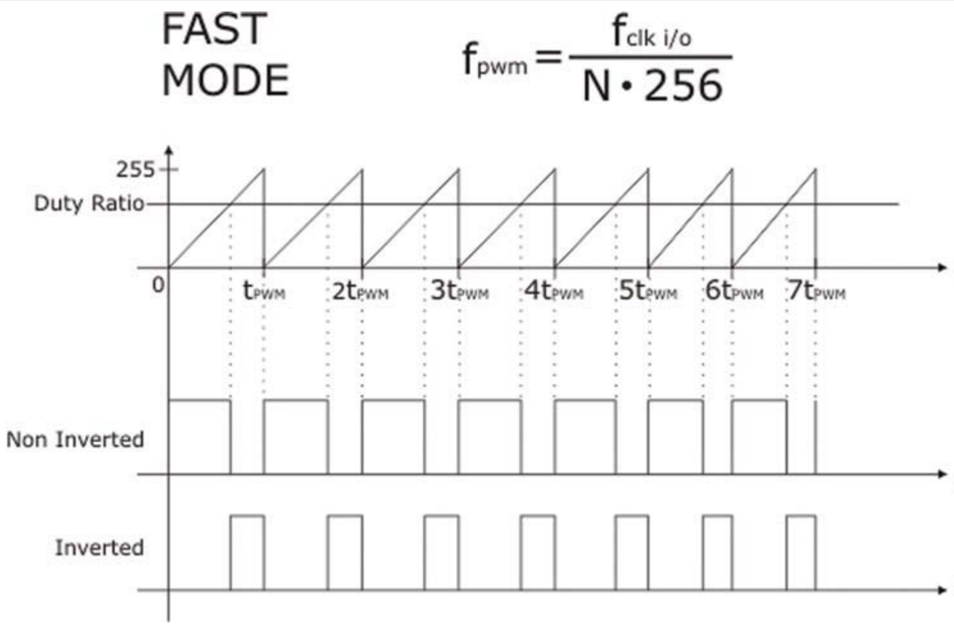
Note: Not all the AVR MCUs support both PWM and PWM1 library. The best way to verify this is by checking the datasheet for the desired MCU. Also you can check this by selecting a MCU in mikroC PRO for AVR looking at the Library Manager. If library manager loads both PWM and PWM1 library (you are able to check them) then this MCU supports both PWM libraries. Here you can take full advantage of our Code Assistant and Parameter Assistant feature of our compiler.

PWM1_Init

<table>
<tr><td>Prototype</td><td><code>void PWM1_Init(unsigned short wave_mode, unsigned short prescaler, unsigned short inverted, unsigned short duty);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initializes the PWM module. Parameter <code>wave_mode</code> is a desired PWM mode. There are two modes: Phase Correct and Fast PWM. Parameter <code>prescaler</code> chooses prescale value N = 1,8,64,256 or 1024 (some modules support 32 and 128, but for this you will need to check the datasheet for the desired MCU). Paremeter <code>inverted</code> is for choosing between inverted and non inverted PWM signal. Parameter <code>duty</code> sets duty ratio from 0 to 255. PWM signal graphs and formulas are shown below.



The N variable represents the <code>prescaler</code> factor (1, 8, 64, 256, or 1024). Some modules also support 32 and 128 <code>prescaler</code> value, but for this you will need to check the datasheet for the desired MCU)</td></tr>
</table>

<table>
<tr><td>Description</td><td>

The N variable represents the <code>prescaler</code> factor (1, 8, 64, 256, or 1024). Some modules also support 32 and 128 <code>prescaler</code> value, but for this you will need to check the datasheet for the desired MCU)

PWM1_Init must be called before using other functions from PWM Library.</td></tr>
<tr><td>Requires</td><td>You need a CMO on the given MCU (that supports PWM).

Before calling this routine you must set the output pin for the PWM (according to the datasheet):
<code>DDRD.7 = 1; // set PORTD pin 7 as output for the PWM1</code>
This code oxample is for ATmega16 (second PWM module), for different MCU please consult datasheet for the correct pinout of the PWM module or modules.</td></tr>
<tr><td>Example</td><td>Initialize PWM module:

<code>PWM1_Init(_PWM1_FAST_MODE, _PWM1_PRESCALER_8, _PWM1_NON_INVERTED, 127);</code></td></tr>
</table>

PWM1_Set_Duty

Prototype	`void PWM1_Set_Duty(unsigned short duty);`
Returns	Nothing.
Description	Changes PWM duty ratio. Parameter duty takes values from 0 to 255, where 0 is 0%, 127 is 50%, and 255 is 100% duty ratio. Other specific values for duty ratio can be calculated as `(Percent*255)/100`.
Requires	PWM module must to be initialised (PWM1_Init) before using PWM_Set_Duty function.
Example	For example lets set duty ratio to 75%: `PWM1_Set_Duty(192);`

PWM1_Start

Prototype	`void PWM1_Start();`
Returns	Nothing.
Description	Starts PWM.
Requires	MCU must have CMO module to use this library. PWM1_Init must be called before using this routine.
Example	`PWM1_Start();`

PWM1_Stop

Prototype	`void PWM1_Stop();`
Returns	Nothing.
Description	Stops the PWM.
Requires	MCU must have CMO module to use this library. PWM1_Init and PWM1_Start must be called before using this routine using this routine, otherwise it will have no effect as the PWM module is not running.
Example	`PWM1_Stop();`

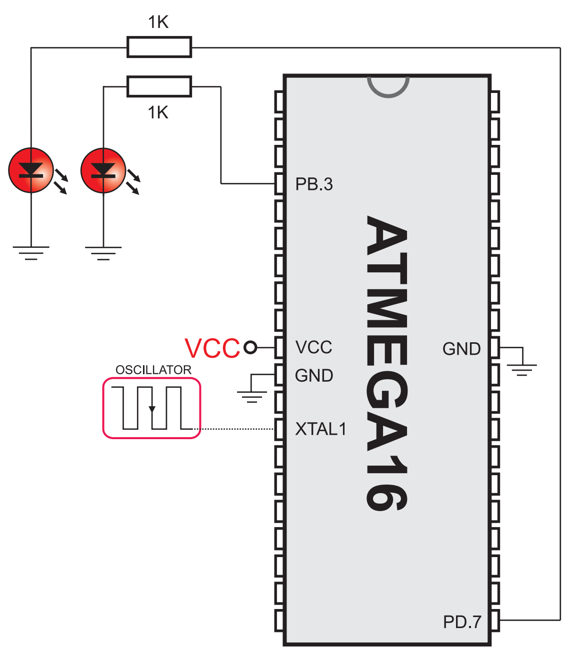
Library Example

The example changes PWM duty ratio on pin PB3 continually. If LED is connected to PB3, you can observe the gradual change of emitted light.

```
char current_duty;
char current_duty1;

void main(){

  DDB0 = 0;                          // Set PORTB pin 0 as input
  DDB1 = 0;                          // Set PORTB pin 1 as input

  DDC0 = 0;                          // Set PORTC pin 0 as input
  DDC1 = 0;                          // Set PORTC pin 1 as input

  current_duty      = 127;         // initial value for current_duty
  current_duty1     = 127;         // initial value for current_duty

  DDRB.B3 = 1;                      // Set PORTB pin 3 as output pin
for the PWM (according to datasheet)
  DDRD.B7 = 1;                      // Set PORTD pin 7 as output pin
for the PWM (according to datasheet)

    PWM_Init(_PWM_FAST_MODE,  _PWM_PRESCALER_8,  _PWM_NON_INVERTED,
127);

   PWM1_Init(_PWM1_FAST_MODE, _PWM1_PRESCALER_8, _PWM1_NON_INVERTED,
127);

  do {
    if (PINB.B0) {               // Detect if PORTB pin 0 is pressed
     Delay_ms(40);          // Small delay to avoid deboucing effect
      current_duty++;                          // Increment duty ratio
      PWM_Set_Duty(current_duty);             // Set incremented duty
    }
    else
      if (PINB.B1) {             // Detect if PORTB pin 1 is pressed
        Delay_ms(40);        // Small delay to avoid debouncing effect
         current_duty--;                       // Decrement duty ratio
        PWM_Set_Duty(current_duty);     // Set decremented duty ratio
      }
      else
        if (PINC.B0) {           // Detect if PORTC pin 0 is pressed
          Delay_ms(40);      // Small delay to avoid debouncing effect
           current_duty1++;                    // Increment duty ratio
           PWM1_Set_Duty(current_duty1);      // Set incremented duty
        }
```

```
  else
          if (PINC.B1) {          // Detect if PORTC pin 1 is pressed
            Delay_ms(40);   // Small delay to avoid debouching effect
            current_duty1--;                 // Decrement duty ratio
             PWM1_Set_Duty(current_duty1);         // Set decremented
duty ratio
           }

  }  while(1);                             // Endless loop

  }
```

HW Connection



PWM demonstration

PWM 16 BIT LIBRARY

CMO module is available with a number of AVR MCUs. mikroC PRO for AVR provides library which simplifies using PWM HW Module.

Note: For better understanding of PWM module it would be best to start with the example provided in Examples folder of our mikroC PRO for AVR compiler. When you select a MCU, mikroC PRO for AVR automaticaly loads the correct PWM-16bit library, which can be verified by looking at the Library Manager. PWM library handles and initializes the PWM module on the given AVR MCU, but it is up to user to set the correct pins as PWM output, this topic will be covered later in this section.

Library Routines

- PWM16bit_Init
- PWM16bit_Change_Duty
- PWM16bit_Start
- PWM16bit_Stop

Predefined constants used in PWM-16bit library

The following variables are used in PWM library functions:	Description:
`_PWM16_PHASE_CORRECT_MODE_8BIT`	Selects Phase Correct, 8-bit mode.
`_PWM16_PHASE_CORRECT_MODE_9BIT`	Selects Phase Correct, 9-bit mode.
`_PWM16_PHASE_CORRECT_MODE_10BIT`	Selects Phase Correct, 10-bit mode.
`_PWM16_FAST_MODE_8BIT`	Selects Fast, 8-bit mode.
`_PWM16_FAST_MODE_9BIT`	Selects Fast, 9-bit mode.
`_PWM16_FAST_MODE_10BIT`	Selects Fast, 10-bit mode.
`_PWM16_PRESCALER_16bit_1`	Sets prescaler value to 1 (No prescaling).
`_PWM16_PRESCALER_16bit_8`	Sets prescaler value to 8.
`_PWM16_PRESCALER_16bit_64`	Sets prescaler value to 64.
`_PWM16_PRESCALER_16bit_256`	Sets prescaler value to 256.

_PWM16_PRESCALER_16bit_1024	Sets prescaler value to 1024.
_PWM16_INVERTED	Selects the inverted PWM-16bit mode.
_PWM16__NON_INVERTED	Selects the normal (non inverted) PWM-16bit mode.
_TIMER1	Selects the Timer/Counter1 (used with PWM16bit_Start and PWM16bit_Stop.
_TIMER3	Selects the Timer/Counter3 (used with PWM16bit_Start and PWM16bit_Stop.
_TIMER1_CH_A	Selects the channel A on Timer/Counter1 (used with PWM16bit_Change_Duty).
_TIMER1_CH_B	Selects the channel B on Timer/Counter1 (used with PWM16bit_Change_Duty).
_TIMER1_CH_C	Selects the channel C on Timer/Counter1 (used with PWM16bit_Change_Duty).
_TIMER3_CH_A	Selects the channel A on Timer/Counter3 (used with PWM16bit_Change_Duty).
_TIMER3_CH_B	Selects the channel B on Timer/Counter3 (used with PWM16bit_Change_Duty).
_TIMER3_CH_C	Selects the channel C on Timer/Counter3 (used with PWM16bit_Change_Duty).

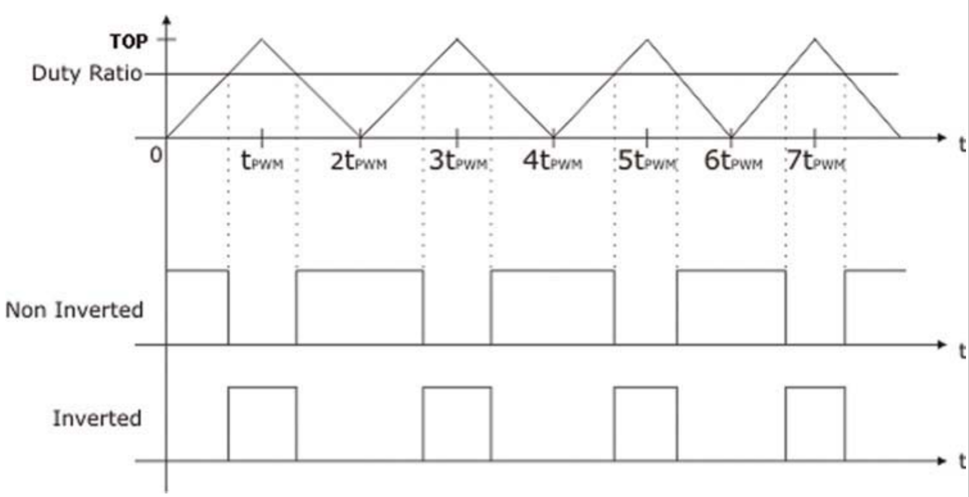
Note: Not all of the MCUs have 16bit PWM, and not all of the MCUs have both Timer/Counter1 and Timer/Counter3. Sometimes, like its the case with ATmega168, MCU has only Timer/Counter1 and channels A and B. Therefore constants that have in their name Timer3 or channel C are invalid (for ATmega168) and will not be visible from Code Assistant. It is highly advisable to use this feature, since it handles all the constants (available) and eliminates any chance of typing error.

PWM16bit_Init

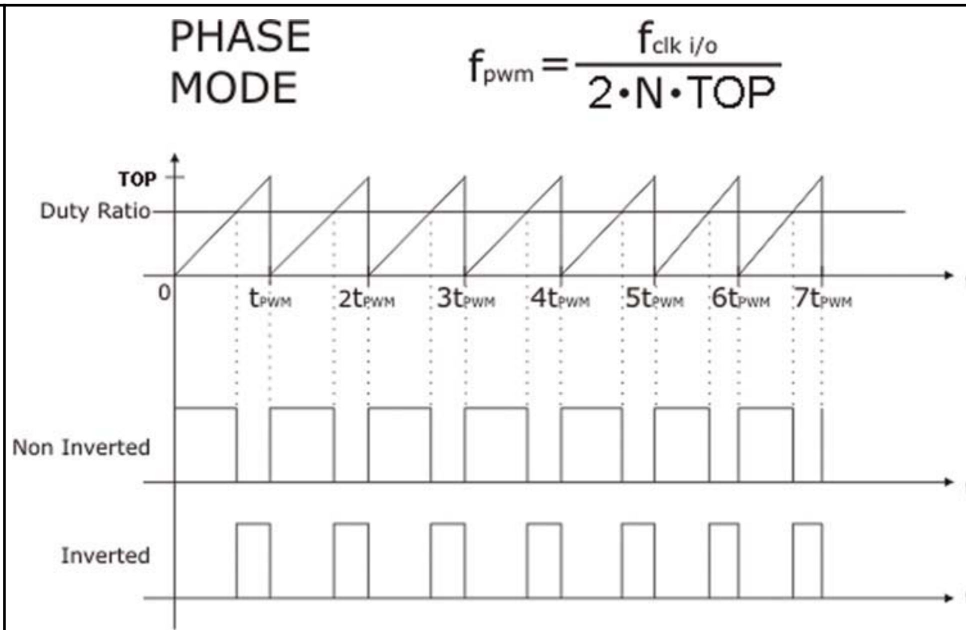
<table>
<tr><td>Prototype</td><td><code>void PWM16bit_Init(unsigned short wave_mode, unsigned short prescaler, unsigned short inverted, unsigned short duty);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>
Initializes the PWM module. Parameter <code>wave_mode</code> is a desired PWM-16bit mode.
There are several modes included :

- PWM, Phase Correct, 8-bit
- PWM, Phase Correct, 9-bit
- PWM, Phase Correct, 10-bit
- Fast PWM, 8-bit
- Fast PWM, 9-bit
- Fast PWM, 10-bit

Parameter <code>prescaler</code> chooses prescale value N = 1,8,64,256 or 1024 (some modules support 32 and 128, but for this you will need to check the datasheet for the desired MCU). Paremeter <code>inverted</code> is for choosing between inverted and non inverted PWM signal. Parameter <code>duty</code> sets duty ratio from 0 to TOP value (this value varies on the PWM wave mode selected). PWM signal graphs and formulas are shown below.

FAST MODE
$$f_{pwm} = \frac{f_{clk\ i/o}}{N \cdot (1+TOP)}$$


The N variable represents the <code>prescaler</code> factor (1, 8, 64, 256, or 1024).
</td></tr>
</table>

<table>
<tr><td>Description</td><td>


The N variable represents the <code>prescaler</code> factor (1, 8, 64, 256, or 1024).

PWM16bit_Init must be called before using other functions from PWM Library.
</td></tr>
<tr><td>Requires</td><td>
You need a CMO on the given MCU (that supports PWM-16bit).

Before calling this routine you must set the output pin for the PWM (according to the datasheet):
<code>DDRB.B1 = 1; // set PORTB pin 1 as output for the PWM-16bit</code>
This code example is for ATmega168, for different MCU please consult datasheet for the correct pinout of the PWM module or modules.
</td></tr>
<tr><td>Example</td><td>
Initialize PWM-16bit module:

<code>PWM16bit_Init(_PWM16_PHASE_CORRECT_MODE_8BIT, _PWM16_PRESCALER_16bit_8, _PWM16_NON_INVERTED, 255, _TIMER1);</code>
</td></tr>
</table>

PWM16bit_Change_Duty

<table>
<tr><td>Prototype</td><td><code>void PWM16bit_Change_Duty(unsigned duty, unsigned short channel);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Changes PWM duty ratio. Parameter duty takes values shown on the table below. Where 0 is 0%, and TOP value is 100% duty ratio. Other specific values for duty ratio can be calculated as <code>(Percent*TOP)/100</code>.
<table>
<tr><th>Timer/Counter Mode of Operation :</th><th>TOP :</th><th>Update of OCRnX at :</th><th>TOVn Flag Set on :</th></tr>
<tr><td>PWM, Phase Correct, 8 bit</td><td>0x00FF</td><td>TOP</td><td>BOTTOM</td></tr>
<tr><td>PWM, Phase Correct, 9 bit</td><td>0x01FF</td><td>TOP</td><td>BOTTOM</td></tr>
<tr><td>PWM, Phase Correct, 10 bit</td><td>0x03FF</td><td>TOP</td><td>BOTTOM</td></tr>
<tr><td>Fast PWM, 8 bit</td><td>0x00FF</td><td>TOP</td><td>TOP</td></tr>
<tr><td>Fast PWM, 9 bit</td><td>0x01FF</td><td>TOP</td><td>TOP</td></tr>
<tr><td>Fast PWM, 10 bit</td><td>0x03FF</td><td>TOP</td><td>TOP</td></tr>
</table></td></tr>
<tr><td>Requires</td><td>PWM module must to be initialised (PWM16bit_Init) before using PWM_Set_Duty function.</td></tr>
<tr><td>Example</td><td>Example lets set duty ratio to :
<code>PWM16bit_Change_Duty(300, _TIMER1_CH_A);</code></td></tr>
</table>

PWM16bit_Start

Prototype	`void PWM16bit_Start(unsigned int timer);`
Returns	Nothing.
Description	Starts PWM-16bit module with alredy preset values (wave mode, prescaler, inverted and duty) given in the PWM16bit_Init.
Requires	MCU must have CMO module to use this library. PWM16bit_Init must be called before using this routine, otherwise it will have no effect as the PWM module is not initialised.

Example	`PWM16bit_Start( _TIMER1 );       // Starts the PWM-16bit module on Timer/Counter1`
	
	or
	
	`PWM16bit_Start( _TIMER3 );       // Starts the PWM-16bit module on Timer/Counter3`

PWM16bit_Stop

Prototype	`void PWM16_Stop(unsigned int timer);`
Returns	Nothing.
Description	Stops the PWM-16bit module, connected to Timer/Counter set in this stop function.
Requires	MCU must have CMO module to use this library. Like in PWM16bit_Start before, PWM16bit_Init must be called before using this routine , otherwise it will have no effect as the PWM module is not running.

Example	`PWM16bit_Stop( _TIMER1 );        // Stops the PWM-16bit module on Timer/Counter1`
	
	or
	
	`PWM16bit_Stop( _TIMER3 );        // Stops the PWM-16bit module on Timer/Counter3`

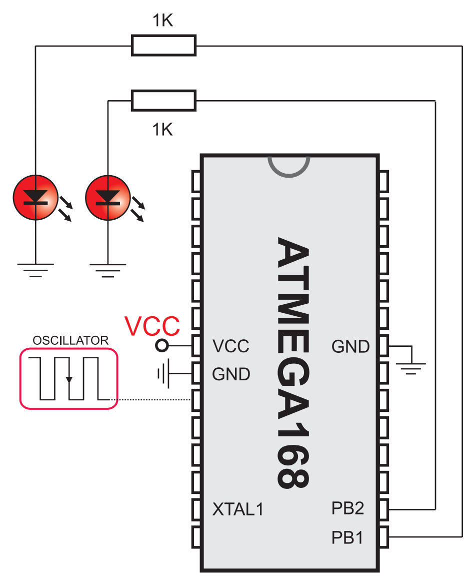
Library Example

The example changes PWM duty ratio continually by pressing buttons on PORC (0-3). If LED is connected to PORTB.1 or PORTB.2 ,you can observe the gradual change of emitted light. This example is written for ATmega168. This AVR MCU has only Timer/Counter1 split over two channels A and B. In this example we are changing the duty ratio on both of these channels.

```
char current_duty;
char current_duty1;

void main(){

  DDC0_bit = 0;                     // Set PORTC pin 0 as input
  DDC1_bit = 0;                     // Set PORTC pin 1 as input

  DDC2_bit = 0;                     // Set PORTC pin 2 as input
  DDC3_bit = 0;                     // Set PORTC pin 3 as input

  current_duty     = 255;          // initial value for current_duty
  current_duty1    = 255;          // initial value for current_duty

  DDRB.B1 = 1;                      // Set PORTB pin 1 as output pin
for the PWM (according to datasheet)
  DDRB.B2 = 1;                      // Set PORTB pin 2 as output pin
for the PWM (according to datasheet)

     PWM16bit_Init(_PWM16_FAST_MODE_9BIT,  _PWM16_PRESCALER_16bit_1,
_PWM16_INVERTED, 255, 1);

  do {
    if (PINC.B0) {         // Detect if PORTC pin 0 is pressed
      Delay_ms(40);      // Small delay to avoid deboucing effect
      current_duty++;             // Increment duty ratio
      PWM16bit_Change_Duty(current_duty, _TIMER1_CH_A);
// Set incremented duty
    }
    else
      if (PINC.B1) {              // Detect if PORTC pin 1 is pressed
        Delay_ms(40);      // Small delay to avoid deboucing effect
        current_duty--;           // Decrement duty ratio
        PWM16bit_Change_Duty(current_duty, _TIMER1_CH_A);
// Set decremented duty ratio
      }
      else
        if (PINC.B2) {            // Detect if PORTC pin 2 is pressed
          Delay_ms(40);    // Small delay to avoid deboucing effect
          current_duty1++;              // Increment duty ratio
          PWM16bit_Change_Duty(current_duty1, _TIMER1_CH_B);
// Set incremented duty
        }
```

```
else
            if (PINC.B3) {       // Detect if PORTC pin 3 is pressed
             Delay_ms(40);    // Small delay to avoid deboucing effect
               current_duty1--;     // Decrement duty ratio
               PWM16bit_Change_Duty(current_duty1, _TIMER1_CH_B);
// Set decremented duty ratio
            }

  } while(1);                          // Endless loop

  }
```

HW Connection



PWM demonstration

RS-485 LIBRARY

RS-485 is a multipoint communication which allows multiple devices to be connected to a single bus. The mikroC PRO for AVR provides a set of library routines for comfortable work with RS485 system using Master/Slave architecture. Master and Slave devices interchange packets of information. Each of these packets contains synchronization bytes, CRC byte, address byte and the data. Each Slave has unique address and receives only packets addressed to it. The Slave can never initiate communication.

It is the user's responsibility to ensure that only one device transmits via 485 bus at a time.

The RS-485 routines require the UART module. Pins of UART need to be attached to RS-485 interface transceiver, such as LTC485 or similar (see schematic at the bottom of this page).

Library constants:

- START byte value = 150
- STOP byte value = 169
- Address 50 is the broadcast address for all Slaves (packets containing address 50 will be received by all Slaves except the Slaves with addresses 150 and 169).

Note:

- Prior to calling any of this library routines, UART_Wr_Ptr needs to be initialized with the appropriate UART_Write routine.
- Prior to calling any of this library routines, UART_Rd_Ptr needs to be initialized with the appropriate UART_Read routine.
- Prior to calling any of this library routines, UART_Rdy_Ptr needs to be initialized with the appropriate UART_Ready routine.
- Prior to calling any of this library routines, UART_TX_Idle_Ptr needs to be initialized with the appropriate UART_TX_Idle routine.

External dependencies of RS-485 Library

The following variable must be defined in all projects using RS-485 Library:	Description:	Example :
`extern sfr sbit RS485_rxtx_pin;`	Control RS-485 Transmit/Receive operation mode	`sbit RS485_rxtx_pin at PORTD.B2;`
`extern sfr sbit RS485_rxtx_pin_direction;`	Direction of the RS-485 Transmit/Receive pin	`sbit RS485_rxtx_pin_direction at DDRD.B2;`

Library Routines

- RS485Master_Init
- RS485Master_Receive
- RS485Master_Send
- RS485Slave_Init
- RS485Slave_Receive
- RS485Slave_Send

RS485Master_Init

Prototype	`void RS485Master_Init();`
Returns	Nothing.
Description	Initializes MCU as a Master for RS-485 communication.
Requires	Global variables : - `RS485_rxtx_pin` - this pin is connected to RE/DE input of RS-485 transceiver(see schematic at the bottom of this page). RE/DE signal controls RS-485 transceiver operation mode. - `RS485_rxtx_pin_direction` - direction of the RS-485 Transmit/Receive pin must be defined before using this function. UART HW module needs to be initialized. See UARTx_Init.

Example	<pre>// RS485 module pinout
	sbit RS485_rxtx_pin_direction at PORTC.B2; // transmit/receive control set to PORTC.Bit2
	
	// Pin direction
	sbit RS485_rxtx_pin_direction at DDRD.B2; // RxTx pin direction set as output
	 // Pass pointers to UART functions of used UART module
	UART_Wr_Ptr = UART1_Write;
	UART_Rd_Ptr = UART1_Read;
	UART_Rdy_Ptr = UART1_Data_Ready;
	UART_TX_Idle_Ptr = UART1_TX_Idle;
	
	...
	UART1_Init(9600); // initialize UART1 module
	RS485Master_Init(); // intialize MCU as a Master for RS-485 communication</pre>

RS485Master_Receive

Prototype	`void RS485Master_Receive(char *data_buffer);`
Returns	Nothing.
Description	Receives messages from Slaves. Messages are multi-byte, so this routine must be called for each byte received. Parameters : - `data_buffer`: 7 byte buffer for storing received data, in the following manner: - `data[0..2]` : message content - `data[3]` : number of message bytes received, 1–3 - `data[4]` : is set to 255 when message is received - `data[5]` : is set to 255 if error has occurred - `data[6]` : address of the Slave which sent the message The function automatically adjusts `data[4]` and `data[5]` upon every received message. These flags need to be cleared by software.
Requires	MCU must be initialized as a Master for RS-485 communication. See RS485Master_Init.

Example	`char msg[8];`
	`...`
	`RS485Master_Receive(msg);`

RS485Master_Send

Prototype	`void RS485Master_Send(char *data_buffer, char datalen, char Slave_address);`
Returns	Nothing.
Description	Sends message to Slave(s). Message format can be found at the bottom of this page. Parameters : - `data_buffer`: data to be sent - `datalen`: number of bytes for transmition. Valid values: 0...3. - `Slave_address`: Slave(s) address
Requires	MCU must be initialized as a Master for RS-485 communication. See RS485Master_Init. It is the user's responsibility to ensure (by protocol) that only one device sends data via 485 bus at a time.

Example	`char msg[8];`
	`...`
	`// send 3 bytes of data to Slave with address 0x12`
	`RS485Master_Send(msg, 3, 0x12);`

RS485Slave_Init

Prototype	`void RS485Slave_Init(char Slave_address);`
Returns	Nothing.
Description	Initializes MCU as a Slave for RS-485 communication. Parameters : - `Slave_address`: Slave address
Requires	Global variables : - `RS485_rxtx_pin` - this pin is connected to RE/DE input of RS-485 transceiver(see schematic at the bottom of this page). RE/DE signal controls RS-485 transceiver operation mode. Valid values: `1` (for transmitting) and `0` (for receiving) - `RS485_rxtx_pin_direction` - direction of the RS-485 Transmit/Receive pin must be defined before using this function. UART HW module needs to be initialized. See UARTx_Init.
Example	(see code below)

```
// RS485 module pinout
sbit RS485_rxtx_pin at PORTD.B2;      // transmit/receive control
set to PORTC.Bit2

// Pin direction
sbit RS485_rxtx_pin_direction at DDRD.B2;    // RxTx pin direction
set as output
 // Pass pointers to UART functions of used UART module
UART_Wr_Ptr = UART1_Write;
UART_Rd_Ptr = UART1_Read;
UART_Rdy_Ptr = UART1_Data_Ready;
UART_TX_Idle_Ptr = UART1_TX_Idle;

...
UART1_Init(9600);                    // initialize UART1 module
RS485Slave_Init(160);                 // intialize MCU as a Slave
for RS-485 communication with address 160
```

RS485Slave_Receive

Prototype	`void RS485Slave_Receive(char *data_buffer);`
Returns	Nothing.
Description	Receives messages from Master. If Slave address and Message address field don't match then the message will be discarded. Messages are multi-byte, so this routine must be called for each byte received. Parameters : - `data_buffer`: 6 byte buffer for storing received data, in the following manner: - `data[0..2]` : message content - `data[3]` : number of message bytes received, 1–3 - `data[4]` : is set to 255 when message is received - `data[5]` : is set to 255 if error has occurred The function automatically adjusts `data[4]` and `data[5]` upon every received message. These flags need to be cleared by software.
Requires	MCU must be initialized as a Slave for RS-485 communication. See RS485Slave_Init.

Example	`char msg[8];`
	`...`
	`RS485Slave_Read(msg);`

RS485Slave_Send

Prototype	`void RS485Slave_Send(char *data_buffer, char datalen);`
Returns	Nothing.
Description	Sends message to Master. Message format can be found at the bottom of this page. Parameters : - `data_buffer`: data to be sent - `datalen`: number of bytes for transmition. Valid values: 0...3.
Requires	MCU must be initialized as a Slave for RS-485 communication. See RS485Slave_Init. It is the user's responsibility to ensure (by protocol) that only one device sends data via 485 bus at a time.

Example	`char msg[8];`
	`...`
	`// send 2 bytes of data to the Master`
	`RS485Slave_Send(msg, 2);`
	
	Library Example

Library Example

This is a simple demonstration of RS485 Library routines usage.

Master sends message to Slave with address 160 and waits for a response. The Slave accepts data, increments it and sends it back to the Master. Master then does the same and sends incremented data back to Slave, etc.

Master displays received data on P0, while error on receive (0xAA) and number of consecutive unsuccessful retries are displayed on P1. Slave displays received data on P0, while error on receive (0xAA) is displayed on P1. Hardware configurations in this example are made for the EasyAVR5 board and ATMEGA16.

RS485 Master code:

```
char dat[10];                          // buffer for receving/send-
ing messages
char i,j;

sbit  RS485_rxtx_pin  at PORTD.B2;           // set transcieve pin
sbit  RS485_rxtx_pin_direction at DDRD.B2;   // set transcieve pin
direction

// Interrupt routine
void interrupt() org 0x16 {
  RS485Master_Receive(dat);
}

void main(){
  long cnt = 0;
  PORTA  = 0;                            // clear PORTA
  PORTB  = 0;                            // clear PORTB
  PORTC  = 0;                            // clear PORTC

  DDRA   = 0xFF;                         // set PORTA as output
  DDRB   = 0xFF;                         // set PORTB as output
  DDRC   = 0xFF;                         // set PORTB as output

  // Pass pointers to UART functions of used UART module
  UART_Wr_Ptr = UART1_Write;
  UART_Rd_Ptr = UART1_Read;
  UART_Rdy_Ptr = UART1_Data_Ready;
  UART_TX_Idle = UART1_TX_Idle;

  UART1_Init(9600);                      // initialize UART1 module
  Delay_ms(100);

  RS485Master_Init();                    // initialize MCU as Master
  dat[0]  = 0xAA;
  dat[1]  = 0xF0;
  dat[2]  = 0x0F;
  dat[4]  = 0;            // ensure that message received flag is 0
  dat[5]  = 0;                    // ensure that error flag is 0
  dat[6]  = 0;

  RS485Master_Send(dat,1,160);

  SREG_I   = 1;                     // enable global interrupt
  RXCIE    = 1;              // enable interrupt on usart receive

while (1){
                        // upon completed valid message receiving
                         //    data[4] is set to 255
    cnt++;
```

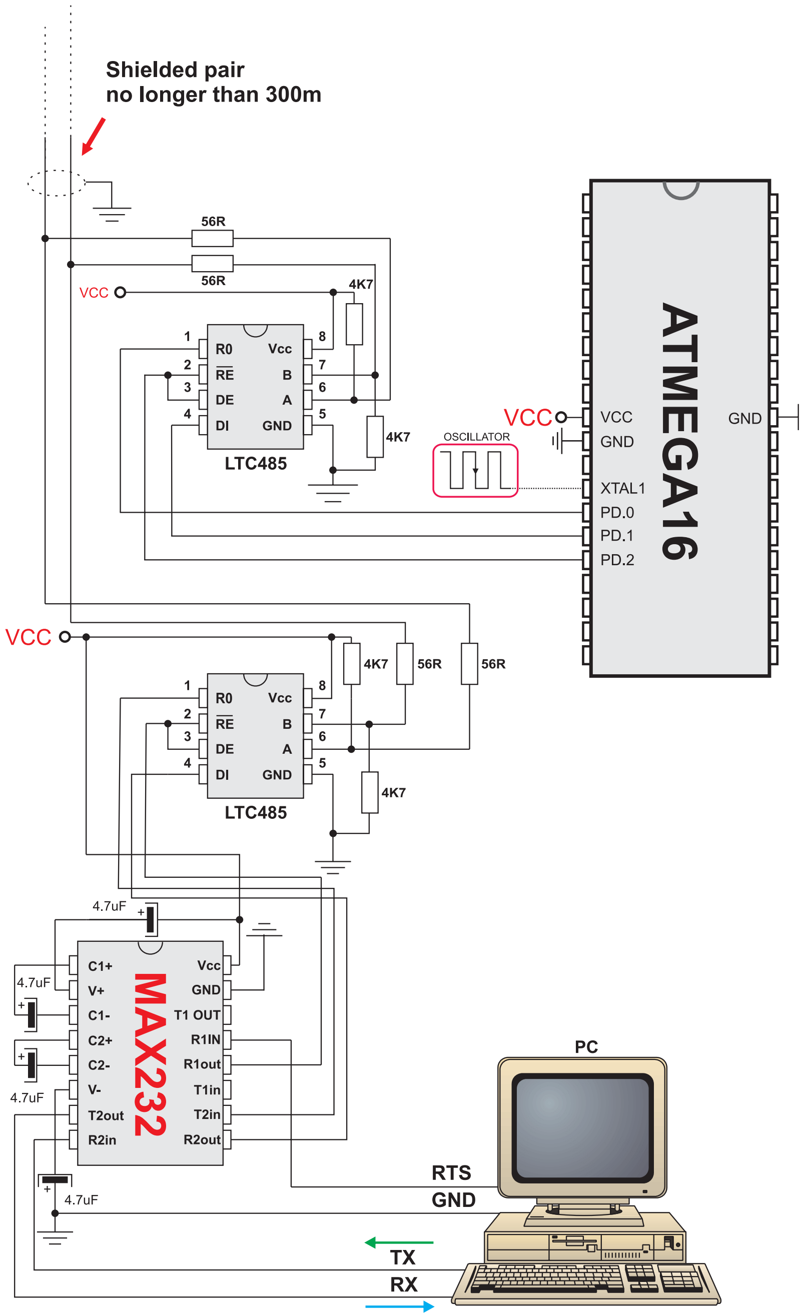
```
    if (dat[5])  {                  // if an error detected, signal it
      PORTC = dat[5];                      //   by setting PORTC
    }
    if (dat[4]) {                  // if message received successfully
      cnt = 0;
      dat[4]  = 0;                        // clear message received flag
      j = dat[3];
      for (i = 1; i <= dat[3]; i++) {   // show data on PORTB
        PORTB = dat[i-1];
     }                                    // increment received dat[0]
      dat[0]  = dat[0]+1;                  // send back to Slave
      Delay_ms(1);
      RS485Master_Send(dat,1,160);

    }

    if (cnt > 100000) {          // if in 100000 poll-cycles the answer
      PORTA++;                          //   was not detected, signal
      cnt = 0;                           //   failure of send-message
      RS485Master_Send(dat,1,160);
      if (PORTA > 10){                    // if sending failed 10 times
        PORTA = 0;
        RS485Master_Send(dat,1,50);     //   send message on broad-
cast address
      }
     }
   }
}
```

RS485 Slave code:

```
char dat[9];                // buffer for receving/sending messages
char i,j;

sbit  RS485_rxtx_pin  at PORTD.B2;            // set transcieve pin
sbit  RS485_rxtx_pin_direction at DDRD.B2;    // set transcieve pin
direction

// Interrupt routine
void interrupt() org 0x16 {
  RS485Slave_Receive(dat);
}

void main() {
  PORTB = 0;                              // clear PORTB
  PORTC = 0;                              // clear PORTC

  DDRB = 0xFF;                            // set PORTB as output
  DDRC = 0xFF;                            // set PORTB as output
```

```
    // Pass pointers to UART functions of used UART module
    UART_Wr_Ptr = UART1_Write;
    UART_Rd_Ptr = UART1_Read;
    UART_Rdy_Ptr = UART1_Data_Ready;
    UART_TX_Idle = UART1_TX_Idle;

    UART1_Init(9600);                    // initialize UART1 module
    Delay_ms(100);
    RS485Slave_Init(160);        // Intialize MCU as Slave, address 160

    dat[4] = 0;             // ensure that message received flag is 0
    dat[5] = 0;             // ensure that message received flag is 0
    dat[6] = 0;                     // ensure that error flag is 0

    SREG_I  = 1;                      // enable global interrupt
    RXCIE  = 1;                     // enable interrupt on usart receive

    while (1) {

      if (dat[5])  {              // if an error detected, signal it by
        PORTC = dat[5];                    //   setting PORTC
        dat[5] = 0;
      }
      if (dat[4]) {              // upon completed valid message receive
        dat[4] = 0;                        //   data[4] is set to 0xFF
        j = dat[3];

        for (i = 1; i <= dat[3];i++){   // show data on PORTB
          PORTB = dat[i-1];
        }
        dat[0] = dat[0]+1;                // increment received dat[0]
        Delay_ms(1);
        RS485Slave_Send(dat,1);         //   and send it back to Master
      }
    }
}
```

HW Connection



Example of interfacing PC to AVR MCU via RS485 bus with LTC485 as RS-485 transceiver

Message format and CRC calculations

Q: How is CRC checksum calculated on RS485 Master side?

```
START_BYTE = 0x96; // 10010110
STOP_BYTE  = 0xA9; // 10101001


PACKAGE:
--------
START_BYTE 0x96
ADDRESS
DATALEN
[ DATA1]              // if exists
[ DATA2]              // if exists
[ DATA3]              // if exists
CRC
STOP_BYTE  0xA9


DATALEN bits
------------
bit7 = 1  MASTER SENDS
       0   SLAVE  SENDS
bit6 = 1  ADDRESS WAS XORed with 1, IT WAS EQUAL TO START_BYTE or
STOP_BYTE
       0  ADDRESS UNCHANGED
bit5 = 0  FIXED
bit4 = 1   DATA3 (if exists) WAS XORed with 1, IT WAS EQUAL TO
START_BYTE or STOP_BYTE
       0  DATA3 (if exists) UNCHANGED
bit3 = 1   DATA2 (if exists) WAS XORed with 1, IT WAS EQUAL TO
START_BYTE or STOP_BYTE
       0  DATA2 (if exists) UNCHANGED
bit2 = 1   DATA1 (if exists) WAS XORed with 1, IT WAS EQUAL TO
START_BYTE or STOP_BYTE
       0  DATA1 (if exists) UNCHANGED
bit1bit0 = 0 to 3 NUMBER OF DATA BYTES SEND


CRC generation :
----------------
crc_send  = datalen ^ address;
crc_send ^= data[ 0] ;     // if exists
crc_send ^= data[ 1] ;     // if exists
crc_send ^= data[ 2] ;     // if exists
crc_send = ~crc_send;
if ((crc_send == START_BYTE) || (crc_send == STOP_BYTE))
   crc_send++;

NOTE:  DATALEN<4..0>  can  not  take  the  START_BYTE<4..0>  or
STOP_BYTE<4..0> values.
```

Software I^{2}C Library

The mikroC PRO for AVR provides routines for implementing Software I^{2}C communication. These routines are hardware independent and can be used with any MCU. The Software I^{2}C library enables you to use MCU as Master in I^{2}C communication. Multi-master mode is not supported.

Note: This library implements time-based activities, so interrupts need to be disabled when using Software I^{2}C.

Note: All Software I^{2}C Library functions are blocking-call functions (they are waiting for I^{2}C clock line to become logical one).

Note: The pins used for I^{2}C communication should be connected to the pull-up resistors. Turning off the LEDs connected to these pins may also be required.

External dependecies of Soft_I2C Library

The following variable must be defined in all projects using RS-485 Library:	Description:	Example :
`extern sbit Soft_I2C_Scl_Output;`	Soft I^{2}C Clock output line.	`sbit Soft_I2C_Scl_Output at PORTC.B0;`
`extern sbit Soft_I2C_Sda_Output;`	Soft I^{2}C Data output line.	`sbit Soft_I2C_Sda_Output at PORTC.B1;`
`extern sbit Soft_I2C_Scl_Input;`	Soft I^{2}C Clock input line.	`sbit Soft_I2C_Scl_Input at PINC.B0;`
`extern sbit Soft_I2C_Sda_Input;`	Soft I^{2}C Data input line.	`sbit Soft_I2C_Sda_Input at PINC.B1;`
`extern sbit Soft_I2C_Scl_Pin_Direction;`	Direction of the Soft I^{2}C Clock pin.	`sbit Soft_I2C_Scl_Pin_Direction at DDRC.B0;`
`extern sbit Soft_I2C_Sda_Pin_Direction;`	Direction of the Soft I^{2}C Data pin.	`sbit Soft_I2C_Sda_Pin_Direction at DDRC.B0;`

Library Routines

- Soft_I2C_Init
- Soft_I2C_Start
- Soft_I2C_Read
- Soft_I2C_Write
- Soft_I2C_Stop
- Soft_I2C_Break

Soft_I2C_Init

Prototype	`void Soft_I2C_Init();`
Returns	Nothing.
Description	Configures the software I^2C module.
Requires	Global variables : - `Soft_I2C_Scl`: Soft I C clock line - `Soft_I2C_Sda`: Soft I C data line - `Soft_I2C_Scl_Pin_Direction`: Direction of the Soft I C clock pin - `Soft_I2C_Sda_Pin_Direction`: Direction of the Soft I C data pin must be defined before using this function.

Example	`// Software I2C connections`
	`sbit Soft_I2C_Scl_Output     at PORTC.B0;`
	`sbit Soft_I2C_Sda_Output     at PORTC.B1;`
	`sbit Soft_I2C_Scl_Input      at PINC.B0;`
	`sbit Soft_I2C_Sda_Input      at PINC.B1;`
	`sbit Soft_I2C_Scl_Direction at DDRC.B0;`
	`sbit Soft_I2C_Sda_Direction at DDRC.B1;`
	`// End Software I2C connections`
	
	`...`
	`Soft_I2C_Init();`

Soft_I2C_Start

Prototype	`void Soft_I2C_Start(void);`
Returns	Nothing.
Description	Determines if the I^2C bus is free and issues START signal.
Requires	Software I^2C must be configured before using this function. See Soft_I2C_Init routine.
Example	`// Issue START signal` `Soft_I2C_Start();`

Soft_I2C_Read

Prototype	`unsigned short Soft_I2C_Read(unsigned int ack);`
Returns	One byte from the Slave.
Description	Reads one byte from the slave. Parameters : - `ack`: acknowledge signal parameter. If the `ack==0` not *acknowledge* signal will be sent after reading, otherwise the *acknowledge* signal will be sent.
Requires	Soft I˛C must be configured before using this function. See Soft_I2C_Init routine. Also, START signal needs to be issued in order to use this function. See Soft_I2C_Start routine.

Example	`unsigned short take;`
	`...`
	`// Read data and send the not_acknowledge signal`
	`take = Soft_I2C_Read(0);`

Soft_I2C_Write

Prototype	`unsigned short Soft_I2C_Write(unsigned short Data_);b`
Returns	- `0` if there were no errors. - `1` if write collision was detected on the I¸C bus.
Description	Sends data byte via the I¸C bus. Parameters : - `Data`: data to be sent
Requires	Soft I¸C must be configured before using this function. See Soft_I2C_Init routine. Also, START signal needs to be issued in order to use this function. See Soft_I2C_Start routine.

Example	`unsigned short data, error;`
	`...`
	`error = Soft_I2C_Write(data);`
	`error = Soft_I2C_Write(0xA3);`

Soft_I2C_Stop

Prototype	`void Soft_I2C_Stop(void);`
Returns	Nothing.
Description	Issues STOP signal.
Requires	Soft I^2C must be configured before using this function. See Soft_I2C_Init routine.
Example	`// Issue STOP signal` `Soft_I2C_Stop();`

Soft_I2C_Break

<table>
<tr><td>Prototype</td><td><code>void Soft_I2C_Break(void);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>All Software I2C Library functions can block the program flow (see note at the top of this page). Call this routine from interrupt to unblock the program execution. This mechanism is similar to WDT.

Note: Interrupts should be disabled before using Software I2C routins again (see note at the top of this page).</td></tr>
<tr><td>Requires</td><td>Nothing.</td></tr>
<tr><td>Example</td><td><pre>
// Software I2C connections
sbit Soft_I2C_Scl_Output   at PORTC.B0;
sbit Soft_I2C_Sda_Output   at PORTC.B1;
sbit Soft_I2C_Scl_Input   at PINC.B0;
sbit Soft_I2C_Sda_Input   at PINC.B1;
sbit Soft_I2C_Scl_Direction at DDRC.B0;
sbit Soft_I2C_Sda_Direction at DDRC.B1;
// End Software I2C connections

char counter = 0;

void Timer0Overflow_ISR() org 0x12 {

  if (counter >= 20) {
    Soft_I2C_Break();
    counter = 0;   // reset counter
  }
  else
    counter++;   // increment counter
}

void main() {

  TOIE0_bit = 1;   // Timer0 overflow interrupt
enable
  TCCR0_bit = 5;   // Start timer with 1024 prescaler

  SREG_I_bt = 0;   // Interrupt disable

  ...

  // try Soft_I2C_Init with blocking prevention mechanism
  SREG_I_bit = 1;   // Interrupt enable
  Soft_I2C_Init();
  SREG_I_bit = 0;   // Interrupt disable

  ...

}
</pre></td></tr>
</table>

Library Example

The example demonstrates Software I²C Library routines usage. The AVR MCU is connected (SCL, SDA pins) to PCF8583 RTC (real-time clock). Program reads date and time are read from the RTC and prints it on LCD.

```
char seconds, minutes, hours, day, month, year;    // Global date/time
variables

// Software I2C connections
sbit Soft_I2C_Scl_Output    at PORTC.B0;
sbit Soft_I2C_Sda_Output    at PORTC.B1;
sbit Soft_I2C_Scl_Input     at PINC.B0;
sbit Soft_I2C_Sda_Input     at PINC.B1;
sbit Soft_I2C_Scl_Direction at DDRC.B0;
sbit Soft_I2C_Sda_Direction at DDRC.B1;
// End Software I2C connections

// LCD module connections
sbit LCD_RS at PORTD.B2;
sbit LCD_EN at PORTD.B3;
sbit LCD_D4 at PORTD.B4;
sbit LCD_D5 at PORTD.B5;
sbit LCD_D6 at PORTD.B6;
sbit LCD_D7 at PORTD.B7;
sbit LCD_RS_Direction at DDRD.B2;
sbit LCD_EN_Direction at DDRD.B3;
sbit LCD_D4_Direction at DDRD.B4;
sbit LCD_D5_Direction at DDRD.B5;
sbit LCD_D6_Direction at DDRD.B6;
sbit LCD_D7_Direction at DDRD.B7;
// End LCD module connections


//-------------------- Reads time and date information from RTC
(PCF8583)
void Read_Time() {

  Soft_I2C_Start();             // Issue start signal
  Soft_I2C_Write(0xA0);       // Address PCF8583, see PCF8583 datasheet
  Soft_I2C_Write(2);           // Start from address 2
  Soft_I2C_Start();             // Issue repeated start signal
  Soft_I2C_Write(0xA1);        // Address PCF8583 for reading R/W=1

  seconds = Soft_I2C_Read(1);      // Read seconds byte
  minutes = Soft_I2C_Read(1);      // Read minutes byte
  hours = Soft_I2C_Read(1);        // Read hours byte
  day = Soft_I2C_Read(1);          // Read year/day byte
  month = Soft_I2C_Read(0);        // Read weekday/month byte
  Soft_I2C_Stop();                 // Issue stop signal
```

```
}

//-------------------- Formats date and time
void Transform_Time() {
  seconds  =  ((seconds & 0xF0) >> 4)*10 + (seconds & 0x0F);  // 
Transform seconds
  minutes  =  ((minutes & 0xF0) >> 4)*10 + (minutes & 0x0F);  // 
Transform months
  hours    =  ((hours & 0xF0)  >> 4)*10  + (hours & 0x0F);    // 
Transform hours
  year     =   (day & 0xC0) >> 6;                              // 
Transform year
  day      =  ((day & 0x30) >> 4)*10    + (day & 0x0F);        // 
Transform day
  month    =  ((month & 0x10)  >> 4)*10 + (month & 0x0F);      // 
Transform month
}

//-------------------- Output values to LCD
void Display_Time() {

   Lcd_Chr(1, 6, (day / 10)   + 48);    // Print tens digit of day 
variable
   Lcd_Chr(1, 7, (day % 10)   + 48);    // Print oness digit of day 
variable
   Lcd_Chr(1, 9, (month / 10) + 48);
   Lcd_Chr(1,10, (month % 10) + 48);
   Lcd_Chr(1,15,  year         + 56);    // Print year vaiable + 8 
(start from year 2008)

   Lcd_Chr(2, 6, (hours / 10)   + 48);
   Lcd_Chr(2, 7, (hours % 10)   + 48);
   Lcd_Chr(2, 9, (minutes / 10) + 48);
   Lcd_Chr(2,10, (minutes % 10) + 48);
   Lcd_Chr(2,12, (seconds / 10) + 48);
   Lcd_Chr(2,13, (seconds % 10) + 48);
}

//------------------ Performs project-wide init
void Init_Main() {

  Soft_I2C_Init();           // Initialize Soft I2C communication

  Lcd_Init();                // Initialize LCD
  Lcd_Cmd(LCD_CLEAR);        // Clear LCD display
  Lcd_Cmd(LCD_CURSOR_OFF);   // Turn cursor off
```

```
 Lcd_Out(1,1,"Date:");       // Prepare and output static text on LCD
  Lcd_Chr(1,8,':');
  Lcd_Chr(1,11,':');
  Lcd_Out(2,1,"Time:");
  Lcd_Chr(2,8,':');
  Lcd_Chr(2,11,':');
  Lcd_Out(1,12,"200");
}

//----------------- Main procedure
void main() {
  Init_Main();                  // Perform initialization

  while (1) {                   // Endless loop
    Read_Time();                // Read time from RTC(PCF8583)
    Transform_Time();           // Format date and time
    Display_Time();             // Prepare and display on LCD

    Delay_ms(1000);             // Wait 1 second
  }
}
```

SOFTWARE SPI LIBRARY

The mikroC PRO for AVR provides routines for implementing Software SPI communication. These routines are hardware independent and can be used with any MCU. The Software SPI Library provides easy communication with other devices via SPI: A/D converters, D/A converters, MAX7219, LTC1290, etc.

Library configuration:

- SPI to Master mode
- Clock value = 20 kHz.
- Data sampled at the middle of interval.
- Clock idle state low.
- Data sampled at the middle of interval.
- Data transmitted at low to high edge.

Note: The Software SPI library implements time-based activities, so interrupts need to be disabled when using it.

External dependencies of Software SPI Library

The following variables must be defined in all projects using Software SPI Library:	Description:	Example :
`extern sfr sbit Chip_Select;`	Chip select line.	`sbit Chip_Select at PORTB.B0;`
`extern sfr sbit SoftSpi_SDI;`	Data In line.	`sbit SoftSpi_SDI at PINB.B6;`
`extern sfr sbit SoftSpi_SDO;`	Data Out line.	`sbit SoftSpi_SDO at PORTB.B5;`
`extern sfr sbit SoftSpi_CLK;`	Clock line.	`sbit SoftSpi_CLK at PORTB.B7;`
`extern sfr sbit Chip_Select;`	Direction of the Chip select pin.	`sbit Chip_Select at PINB.B6;`
`extern sfr sbit Chip_Select_Direction;`	Direction of the Data In pin.	`sbit Chip_Select_Direction at DDRB.B0;`
`extern sfr sbit SoftSpi_SDO_Direction;`	Direction of the Data Out pin	`sbit SoftSpi_SDO_Direction at DDRB.B5;`
`extern sfr sbit SoftSpi_CLK_Direction;`	Direction of the Clock pin.	`sbit SoftSpi_CLK_Direction at DDRB.B7;`

Library Routines

- Soft_SPI_Init
- Soft_SPI_Read
- Soft_SPI_Write

Soft_SPI_Init

Prototype	`void Soft_SPI_Init();`
Returns	Nothing.
Description	Configures and initializes the software SPI module.
Requires	Global variables: - `Chip_Select`: Chip_Select line - `SoftSpi_SDI`: Data in line - `SoftSpi_SDO`: Data out line - `SoftSpi_CLK`: Data clock line - `Chip_Select_Direction`: Direction of the Chip_Select_Direction pin - `SoftSpi_SDI_Direction`: Direction of the Data in pin - `SoftSpi_SDO_Direction`: Direction of the Data out pin - `SoftSpi_CLK_Direction`: Direction of the Data clock pin must be defined before using this function.

Example	`// Software SPI module connections`
	`sbit Chip_Select at PORTB.B0;`
	`sbit SoftSpi_CLK at PORTB.B7;`
	`sbit SoftSpi_SDI at PINB.B6;   // Note: Input signal`
	`sbit SoftSpi_SDO at PORTB.B5;`
	
	`sbit Chip_Select_Direction at DDRB.B0;`
	`sbit SoftSpi_CLK_Direction at DDRB.B7;`
	`sbit SoftSpi_SDI_Direction at DDRB.B6;`
	`sbit SoftSpi_SDO_Direction at DDRB.B5;`
	`// End Software SPI module connections`
	`...`
	`Soft_SPI_Init(); // Init Soft_SPI`

Soft_SPI_Read

Prototype	`unsigned short Soft_SPI_Read(char sdata);`
Returns	Byte received via the SPI bus.
Description	This routine performs 3 operations simultaneously. It provides clock for the Software SPI bus, reads a byte and sends a byte. Parameters : - `sdata`: data to be sent.
Requires	Soft SPI must be initialized before using this function. See Soft_SPI_Init routine.

Example	`unsigned short data_read;`
	`char data_send;`
	`...`
	`// Read a byte and assign it to data_read variable`
	`// (data_send byte will be sent via SPI during the Read operation)`
	`data_read = Soft_SPI_Read(data_send);`

Soft_SPI_Write

Prototype	`void Soft_SPI_Write(char sdata);`
Returns	Nothing.
Description	This routine sends one byte via the Software SPI bus. Parameters : - `sdata`: data to be sent.
Requires	Soft SPI must be initialized before using this function. See Soft_SPI_Init routine.
Example	`// Write a byte to the Soft SPI bus` `Soft_SPI_Write(0xAA);`

Library Example

This code demonstrates using library routines for Soft_SPI communication. Also, this example demonstrates working with Microchip's MCP4921 12-bit D/A converter.

```
// DAC module connections
sbit Chip_Select at PORTB.B0;
sbit SoftSpi_CLK at PORTB.B7;
sbit SoftSpi_SDI at PINB.B6;  // Note: Input signal
sbit SoftSpi_SDO at PORTB.B5;

sbit Chip_Select_Direction at DDRB.B0;
sbit SoftSpi_CLK_Direction at DDRB.B7;
sbit SoftSpi_SDI_Direction at DDRB.B6;
sbit SoftSpi_SDO_Direction at DDRB.B5;
// End DAC module connections

unsigned int value;

void InitMain() {
  DDA0 = 0;                                      // Set PA0 pin as input
  DDA1 = 0;                                      // Set PA1 pin as input
  Chip_Select = 1;                               // Deselect DAC
  Chip_Select_Direction = 1;                    // Set CS# pin as Output
  Soft_SPI_Init();                               // Initialize Soft_SPI
}

// DAC increments (0..4095) --> output voltage (0..Vref)
void DAC_Output(unsigned int valueDAC) {
  char temp;

  Chip_Select = 0;                               // Select DAC chip

  // Send High Byte
  temp = (valueDAC >> 8) & 0x0F;                // Store valueDAC[11..8]
to temp[3..0]
  temp |= 0x30;                                   // Define DAC setting,
see MCP4921 datasheet
  Soft_SPI_Write(temp);                    // Send high byte via Soft SPI

  // Send Low Byte
  temp = valueDAC;                               // Store valueDAC[7..0]
to temp[7..0]
  Soft_SPI_Write(temp);                     // Send low byte via Soft SPI

  Chip_Select = 1;                               // Deselect DAC chip
}
```

```
void main() {

  InitMain();                          // Perform main initialization

  value = 2048;                        // When program starts, DAC gives
                                       //    the output in the mid-range

  while (1) {                                  // Endless loop

    if ((PINA.B0) && (value < 4095)) {     // If PA0 button is pressed
       value++;                                //    increment value
       }
     else {
       if ((PINA.B1) && (value > 0)) {      // If PA1 button is pressed
          value--;                             //    decrement value
          }
       }

     DAC_Output(value);                       // Send value to DAC chip
     Delay_ms(1);                           // Slow down key repeat pace
  }
}
```

SOFTWARE UART LIBRARY

The mikroC PRO for AVR provides routines for implementing Software UART communication. These routines are hardware independent and can be used with any MCU. The Software UART Library provides easy communication with other devices via the RS232 protocol.

Note: The Software UART library implements time-based activities, so interrupts need to be disabled when using it.

External dependencies of Software UART Library

The following variables must be defined in all projects using Software UART Library:	Description:	Example :
`extern sfr sbit Soft_UART_Rx_Pin;`	Receive line.	`sbit Soft_UART_Rx_Pin at PIND.B0;`
`extern sfr sbit Soft_UART_Tx_Pin;`	Transmit line.	`sbit Soft_UART_Tx_Pin at PORTD.B1;`
`extern sfr sbit Soft_UART_Rx_Pin_Direction;`	Direction of the Receive pin.	`sbit Soft_UART_Rx_Pin_Direction at DDRD.B0;`
`extern sfr sbit Soft_UART_Tx_Pin_Direction;`	Direction of the Transmit pin.	`sbit Soft_UART_Tx_Pin_Direction at DDRD.B1;`

Library Routines

- Soft_UART_Init
- Soft_UART_Read
- Soft_UART_Write
- Soft_UART_Break

Soft_UART_Init

<table>
<tr><td>Prototype</td><td><code>char Soft_UART_Init(unsigned long baud_rate, char inverted);</code></td></tr>
<tr><td>Returns</td><td>- <code>2</code> - error, requested baud rate is too low
- <code>1</code> - error, requested baud rate is too high
- <code>0</code> - successfull initialization</td></tr>
<tr><td>Description</td><td>Configures and initializes the software UART module.

Parameters :

- <code>baud_rate</code>: baud rate to be set. Maximum baud rate depends on the MCU’s clock and working conditions.
- <code>inverted</code>: inverted output flag. When set to a non-zero value, inverted logic on output is used.

Software UART routines use Delay_Cyc routine. If requested baud rate is too low then calculated parameter for calling <code>Delay_Cyc</code> exceeeds <code>Delay_Cyc</code> argument range.

If requested baud rate is too high then rounding error of <code>Delay_Cyc</code> argument corrupts Software UART timings.</td></tr>
<tr><td>Requires</td><td>Global variables:

- <code>Soft_UART_Rx_Pin</code>: Receiver pin
- <code>Soft_UART_Tx_Pin</code>: Transmiter pin
- <code>Soft_UART_Rx_Pin_Direction</code>: Direction of the Receiver pin
- <code>Soft_UART_Tx_Pin_Direction</code>: Direction of the Transmiter pin

must be defined before using this function.</td></tr>
<tr><td>Example</td><td><pre>// Soft UART connections
sbit Soft_UART_Rx_Pin at PIND.B0;
sbit Soft_UART_Tx_Pin at PORTD.B1;
sbit Soft_UART_Rx_Pin_Direction at DDRD.B0;
sbit Soft_UART_Tx_Pin_Direction at DDRD.B1;
// End Soft UART connections
...
// Initialize Software UART communication at 9600 bps.
Soft_UART_Init(9600, 0);</pre></td></tr>
</table>

Soft_UART_Read

Prototype	`char Soft_UART_Read(char * error);`
Returns	Byte received via UART.
Description	The function receives a byte via software UART. This is a blocking function call (waits for start bit). Programmer can unblock it by calling Soft_UART_Break routine. Parameters : - `error`: Error flag. Error code is returned through this variable. `0` - no error `1` - stop bit error `255` - user abort, Soft_UART_Break called
Requires	Software UART must be initialized before using this function. See the Soft_UART_Init routine.

Example	`char data, error;`
	`...`
	`// wait until data is received`
	`do`
	`  data = Soft_UART_Read(&error);`
	`while (error);`
	
	`// Now we can work with data:`
	`if (data) {...}`

Soft_UART_Write

Prototype	`void Soft_UART_Write(char udata);`
Returns	Nothing.
Description	This routine sends one byte via the Software UART bus. Parameters : - `udata:` data to be sent.
Requires	Software UART must be initialized before using this function. See the Soft_UART_Init routine. Be aware that during transmission, software UART is incapable of receiving data – data transfer protocol must be set in such a way to prevent loss of information.

Example	`char some_byte = 0x0A;`
	`...`
	`// Write a byte via Soft Uart`
	`Soft_UART_Write(some_byte);`

Soft_UART_Break

<table>
<tr><td>Prototype</td><td><code>void Soft_UART_Break();</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Soft_UART_Read is blocking routine and it can block the program flow. Call this routine from interrupt to unblock the program execution. This mechanism is similar to WDT.

Note: Interrupts should be disabled before using Software UART routines again (see note at the top of this page).</td></tr>
<tr><td>Requires</td><td>Nothing.</td></tr>
<tr><td>Example</td><td>See code below.</td></tr>
</table>

```
char data1, error, counter = 0;

void Timer0Overflow_ISR() org 0x12 {

  if (counter >= 20) {
    Soft_UART_Break();
    counter = 0;                    // reset counter
  }
  else
    counter++;                      // increment counter
}

void main() {

  TOIE0_bit   = 1;                        // Timer0 overflow inter-
rupt enable
  TCCR0_bit   = 5;                   // Start timer with 1024
prescaler

  SREG_I = 0;                       // Interrupt disable

  ...

  Soft_UART_Init(9600);
  Soft_UART_Write(0x55);

  ...

  // try Soft_UART_Read with blocking prevention mechanism
  SREG_I_bit = 1;                         // Interrupt enable
  data1 = Soft_UART_Read(&error);
  SREG_I_bit = 0;                         // Interrupt disable

  ...

}
```

Library Example

This example demonstrates simple data exchange via software UART. If MCU is connected to the PC, you can test the example from the mikroC PRO for AVR USART Terminal Tool.

```
// Soft UART connections
sbit  Soft_UART_Rx_Pin at PIND.B0;
sbit  Soft_UART_Tx_Pin at PORTD.B1;
sbit  Soft_UART_Rx_Pin_Direction at DDRD.B0;
sbit  Soft_UART_Tx_Pin_Direction at DDRD.B1;
// End Soft UART connections

char i, error, byte_read;                    // Auxiliary variables

void main(){

  DDRB = 0xFF;                                 // Set PORTB as output
(error signalization)
  PORTB = 0;                                  // No error

  error = Soft_UART_Init(9600, 0);          // Initialize Soft UART at
9600 bps
  if (error > 0) {
    PORTB = error;                            // Signalize Init error
    while(1);                                 // Stop program
  }
  Delay_ms(100);

  for (i = 'z'; i >= 'A'; i--) {              // Send bytes from 'z'
downto 'A'
    Soft_UART_Write(i);
    Delay_ms(100);
  }

  while(1) {                                  // Endless loop
     byte_read = Soft_UART_Read(&error);    // Read byte, then test
error flag
    if (error)                               // If error was detected
      PORTB = error;                         //   signal it on PORTB
    else
     Soft_UART_Write(byte_read);          // If error was not detect-
ed, return byte read
    }
}
```

SOUND LIBRARY

The mikroC PRO for AVR provides a Sound Library to supply users with routines necessary for sound signalization in their applications. Sound generation needs additional hardware, such as piezo-speaker (example of piezo-speaker interface is given on the schematic at the bottom of this page).

External dependencies of Sound Library

The following variables must be defined in all projects using Sound Library:	Description:	Example :
`extern sfr sbit Sound_Play_Pin;`	Sound output pin.	`sbit Sound_Play_Pin at PORTC.B3;`
`extern sfr sbit Sound_Play_Pin_Direction;`	Direction of the Sound output pin.	`sbit Sound_Play_Pin_Direction at DDRC.B3;`

Library Routines

- Sound_Init
- Sound_Play

Sound_Init

Prototype	`void Sound_Init();`
Returns	Nothing.
Description	Configures the appropriate MCU pin for sound generation.
Requires	Global variables: - `Sound_Play_Pin`: Sound output pin - `Sound_Play_Pin_Direction`: Direction of the Sound output pin must be defined before using this function.

Example	`// Sound library connections`
	`sbit Sound_Play_Pin at PORTC.B3;`
	`sbit Sound_Play_Pin_direction at DDRC.B3;`
	`// End of Sound library connections`
	
	`...`
	`Sound_Init();`

Sound_Play

Prototype	`void Sound_Play(unsigned freq_in_hz, unsigned duration_ms);`
Returns	Nothing.
Description	Generates the square wave signal on the appropriate pin. Parameters : - `freq_in_hz`: signal frequency in Hertz (Hz) - `duration_ms`: signal duration in miliseconds (ms)
Requires	In order to hear the sound, you need a piezo speaker (or other hardware) on designated port. Also, you must call Sound_Init to prepare hardware for output before using this function.
Example	`// Play sound of 1KHz in duration of 100ms` `Sound_Play(1000, 100);`

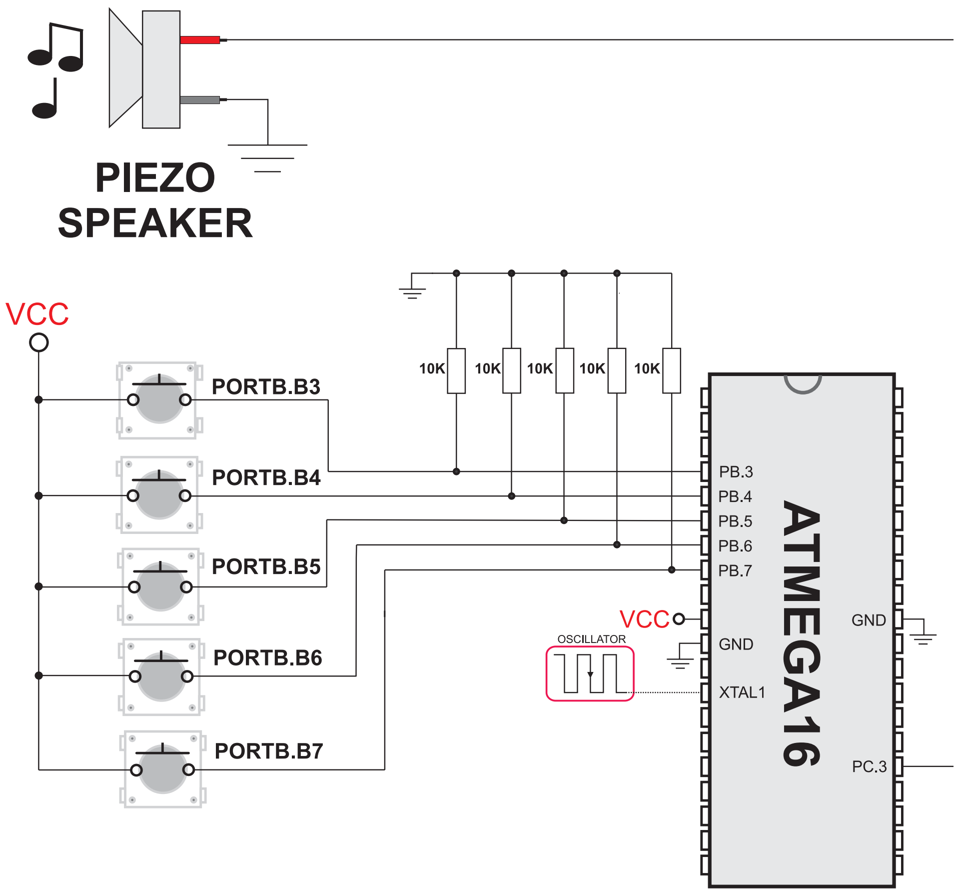
Library Example

The example is a simple demonstration of how to use the Sound Library for playing tones on a piezo speaker.

```
// Sound connections
sbit Sound_Play_Pin at PORTC.B3;
sbit Sound_Play_Pin_direction at DDRC.B3;
// End Sound connections

void Tone1() {
  Sound_Play(500, 200);        // Frequency = 500Hz, Duration = 200ms
}

void Tone2() {
  Sound_Play(555, 200);        // Frequency = 555Hz, Duration = 200ms
}

void Tone3() {
  Sound_Play(625, 200);        // Frequency = 625Hz, Duration = 200ms
}

void Melody() {                    // Plays the melody "Yellow house"
  Tone1(); Tone2(); Tone3(); Tone3();
  Tone1(); Tone2(); Tone3(); Tone3();
  Tone1(); Tone2(); Tone3();
  Tone1(); Tone2(); Tone3(); Tone3();
  Tone1(); Tone2(); Tone3();
  Tone3(); Tone3(); Tone2(); Tone2(); Tone1();
}

void ToneA() {                     // Tones used in Melody2 function
  Sound_Play(1250, 20);
}
void ToneC() {
  Sound_Play(1450, 20);
}
void ToneE() {
  Sound_Play(1650, 80);
}

void Melody2() {                   // Plays Melody2
 unsigned short i;
  for (i = 9; i > 0; i--) {
    ToneA();
    ToneC();
    ToneE();
    }
}
```

```
void main() {

  DDRB = 0x00;                         // Configure PORTB as input
  Sound_Init();                        // Initialize sound pin

  Sound_Play(500, 1000);      // Play starting sound, 2kHz, 1 second

  while (1) {                          // endless loop

    if (PINB.B7)                     // If PORTB.7 is pressed play Tone1
      Tone1();                         //
    while (PINB.B7) ;                  // Wait for button to be released

    if (PINB.B6)                     // If PORTB.6 is pressed play Tone2
      Tone2();                         //
    while (PINB.B6) ;                  // Wait for button to be released

    if (PINB.B5)                     // If PORTB.5 is pressed play Tone3
      Tone3();                         //
    while (PINB.B5) ;                  // Wait for button to be released

    if (PINB.B4)                   // If PORTB.4 is pressed play Melody2
      Melody2();                       //
    while (PINB.B4) ;                  // Wait for button to be released

    if (PINB.B3)                    // If PORTB.3 is pressed play Melody
      Melody();                        //
    while (PINB.B3) ;                  // Wait for button to be released
  }
}
```

HW Connection



Example of Sound Library connection

SPI LIBRARY

mikroC PRO for AVR provides a library for comfortable with SPI work in Master mode. The AVR MCU can easily communicate with other devices via SPI: A/D converters, D/A converters, MAX7219, LTC1290, etc.

Note: Some AVR MCU's have alternative SPI ports, which SPI signals can be redirected to by setting or clearing SPIPS (SPI Pin Select) bit of the MCUCR register. Please consult the appropriate datasheet.

Library Routines

- SPI1_Init
- SPI1_Init_Advanced
- SPI1_Read
- SPI1_Write

SPI1_Init

Prototype	`void SPI1_Init();`
Returns	Nothing.
Description	This routine configures and enables SPI module with the following settings: - master mode - 8 bit data transfer - most significant bit sent first - serial clock low when idle - data sampled on leading edge - serial clock = fosc/4
Requires	MCU must have SPI module.
Example	`// Initialize the SPI1 module with default settings` `SPI1_Init();`

SPI1_Init_Advanced

Prototype	`void SPI1_Init_Advanced(char mode, char fcy_div, char clock_and_edge)`
Returns	Nothing.
Description	Configures and initializes SPI. SPI1_Init_Advanced or SPI1_Init needs to be called before using other functions of SPI Library. Parameters mode, fcy_div and clock_and_edge determine the work mode for SPI, and can have the following values: (see table below) **Note**: Some SPI clock speeds are not supported by all AVR MCUs and these are: `Fosc/2`, `Fosc/8`, `Fosc/32`. Please consult appropriate datasheet.

Mask	Description	Predefined library const
SPI mode constants:		
0x10	Master mode	_SPI_MASTER
0x00	Slave mode	_SPI_SLAVE
Clock rate select constants:		
0x00	Sck = Fosc/4, Master mode	_SPI_FCY_DIV4
0x01	Sck = Fosc/16, Master mode	_SPI_FCY_DIV16
0x02	Sck = Fosc/64, Master mode	_SPI_FCY_DIV64
0x03	Sck = Fosc/128, Master mode	_SPI_FCY_DIV128
0x04	Sck = Fosc/2, Master mode	_SPI_FCY_DIV2
0x05	Sck = Fosc/8, Master mode	_SPI_FCY_DIV8
0x06	Sck = Fosc/32, Master mode	_SPI_FCY_DIV32
SPI clock polarity and phase constants:		
0x00	Clock idle level is low, sample on rising edge	_SPI_CLK_LO_LEADING
0x04	Clock idle level is low, sample on falling edge	_SPI_CLK_LO_TRAILING
0x08	Clock idle level is high, sample on rising edge	_SPI_CLK_HI_LEADING
0x0C	Clock idle level is high, sample on falling edge	_SPI_CLK_HI_TRAILING

Requires	MCU must have SPI module.
Example	`// Set SPI to the Master Mode, clock = Fosc/32 , clock idle level is high, data sampled on falling edge:` `SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV32, _SPI_CLK_HI_TRAIL-ING);`

SPI1_Read

Prototype	`char SPI1_Read(char buffer);`
Returns	Received data.
Description	Reads one byte from the SPI bus. Parameters : - `buffer`: dummy data for clock generation (see device Datasheet for SPI modules implementation details)
Requires	SPI module must be initialized before using this function. See SPI1_Init and SPI1_Init_Advanced routines.

Example	`// read a byte from the SPI bus`
	`char take, dummy1;`
	`...`
	`take = SPI1_Read(dummy1);`

SPI1_Write

Prototype	`void SPI1_Write(char data_out);`
Returns	Nothing.
Description	Writes byte via the SPI bus. Parameters : - `wrdata`: data to be sent
Requires	SPI module must be initialized before using this function. See SPI1_Init and SPI1_Init_Advanced routines.

Example	`// write a byte to the SPI bus`
	`char buffer;`
	`...`
	`SPI1_Write(buffer);`

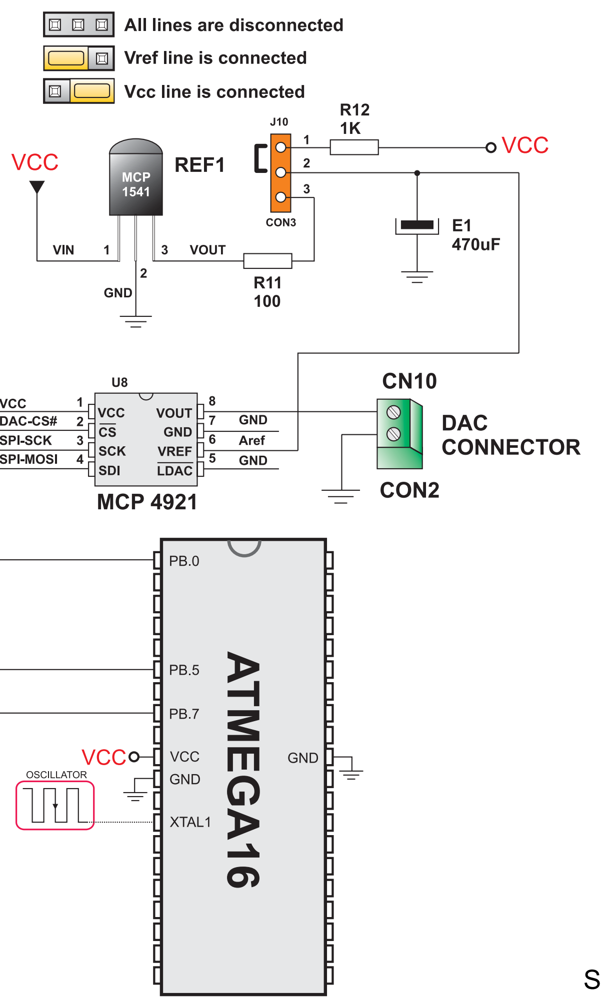
Library Example

The code demonstrates how to use SPI library functions for communication between SPI module of the MCU and MAX7219 chip. MAX7219 controls eight 7 segment displays.

```
// DAC module connections
sbit Chip_Select at PORTB.B0;
sbit Chip_Select_Direction at DDRB.B0;
// End DAC module connections

unsigned int value;

void InitMain() {
  DDA0 = 0;                                     // Set PA0 pin as input
  DDA1 = 0;                                     // Set PA1 pin as input
  Chip_Select = 1;                              // Deselect DAC
  Chip_Select_Direction = 1;                   // Set CS# pin as Output
  SPI1_Init();                                 // Initialize SPI1 module
}

// DAC increments (0..4095) --> output voltage (0..Vref)
void DAC_Output(unsigned int valueDAC) {
  char temp;

  Chip_Select = 0;                              // Select DAC chip

  // Send High Byte
  temp = (valueDAC >> 8) & 0x0F;               // Store valueDAC[11..8]
to temp[3..0]
  temp |= 0x30;           // Define DAC setting, see MCP4921 datasheet
  SPI1_Write(temp);                            // Send high byte via SPI

  // Send Low Byte
  temp = valueDAC;              // Store valueDAC[7..0] to temp[7..0]
  SPI1_Write(temp);                          // Send low byte via SPI

  Chip_Select = 1;                              // Deselect DAC chip
}

void main() {

  InitMain();                             // Perform main initialization

  value = 2048;                         // When program starts, DAC gives
                                       //    the output in the mid-range

  while (1) {                                   // Endless loop
```

```
if ((PINA.B0) && (value < 4095)) {     // If PA0 button is pressed
        value++;                               //   increment value
      }
    else {
      if ((PINA.B1) && (value > 0)) {      // If PA1 button is pressed
        value--;                               //   decrement value
      }
    }

    DAC_Output(value);                       // Send value to DAC chip
    Delay_ms(1);                           // Slow down key repeat pace
  }
}
```

HW Connection



SPI HW connection

SPI ETHERNET LIBRARY

The `ENC28J60` is a stand-alone Ethernet controller with an industry standard Serial Peripheral Interface (SPI™). It is designed to serve as an Ethernet network interface for any controller equipped with SPI.

The `ENC28J60` meets all of the IEEE 802.3 specifications. It incorporates a number of packet filtering schemes to limit incoming packets. It also provides an internal DMA module for fast data throughput and hardware assisted IP checksum calculations. Communication with the host controller is implemented via two interrupt pins and the SPI, with data rates of up to 10 Mb/s. Two dedicated pins are used for LED link and network activity indication.

This library is designed to simplify handling of the underlying hardware (`ENC28J60`). It works with any AVR MCU with integrated SPI and more than 4 Kb ROM memory.

SPI Ethernet library supports:

- IPv4 protocol.
- ARP requests.
- ICMP echo requests.
- UDP requests.
- TCP requests (no stack, no packet reconstruction).
- packet fragmentation is **NOT** supported.

Note: For advanced users there are header files (`"eth_enc28j60LibDef.h"` and `"eth_enc28j60LibPrivate.h"`) in `Uses` folder of the compiler with description of all routines and global variables, relevant to the user, implemented in the SPI Ethernet Library.

Note: The appropriate hardware SPI module must be initialized before using any of the SPI Ethernet library routines. Refer to SPI Library.

Note: The appropriate hardware SPI module must be initialized before using any of the SPI Ethernet library routines. Refer to SPI Library.

External dependencies of SPI Ethernet Library

The following variables must be defined in all projects using SPI Ethernet Library:	Description:	Example :
`extern sfr sbit SPI_Ethernet_CS;`	ENC28J60 chip select pin.	`sbit SPI_Ethernet_CS at PORTB.B4;`
`extern sfr sbit SPI_Ethernet_RST;`	ENC28J60 reset pin.	`sbit SPI_Ethernet_RST at PORTB.B5;`
`extern sfr sbit SPI_Ethernet_CS_Direction;`	Direction of the ENC28J60 chip select pin.	`sbit SPI_Ethernet_CS_Direction at DDRB.B4;`
`extern sfr sbit SPI_Ethernet_RST_Direction;`	Direction of the ENC28J60 reset pin.	`sbit SPI_Ethernet_RST_Direction at DDRB.B5;`

The following routines must be defined in all project using SPI Ethernet Library:	Description:	Example :
`unsigned int SPI_Ethernet_UserTCP(unsigned char *remoteHost, unsigned int remotePort, unsigned int localPort, unsigned int reqLength) ;`	TCP request handler.	Refer to the library example at the bottom of this page for code implementation.
`unsigned int SPI_Ethernet_UserUDP(unsigned char *remoteHost, unsigned int remotePort, unsigned int destPort, unsigned int reqLength) ;`	UDP request handler.	Refer to the library example at the bottom of this page for code implementation.

Library Routines

- SPI_Ethernet_Init
- SPI_Ethernet_Enable
- SPI_Ethernet_Disable
- SPI_Ethernet_doPacket
- SPI_Ethernet_putByte
- SPI_Ethernet_putBytes
- SPI_Ethernet_putString
- SPI_Ethernet_putConstString
- SPI_Ethernet_putConstBytes
- SPI_Ethernet_getByte
- SPI_Ethernet_getBytes
- SPI_Ethernet_UserTCP
- SPI_Ethernet_UserUDP

The following routines are for the internal use by compiler only:

- SPI_Ethernet_arpResolve
- SPI_Ethernet_checksum
- SPI_Ethernet_clearBitReg
- SPI_Ethernet_confNetwork
- SPI_Ethernet_delay
- SPI_Ethernet_DHCPmsg
- SPI_Ethernet_DHCPReceive
- SPI_Ethernet_dnsResolve
- SPI_Ethernet_doARP
- SPI_Ethernet_doDHCP
- SPI_Ethernet_doDHCPLeaseTime
- SPI_Ethernet_doDNS
- SPI_Ethernet_doTCP
- SPI_Ethernet_doUDP
- SPI_Ethernet_getDnsIpAddress
- SPI_Ethernet_getGwIpAddress
- SPI_Ethernet_getIpAddress
- SPI_Ethernet_getIpMask
- SPI_Ethernet_Init2
- SPI_Ethernet_initDHCP
- SPI_Ethernet_IPswap
- SPI_Ethernet_MACswap
- SPI_Ethernet_memcmp
- SPI_Ethernet_memcpy
- SPI_Ethernet_pktLen
- SPI_Ethernet_RAMcopy
- SPI_Ethernet_readMem
- SPI_Ethernet_readPacket
- SPI_Ethernet_readPHY
- SPI_Ethernet_readReg

- SPI_Ethernet_renewDHCP
- SPI_Ethernet_sendUDP
- SPI_Ethernet_sendUDP2
- SPI_Ethernet_setBitReg
- SPI_Ethernet_setRxReadAddress
- SPI_Ethernet_TXpacket
- SPI_Ethernet_writeAddr
- SPI_Ethernet_writeMem
- SPI_Ethernet_writeMemory
- SPI_Ethernet_writeMemory2
- SPI_Ethernet_writePHY
- SPI_Ethernet_writeReg

SPI_Ethernet_Init

Prototype	`void SPI_Ethernet_Init(unsigned char *mac, unsigned char *ip, unsigned char fullDuplex);`
Returns	Nothing.
Description	This is MAC module routine. It initializes `ENC28J60` controller. This function is internaly splited into 2 parts to help linker when coming short of memory. ENC28J60 controller settings (parameters not mentioned here are set to default): - receive buffer start address : `0x0000`. - receive buffer end address : `0x19AD`. - transmit buffer start address: `0x19AE`. - transmit buffer end address : `0x1FFF`. - RAM buffer read/write pointers in auto-increment mode. - receive filters set to default: CRC + MAC Unicast + MAC Broadcast in OR mode. - flow control with TX and RX pause frames in full duplex mode. - frames are padded to 60 bytes + CRC. - maximum packet size is set to `1518`. - Back-to-Back Inter-Packet Gap: `0x15` in full duplex mode; 0x12 in half duplex mode. - Non-Back-to-Back Inter-Packet Gap: `0x0012` in full duplex mode; `0x0C12` in half duplex mode. - Collision window is set to `63` in half duplex mode to accomodate some `ENC28J60` revisions silicon bugs. - CLKOUT output is disabled to reduce EMI generation. - half duplex loopback disabled. - LED configuration: default (LEDA-link status, LEDB-link activity). Parameters: - `mac`: RAM buffer containing valid MAC address. - `ip`: RAM buffer containing valid IP address. - `fullDuplex`: ethernet duplex mode switch. Valid values: `0` (half duplex mode) and `1` (full duplex mode).

Requires	The appropriate hardware SPI module must be previously initialized. Global variables : - `SPI_Ethernet_CS`: Chip Select line - `SPI_Ethernet_CS_Direction`: Direction of the Chip Select pin - `SPI_Ethernet_RST`: Reset line - `SPI_Ethernet_RST_Direction`: Direction of the Reset pin must be defined before using this function.
Example	see code below

```
#define SPI_Ethernet_HALFDUPLEX      0
#define SPI_Ethernet_FULLDUPLEX      1

// mE ethernet NIC pinout
sfr sbit SPI_Ethernet_Rst at PORTB.B4;
sfr sbit SPI_Ethernet_CS  at PORTB.B5;
sfr sbit SPI_Ethernet_Rst_Direction at DDRB.B4;
sfr sbit SPI_Ethernet_CS_Direction  at DDRB.B5;
// end ethernet NIC definitions

unsigned char myMacAddr[6]  = {0x00, 0x14, 0xA5, 0x76, 0x19, 0x3f}
; // my MAC address
unsigned char myIpAddr      = {192, 168,   1, 60 } ;  // my IP
addr

SPI1_Init();
Spi_Rd_Ptr = SPI1_Read;       // pass pointer to SPI Read function
of used SPI module
SPI_Ethernet_Init(&PORTC, 0, &PORTC, 1, myMacAddr, myIpAddr,
SPI_Ethernet_FULLDUPLEX);
```

SPI_Ethernet_Enable

Prototype	`void SPI_Ethernet_Enable(unsigned char enFlt) ;`
Returns	Nothing.
Description	This is MAC module routine. This routine enables appropriate network traffic on the `ENC28J60` module by the means of it's receive filters (unicast, multicast, broadcast, crc). Specific type of network traffic will be enabled if a corresponding bit of this routine's input parameter is set. Therefore, more than one type of network traffic can be enabled at the same time. For this purpose, predefined library constants (see the table below) can be ORed to form appropriate input value. Parameters: - `enFlt`: network traffic/receive filter flags. Each bit corresponds to the appropriate network traffic/receive filter:

Bit	Mask	Description	Predefined library const
0	0x01	MAC Broadcast traffic/receive filter flag. When set, MAC broadcast traffic will be enabled.	SPI_Ethernet_BROADCAST
1	0x02	MAC Multicast traffic/receive filter flag. When set, MAC multicast traffic will be enabled.	SPI_Ethernet_MULTICAST
2	0x04	not used	none
3	0x08	not used	none
4	0x10	not used	none
5	0x20	CRC check flag. When set, packets with invalid CRC field will be discarded.	SPI_Ethernet_CRC
6	0x40	not used	none
7	0x80	MAC Unicast traffic/receive filter flag. When set, MAC unicast traffic will be enabled.	SPI_Ethernet_UNICAST

Note: Advance filtering available in the `ENC28J60` module such as `Pattern Match`, `Magic Packet` and `Hash Table` can not be enabled by this routine. Additionaly, all filters, except CRC, enabled with this routine will work in OR mode, which means that packet will be received if any of the enabled filters accepts it.

Note: This routine will change receive filter configuration on-the-fly. It will not, in any way, mess with enabling/disabling receive/transmit logic or any other part of the `ENC28J60` module. The `ENC28J60` module should be properly cofigured by the means of SPI_Ethernet_Init routine.

Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.
Example	`SPI_Ethernet_Enable(SPI_Ethernet_CRC | SPI_Ethernet_UNICAST); // enable CRC checking and Unicast traffic`

SPI_Ethernet_Disable

Prototype	`void SPI_Ethernet_Disable(unsigned char disFlt) ;`
Returns	Nothing.
Description	This is MAC module routine. This routine disables appropriate network traffic on the `ENC28J60` module by the means of it's receive filters (unicast, multicast, broadcast, crc). Specific type of network traffic will be disabled if a corresponding bit of this routine's input parameter is set. Therefore, more than one type of network traffic can be disabled at the same time. For this purpose, predefined library constants (see the table below) can be ORed to form appropriate input value. Parameters: - `disFlt`: network traffic/receive filter flags. Each bit corresponds to the appropriate network traffic/receive filter:

Bit	Mask	Description	Predefined library const
`0`	`0x01`	MAC Broadcast traffic/receive filter flag. When set, MAC broadcast traffic will be disabled.	`SPI_Ethernet_BROADCAST`
`1`	`0x02`	MAC Multicast traffic/receive filter flag. When set, MAC multicast traffic will be disabled.	`SPI_Ethernet_MULTICAST`
`2`	`0x04`	not used	`none`
`3`	`0x08`	not used	`none`
`4`	`0x10`	not used	`none`
`5`	`0x20`	CRC check flag. When set, CRC check will be disabled and packets with invalid CRC field will be accepted.	`SPI_Ethernet_CRC`
`6`	`0x40`	not used	`none`
`7`	`0x80`	MAC Unicast traffic/receive filter flag. When set, MAC unicast traffic will be disabled.	`SPI_Ethernet_UNICAST`

Note: Advance filtering available in the `ENC28J60` module such as `Pattern Match`, `Magic Packet` and `Hash Table` can not be disabled by this routine.

Description	**Note**: This routine will change receive filter configuration on-the-fly. It will not, in any way, mess with enabling/disabling receive/transmit logic or any other part of the `ENC28J60` module. The `ENC28J60` module should be properly cofigured by the means of SPI_Ethernet_Init routine.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.
Example	`SPI_Ethernet_Disable(SPI_Ethernet_CRC | SPI_Ethernet_UNICAST); // disable CRC checking and Unicast traffic`

SPI_Ethernet_doPacket

Prototype	`unsigned char SPI_Ethernet_doPacket();`
Returns	- `0` - upon successful packet processing (zero packets received or received packet processed successfully). - `1` - upon reception error or receive buffer corruption. `ENC28J60` controller needs to be restarted. - `2` - received packet was not sent to us (not our IP, nor IP broadcast address). - `3` - received IP packet was not IPv4. - `4` - received packet was of type unknown to the library.
Description	This is MAC module routine. It processes next received packet if such exists. Packets are processed in the following manner: - ARP & ICMP requests are replied automatically. - upon TCP request the SPI_Ethernet_UserTCP function is called for further processing. - upon UDP request the SPI_Ethernet_UserUDP function is called for further processing. **Note**: `SPI_Ethernet_doPacket` must be called as often as possible in user's code.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`while(1) {`
	`   ...`
	`   SPI_Ethernet_doPacket(); // process received packets`
	`   ...`
	`}`

SPI_Ethernet_putByte

Prototype	`void SPI_Ethernet_putByte(unsigned char v);`
Returns	Nothing.
Description	This is MAC module routine. It stores one byte to address pointed by the current `ENC28J60` write pointer (`EWRPT`). Parameters: - `v:` value to store
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`char data;`
	`...`
	`SPI_Ethernet_putByte(data); // put an byte into ENC28J60 buffer`

SPI_Ethernet_putBytes

Prototype	`void SPI_Ethernet_putBytes(unsigned char *ptr, unsigned char n);`
Returns	Nothing.
Description	This is MAC module routine. It stores requested number of bytes into `ENC28J60` RAM starting from current `ENC28J60` write pointer (`EWRPT`) location. Parameters: - `ptr:` RAM buffer containing bytes to be written into `ENC28J60` RAM. - `n:` number of bytes to be written.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`char *buffer =  "mikroElektronika";`
	`...`
	`SPI_Ethernet_putBytes(buffer, 16); // put an RAM array into ENC28J60 buffer`

SPI_Ethernet_putConstBytes

Prototype	`void SPI_Ethernet_putConstBytes(const unsigned char *ptr, unsigned char n);`
Returns	Nothing.
Description	This is MAC module routine. It stores requested number of const bytes into `ENC28J60` RAM starting from current `ENC28J60` write pointer (`EWRPT`) location. Parameters: - `ptr:` const buffer containing bytes to be written into `ENC28J60` RAM. - `n:` number of bytes to be written.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`const char *buffer =  "mikroElektronika";`
	`...`
	`SPI_Ethernet_putConstBytes(buffer, 16); // put a const array into ENC28J60 buffer`

SPI_Ethernet_putString

Prototype	`unsigned int SPI_Ethernet_putString(unsigned char *ptr);`
Returns	Number of bytes written into `ENC28J60` RAM.
Description	This is MAC module routine. It stores whole string (excluding null termination) into `ENC28J60` RAM starting from current `ENC28J60` write pointer (`EWRPT`) location. Parameters: - `ptr:` string to be written into `ENC28J60` RAM.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`char *buffer =  "mikroElektronika";`
	`...`
	`SPI_Ethernet_putString(buffer); // put a RAM string into ENC28J60 buffer`

SPI_Ethernet_putConstString

Prototype	`unsigned int SPI_Ethernet_putConstString(const unsigned char *ptr);`
Returns	Number of bytes written into `ENC28J60` RAM.
Description	This is MAC module routine. It stores whole const string (excluding null termination) into ENC28J60 RAM starting from current ENC28J60 write pointer (EWRPT) location. Parameters: - `ptr:` const string to be written into `ENC28J60` RAM.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`const char *buffer =  "mikroElektronika";`
	`...`
	`SPI_Ethernet_putConstString(buffer); // put a const string into ENC28J60 buffer`

SPI_Ethernet_getByte

Prototype	`unsigned char SPI_Ethernet_getByte();`
Returns	Byte read from `ENC28J60` RAM.
Description	This is MAC module routine. It fetches a byte from address pointed to by current `ENC28J60` read pointer (`ERDPT`).
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`char buffer;`
	`...`
	`buffer = SPI_Ethernet_getByte(); // read a byte from ENC28J60 buffer`

SPI_Ethernet_getBytes

Prototype	`void SPI_Ethernet_getBytes(unsigned char *ptr, unsigned int addr, unsigned char n);`
Returns	Nothing.
Description	This is MAC module routine. It fetches equested number of bytes from `ENC28J60` RAM starting from given address. If value of `0xFFFF` is passed as the address parameter, the reading will start from current `ENC28J60` read pointer (`ERDPT`) location. Parameters: - `ptr:` buffer for storing bytes read from `ENC28J60` RAM. - `addr:` `ENC28J60` RAM start address. Valid values: `0..8192`. - `n:` number of bytes to be read.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.

Example	`char buffer[16];`
	`...`
	`SPI_Ethernet_getBytes(buffer, 0x100, 16); // read 16 bytes, starting from address 0x100`

SPI_Ethernet_UserTCP

Prototype	`unsigned int SPI_Ethernet_UserTCP(unsigned char *remoteHost, unsigned int remotePort, unsigned int localPort, unsigned int reqLength);`
Returns	- `0` - there should not be a reply to the request. - Length of TCP/HTTP reply data field - otherwise.
Description	This is TCP module routine. It is internally called by the library. The user accesses to the TCP/HTTP request by using some of the SPI_Ethernet_get routines. The user puts data in the transmit buffer by using some of the SPI_Ethernet_put routines. The function must return the length in bytes of the TCP/HTTP reply, or 0 if there is nothing to transmit. If there is no need to reply to the TCP/HTTP requests, just define this function with return(0) as a single statement. Parameters: - `remoteHost`: client's IP address. - `remotePort`: client's TCP port. - `localPort`: port to which the request is sent. - `reqLength`: TCP/HTTP request data field length. **Note**: The function source code is provided with appropriate example projects. The code should be adjusted by the user to achieve desired reply.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.
Example	This function is internally called by the library and should not be called by the user's code.

SPI_Ethernet_UserUDP

Prototype	`unsigned int SPI_Ethernet_UserUDP(unsigned char *remoteHost, unsigned int remotePort, unsigned int destPort, unsigned int reqLength);`
Returns	- `0` - there should not be a reply to the request. - Length of UDP reply data field - otherwise.
Description	This is UDP module routine. It is internally called by the library. The user accesses to the UDP request by using some of the SPI_Ethernet_get routines. The user puts data in the transmit buffer by using some of the SPI_Ethernet_put routines. The function must return the length in bytes of the UDP reply, or 0 if nothing to transmit. If you don't need to reply to the UDP requests, just define this function with a return(0) as single statement. Parameters: - `remoteHost`: client's IP address. - `remotePort`: client's port. - `destPort`: port to which the request is sent. - `reqLength`: UDP request data field length. **Note:** The function source code is provided with appropriate example projects. The code should be adjusted by the user to achieve desired reply.
Requires	Ethernet module has to be initialized. See SPI_Ethernet_Init.
Example	This function is internally called by the library and should not be called by the user's code.

Library Example

This code shows how to use the AVR mini Ethernet library :

- the board will reply to ARP & ICMP echo requests
- the board will reply to UDP requests on any port :
returns the request in upper char with a header made of remote host IP & port number

- the board will reply to HTTP requests on port 80, GET method with pathnames :

/ will return the HTML main page
/s will return board status as text string
/t0 ... /t7 will toggle P3.b0 to P3.b7 bit and return HTML main page
all other requests return also HTML main page.

```
// duplex config flags
#define Spi_Ethernet_HALFDUPLEX      0x00  // half duplex
#define Spi_Ethernet_FULLDUPLEX      0x01  // full duplex

// mE ehternet NIC pinout
sfr sbit SPI_Ethernet_Rst at PORTB.B4;
sfr sbit SPI_Ethernet_CS  at PORTB.B5;
sfr sbit SPI_Ethernet_Rst_Direction at DDRB.B4;
sfr sbit SPI_Ethernet_CS_Direction  at DDRB.B5;
// end ethernet NIC definitions

/***********************************************************
 * ROM constant strings
 */
const code unsigned char httpHeader[] = "HTTP/1.1 200 OKnContent-
type: " ;  // HTTP header
const code unsigned char httpMimeTypeHTML[] = "text/htmlnn" ;
// HTML MIME type
const code unsigned char httpMimeTypeScript[] = "text/plainnn" ;
// TEXT MIME type
unsigned char httpMethod[] = "GET /";
/*
 * web page, splited into 2 parts :
 * when coming short of ROM, fragmented data is handled more effi-
ciently by linker
 *
 * this HTML page calls the boards to get its status, and builds
itself with javascript
 */
const code char    *indexPage =                    // Change the IP
address of the page to be refreshed
"<meta http-equiv="refresh" content="3;url=http://192.168.20.60">
<HTML><HEAD></HEAD><BODY>
<h1>AVR + ENC28J60 Mini Web Server</h1>
<a href=/>Reload</a>
<script src=/s></script>
<table><tr><td><table border=1 style="font-size:20px ;font-family:
terminal ;">
<tr><th colspan=2>PINC</th></tr>
<script>
var str,i;
str="";
for(i=0;i<8;i++)
{str+="<tr><td bgcolor=pink>BUTTON #"+i+"</td>";
if(PINC&(1<<i)){str+="<td bgcolor=red>ON";}
else {str+="<td bgcolor=#cccccc>OFF";}
str+="</td></tr>";}
document.write(str) ;
</script>
" ;
```

```
const char    *indexPage2 =  "</table></td><td>
<table border=1 style="font-size:20px ;font-family: terminal ;">
<tr><th colspan=3>PORTD</th></tr>
<script>
var str,i;
str="";
for(i=0;i<8;i++)
{str+="<tr><td bgcolor=yellow>LED #"+i+"</td>";
if(PORTD&(1<<i)){str+="<td bgcolor=red>ON";}
else {str+="<td bgcolor=#cccccc>OFF";}
str+="</td><td><a href=/t"+i+">Toggle</a></td></tr>";}
document.write(str) ;
</script>
</table></td></tr></table>
This                 is                 HTTP                 request
#<script>document.write(REQ)</script></BODY></HTML>
" ;

/***********************************
 * RAM variables
 */
unsigned char   myMacAddr[6] = {0x00, 0x14, 0xA5, 0x76, 0x19, 0x3f}
;   // my MAC address
unsigned  char      myIpAddr[4]     =  {192,   168,   20,   60}   ;
// my IP address
unsigned char  getRequest[15] ;                              //
HTTP request buffer
unsigned char  dyna[29] ;                                    //
buffer for dynamic response
unsigned long  httpCounter = 0 ;                             //
counter of HTTP requests

/*******************************************
 * functions
 */

/*
 * put the constant string pointed to by s to the ENC transmit buffer.
 */
/*unsigned int    putConstString(const code char *s)
        {
        unsigned int ctr = 0 ;

        while(*s)
                {
                Spi_Ethernet_putByte(*s++) ;
                ctr++ ;
                }
        return(ctr) ;
        }*/
```

```
/*
 * it will be much faster to use library Spi_Ethernet_putConstString
routine
 * instead of putConstString routine above. However, the code will
be a little
 * bit bigger. User should choose between size and speed and pick the
implementation that
 * suites him best. If you choose to go with the putConstString def-
inition above
 * the #define line below should be commented out.
 *
 */
#define putConstString  SPI_Ethernet_putConstString

/*
 * put the string pointed to by s to the ENC transmit buffer
 */
/*unsigned int    putString(char *s)
        {
        unsigned int ctr = 0 ;

        while(*s)
                {
                Spi_Ethernet_putByte(*s++) ;

                ctr++ ;
                }
        return(ctr) ;
        }*/
/*
 * it will be much faster to use library Spi_Ethernet_putString rou-
tine
 * instead of putString routine above. However, the code will be a
little
 * bit bigger. User should choose between size and speed and pick the
implementation that
 * suites him best. If you choose to go with the putString defini-
tion above
 * the #define line below should be commented out.
 *
 */
#define putString  SPI_Ethernet_putString

/*
 * this function is called by the library
 * the user accesses to the HTTP request by successive calls to
Spi_Ethernet_getByte()
 * the user puts data in the transmit buffer by successive calls to
Spi_Ethernet_putByte()
 * the function must return the length in bytes of the HTTP reply,
or 0 if nothing to transmit
 *
 * if you don't need to reply to HTTP requests,
 * just define this function with a return(0) as single statement
 *
 */
```

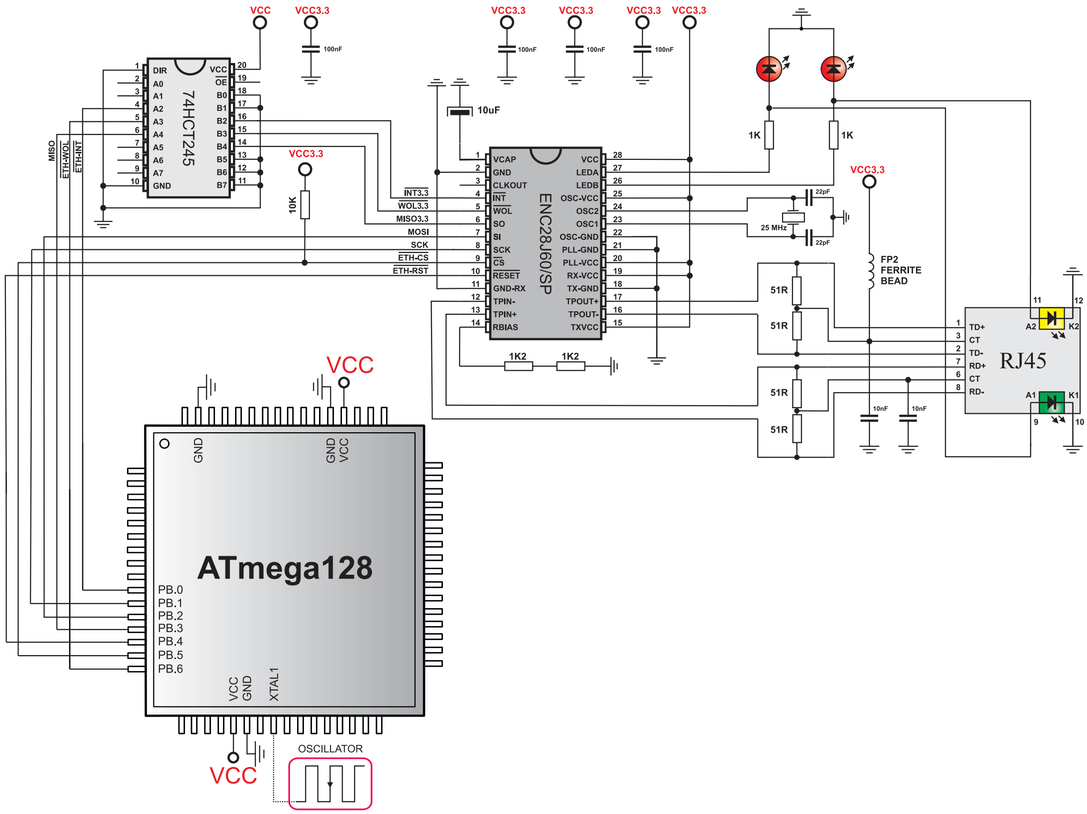
```
unsigned int      SPI_Ethernet_UserTCP(unsigned char *remoteHost,
unsigned int remotePort, unsigned int localPort, unsigned int
reqLength)
        {
        unsigned int    len;            // my reply length

         if(localPort != 80)                // I listen only to web
request on port 80
                {
                return(0) ;
                }

        // get 10 first bytes only of the request, the rest does not
matter here
        for(len = 0 ; len < 10 ; len++)
                {
                getRequest[len] = SPI_Ethernet_getByte() ;
                }
        getRequest[len] = 0 ;

        len = 0;

         if(memcmp(getRequest, httpMethod, 5))          // only GET
method is supported here
                {
                return(0) ;
                }

        httpCounter++ ;                                  // one more
request done

        if(getRequest[5] == 's')                        // if request
path name starts with s, store dynamic data in transmit buffer
                {
                 // the text string replied by this request can be
interpreted as javascript statements
                // by browsers

                len = putConstString(httpHeader) ;               //
HTTP header
                len += putConstString(httpMimeTypeScript) ;      //
with text MIME type

                // add PORTC value (buttons) to reply
                len += putConstString("var PINC=") ;
                WordToStr(PINC, dyna) ;
                len += putString(dyna) ;
                len += putConstString(";") ;

                // add PORTD value (LEDs) to reply
                len += putConstString("var PORTD=") ;
                WordToStr(PORTD, dyna) ;
                len += putString(dyna) ;
                len += putConstString(";") ;
```

```
 // add HTTP requests counter to reply
                    WordToStr(httpCounter, dyna) ;
                    len += putConstString("var REQ=") ;
                    len += putString(dyna) ;
                    len += putConstString(";") ;
                    }
          else if(getRequest[5] == 't')               // if request path
name starts with t, toggle P3 (LED) bit number that comes after
                    {
                    unsigned char   bitMask = 0 ;       // for bit mask

                  if(isdigit(getRequest[6]))        // if 0 <= bit num-
ber <= 9, bits 8 & 9 does not exist but does not matter
                              {
                              bitMask = getRequest[6] - '0' ;          //
convert ASCII to integer
                              bitMask = 1 << bitMask ; // create bit mask
                              PORTD ^= bitMask ;                       //
toggle PORTD with xor operator
                              }
                    }

          if(len == 0)                              // what do to by default
                    {
                    len =  putConstString(httpHeader) ;                //
HTTP header
                    len += putConstString(httpMimeTypeHTML) ;          //
with HTML MIME type
                    len += putConstString(indexPage) ;                 //
HTML page first part
                    len += putConstString(indexPage2) ;                //
HTML page second part
                    }

          return(len) ;                                                //
return to the library with the number of bytes to transmit
          }

/*
 * this function is called by the library
 * the user accesses to the UDP request by successive calls to
Spi_Ethernet_getByte()
 * the user puts data in the transmit buffer by successive calls to
Spi_Ethernet_putByte()
 * the function must return the length in bytes of the UDP reply, or
0 if nothing to transmit
 *
 * if you don't need to reply to UDP requests,
 * just define this function with a return(0) as single statement
 *
 */
```

```
unsigned int      SPI_Ethernet_UserUDP(unsigned char *remoteHost,
unsigned int remotePort, unsigned int destPort, unsigned int
reqLength)
        {
        unsigned int    len ;                          // my reply
length

        // reply is made of the remote host IP address in human read-
able format
        ByteToStr(remoteHost[0], dyna) ;                // first IP
address byte
        dyna[3] = '.' ;
        ByteToStr(remoteHost[1], dyna + 4) ;             // second
        dyna[7] = '.' ;
        ByteToStr(remoteHost[2], dyna + 8) ;             // third
        dyna[11] = '.' ;
        ByteToStr(remoteHost[3], dyna + 12) ;            // fourth

        dyna[15] = ':' ;                                     // add
separator

        // then remote host port number
        WordToStr(remotePort, dyna + 16) ;
        dyna[21] = '[' ;
        WordToStr(destPort, dyna + 22) ;
        dyna[27] = ']' ;
        dyna[28] = 0 ;

         // the total length of the request is the length of the
dynamic string plus the text of the request
        len = 28 + reqLength;

        // puts the dynamic string into the transmit buffer
        SPI_Ethernet_putBytes(dyna, 28) ;

         // then puts the request string converted into upper char
into the transmit buffer
        while(reqLength--)
                {
                SPI_Ethernet_putByte(toupper(SPI_Ethernet_getByte()))
;
                }

        return(len) ;             // back to the library with the
length of the UDP reply
        }
/*
 * main entry
 */
```

```
void    main()
        {

        // set PORTC as input
        DDRC = 0;
        // set PORTD as output
        DDRD = 0xFF;

        /*
         * starts ENC28J60 with :
         * reset bit on PORTB.B4
         * CS bit on PORTB.B5
         * my MAC & IP address
         * full duplex
         */
                    SPI1_Init_Advanced(_SPI_MASTER,   _SPI_FCY_DIV2,
_SPI_CLK_LO_LEADING);
       Spi_Rd_Ptr = SPI1_Read;                                   //
pass pointer to SPI Read function of used SPI module
        SPI_Ethernet_Init(myMacAddr, myIpAddr, Spi_Ethernet_FULLDU-
PLEX) ; // full duplex, CRC + MAC Unicast + MAC Broadcast filtering

        while(1) // do forever
                {
                /*
                * if necessary, test the return value to get error
code
                 */
                  SPI_Ethernet_doPacket() ;    // process incoming
Ethernet packets

                /*
                 * add your stuff here if needed
                 * Spi_Ethernet_doPacket() must be called as often
as possible
                 * otherwise packets could be lost
                 */
                }
        }
```

HW Connection



SPI GRAPHIC LCD LIBRARY

The mikroC PRO for AVR provides a library for operating Graphic Lcd 128x64 (with commonly used Samsung KS108/KS107 controller) via SPI interface.

For creating a custom set of Glcd images use Glcd Bitmap Editor Tool.

Note: The library uses the SPI module for communication. User must initialize SPI module before using the SPI Graphic Lcd Library.

Note: This Library is designed to work with the mikroElektronika's Serial Lcd/Glcd Adapter Board pinout, see schematic at the bottom of this page for details.

External dependencies of SPI Graphic Lcd Library

The implementation of SPI Graphic Lcd Library routines is based on Port Expander Library routines.

Prior to calling any of this library routines, Spi_Rd_Ptr needs to be initialized with the appropriate SPI_Read routine.

External dependencies are the same as Port Expander Library external dependencies.

Library Routines

Basic routines:

- SPI_Glcd_Init
- SPI_Glcd_Set_Side
- SPI_Glcd_Set_Page
- SPI_Glcd_Set_X
- SPI_Glcd_Read_Data
- SPI_Glcd_Write_Data

Advanced routines:

- SPI_Glcd_Fill
- SPI_Glcd_Dot
- SPI_Glcd_Line
- SPI_Glcd_V_Line
- SPI_Glcd_H_Line
- SPI_Glcd_Rectangle
- SPI_Glcd_Box
- SPI_Glcd_Circle
- SPI_Glcd_Set_Font
- SPI_Glcd_Write_Char
- SPI_Glcd_Write_Text
- SPI_Glcd_Image

SPI_Glcd_Init

<table>
<tr><td>Prototype</td><td><code>void SPI_Glcd_Init(char DeviceAddress);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initializes the Glcd module via SPI interface.

Parameters :

- <code>DeviceAddress</code>: SPI expander hardware address, see schematic at the bottom of this page</td></tr>
<tr><td>Requires</td><td>Global variables :

- <code>SPExpanderCS</code>: Chip Select line
- <code>SPExpanderRST</code>: Reset line
- <code>SPExpanderCS_Direction</code>: Direction of the Chip Select pin
- <code>SPExpanderRST_Direction</code>: Direction of the Reset pin

must be defined before using this function.

The SPI module needs to be initialized. See SPI_Init and SPI_Init_Advanced routines.</td></tr>
<tr><td>Example</td><td><pre>
// Port Expander module connections
sbit SPExpanderRST at PORTB.B0;
sbit SPExpanderCS   at PORTB.B1;

sbit SPExpanderRST_Direction at DDRB.B0;
sbit SPExpanderCS_Direction at DDRB.B1;
// End Port Expander module connections

...

// If Port Expander Library uses SPI1 module :
SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV2, _SPI_CLK_HI_TRAIL-
ING); // Initialize SPI module used with PortExpander
SPI_Rd_Ptr = SPI1_Read;   // Pass pointer to SPI
Read function of used SPI module
SPI_Glcd_Init(0);
</pre></td></tr>
</table>

SPI_Glcd_Set_Side

Prototype	`void SPI_Glcd_Set_Side(char x_pos);`
Returns	Nothing.
Description	Selects Glcd side. Refer to the Glcd datasheet for detail explanation. Parameters : - `x_pos`: position on x-axis. Valid values: 0..127 The parameter `x_pos` specifies the Glcd side: values from 0 to 63 specify the left side, values from 64 to 127 specify the right side. **Note**: For side, x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.

Example	The following two lines are equivalent, and both of them select the left side of Glcd:
	
	`SPI_Glcd_Set_Side(0);`
	`SPI_Glcd_Set_Side(10);`

SPI_Glcd_Set_Page

Prototype	`void SPI_Glcd_Set_Page(char page);`
Returns	Nothing.
Description	Selects page of Glcd. Parameters : - `page`: page number. Valid values: 0..7 **Note**: For side, x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`SPI_Glcd_Set_Page(5);`

SPI_Glcd_Set_X

Prototype	`void SPI_Glcd_Set_X(char x_pos);`
Returns	Nothing.
Description	Sets x-axis position to `x_pos` dots from the left border of Glcd within the selected side. Parameters : - `x_pos`: position on x-axis. Valid values: 0..63 **Note**: For side, x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`SPI_Glcd_Set_X(25);`

SPI_Glcd_Read_Data

Prototype	`char SPI_Glcd_Read_Data();`
Returns	One byte from Glcd memory.
Description	Reads data from the current location of Glcd memory and moves to the next location.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines. Glcd side, x-axis position and page should be set first. See the functions SPI_Glcd_Set_Side, SPI_Glcd_Set_X, and SPI_Glcd_Set_Page.

Example	`char data;`
	`...`
	`data = SPI_Glcd_Read_Data();`

SPI_Glcd_Write_Data

Prototype	`void SPI_Glcd_Write_Data(char Ddata);`
Returns	Nothing.
Description	Writes one byte to the current location in Glcd memory and moves to the next location. Parameters : - `Ddata`: data to be written
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines. Glcd side, x-axis position and page should be set first. See the functions SPI_Glcd_Set_Side, SPI_Glcd_Set_X, and SPI_Glcd_Set_Page.

Example	`char data;`
	`...`
	`SPI_Glcd_Write_Data(data);`

SPI_Glcd_Fill

Prototype	`void SPI_Glcd_Fill(char pattern);`
Returns	Nothing.
Description	Fills Glcd memory with byte pattern. Parameters : - `pattern`: byte to fill Glcd memory with To clear the Glcd screen, use `SPI_Glcd_Fill(0)`. To fill the screen completely, use `SPI_Glcd_Fill(0xFF)`.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Clear screen` `SPI_Glcd_Fill(0);`

SPI_Glcd_Dot

Prototype	`void SPI_Glcd_Dot(char x_pos, char y_pos, char color);`
Returns	Nothing.
Description	Draws a dot on Glcd at coordinates (x_pos, y_pos). Parameters : - `x_pos`: x position. Valid values: 0..127 - `y_pos`: y position. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the dot state: 0 clears dot, 1 puts a dot, and 2 inverts dot state. **Note**: For x and y axis layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Invert the dot in the upper left corner` `SPI_Glcd_Dot(0, 0, 2);`

SPI_Glcd_Line

Prototype	`void SPI_Glcd_Line(int x_start, int y_start, int x_end, int y_end, char color);`
Returns	Nothing.
Description	Draws a line on Glcd. Parameters : - `x_start`: x coordinate of the line start. Valid values: 0..127 - `y_start`: y coordinate of the line start. Valid values: 0..63 - `x_end`: x coordinate of the line end. Valid values: 0..127 - `y_end`: y coordinate of the line end. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 Parameter `color` determines the line color: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Draw a line between dots (0,0) and (20,30)` `SPI_Glcd_Line(0, 0, 20, 30, 1);`

SPI_Glcd_V_Line

Prototype	`void SPI_Glcd_V_Line(char y_start, char y_end, char x_pos, char color);`
Returns	Nothing.
Description	Draws a vertical line on Glcd. Parameters : - `y_start`: y coordinate of the line start. Valid values: 0..63 - `y_end`: y coordinate of the line end. Valid values: 0..63 - `x_pos`: x coordinate of vertical line. Valid values: 0..127 - `color`: color parameter. Valid values: 0..2 Parameter `color` determines the line color: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Draw a vertical line between dots (10,5) and (10,25)` `SPI_Glcd_V_Line(5, 25, 10, 1);`

SPI_Glcd_H_Line

Prototype	`void SPI_Glcd_H_Line(char x_start, char x_end, char y_pos, char color);`
Returns	Nothing.
Description	Draws a horizontal line on Glcd. Parameters : - `x_start`: x coordinate of the line start. Valid values: 0..127 - `x_end`: x coordinate of the line end. Valid values: 0..127 - `y_pos`: y coordinate of horizontal line. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the line color: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Draw a horizontal line between dots (10,20) and (50,20)` `SPI_Glcd_H_Line(10, 50, 20, 1);`

SPI_Glcd_Rectangle

Prototype	`void SPI_Glcd_Rectangle(char x_upper_left, char y_upper_left, char x_bottom_right, char y_bottom_right, char color);`
Returns	Nothing.
Description	Draws a rectangle on Glcd. Parameters : - `x_upper_left`: x coordinate of the upper left rectangle corner. Valid values: 0..127 - `y_upper_left`: y coordinate of the upper left rectangle corner. Valid values: 0..63 - `x_bottom_right`: x coordinate of the lower right rectangle corner. Valid values: 0..127 - `y_bottom_right`: y coordinate of the lower right rectangle corner. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the rectangle border: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Draw a rectangle between dots (5,5) and (40,40)` `SPI_Glcd_Rectangle(5, 5, 40, 40, 1);`

SPI_Glcd_Box

Prototype	`void SPI_Glcd_Box(char x_upper_left, char y_upper_left, char x_bottom_right, char y_bottom_right, char color);`
Returns	Nothing.
Description	Draws a box on Glcd. Parameters : - `x_upper_left`: x coordinate of the upper left box corner. Valid values: 0..127 - `y_upper_left`: y coordinate of the upper left box corner. Valid values: 0..63 - `x_bottom_right`: x coordinate of the lower right box corner. Valid values: 0..127 - `y_bottom_right`: y coordinate of the lower right box corner. Valid values: 0..63 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the box fill: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Draw a box between dots (5,15) and (20,40)` `SPI_Glcd_Box(5, 15, 20, 40, 1);`

SPI_Glcd_Circle

Prototype	`void SPI_Glcd_Circle(int x_center, int y_center, int radius, char color);`
Returns	Nothing.
Description	Draws a circle on Glcd. Parameters : - `x_center`: x coordinate of the circle center. Valid values: 0..127 - `y_center`: y coordinate of the circle center. Valid values: 0..63 - `radius`: radius size - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the circle line: 0 white, 1 black, and 2 inverts each dot.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routine.
Example	`// Draw a circle with center in (50,50) and radius=10` `SPI_Glcd_Circle(50, 50, 10, 1);`

SPI_Glcd_Set_Font

Prototype	`void SPI_Glcd_Set_Font(const code char *activeFont, char aFontWidth, char aFontHeight, unsigned int aFontOffs);`
Returns	Nothing.
Description	Sets font that will be used with SPI_Glcd_Write_Char and SPI_Glcd_Write_Text routines. Parameters : - `activeFont`: font to be set. Needs to be formatted as an array of char - `aFontWidth`: width of the font characters in dots. - `aFontHeight`: height of the font characters in dots. - `aFontOffs`: number that represents difference between the mikroC PRO character set and regular ASCII set (eg. if 'A' is 65 in ASCII character, and 'A' is 45 in the mikroC PRO character set, aFontOffs is 20). Demo fonts supplied with the library have an offset of 32, which means that they start with space. The user can use fonts given in the file "__Lib_Glcd_fonts" file located in the Uses folder or create his own fonts.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Use the custom 5x7 font "myfont" which starts with space (32):` `SPI_Glcd_Set_Font(myfont, 5, 7, 32);`

SPI_Glcd_Write_Char

Prototype	`void SPI_Glcd_Write_Char(char chr1, char x_pos, char page_num, char color);`
Returns	Nothing.
Description	Prints character on Glcd. Parameters : - `chr1`: character to be written - `x_pos`: character starting position on x-axis. Valid values: 0..(127-FontWidth) - `page_num`: the number of the page on which character will be written. Valid values: 0..7 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the character: 0 white, 1 black, and 2 inverts each dot. **Note**: For x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines. Use the SPI_Glcd_Set_Font to specify the font for display; if no font is specified, then the default 5x8 font supplied with the library will be used.
Example	`// Write character 'C' on the position 10 inside the page 2:` `SPI_Glcd_Write_Char('C', 10, 2, 1);`

SPI_Glcd_Write_Text

Prototype	`void SPI_Glcd_Write_Text(char text[], char x_pos, char page_num, char color);`
Returns	Nothing.
Description	Prints text on Glcd. Parameters : - `text`: text to be written - `x_pos`: text starting position on x-axis. - `page_num`: the number of the page on which text will be written. Valid values: 0..7 - `color`: color parameter. Valid values: 0..2 The parameter `color` determines the color of the text: 0 white, 1 black, and 2 inverts each dot. **Note**: For x axis and page layout explanation see schematic at the bottom of this page.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines. Use the SPI_Glcd_Set_Font to specify the font for display; if no font is specified, then the default 5x8 font supplied with the library will be used.
Example	`// Write text "Hello world!" on the position 10 inside the page 2:` `SPI_Glcd_Write_Text("Hello world!", 10, 2, 1);`

SPI_Glcd_Image

Prototype	`void SPI_Glcd_Image(const code char *image);`
Returns	Nothing.
Description	Displays bitmap on Glcd. Parameters : - `image`: image to be displayed. Bitmap array can be located in both code and RAM memory (due to the mikroC PRO for AVR pointer to const and pointer to RAM equivalency). Use the mikroC PRO's integrated Glcd Bitmap Editor (menu option **Tools › Glcd Bitmap Editor**) to convert image to a constant array suitable for displaying on Glcd.
Requires	Glcd needs to be initialized for SPI communication, see SPI_Glcd_Init routines.
Example	`// Draw image my_image on Glcd` `SPI_Glcd_Image(my_image);`

Library Example

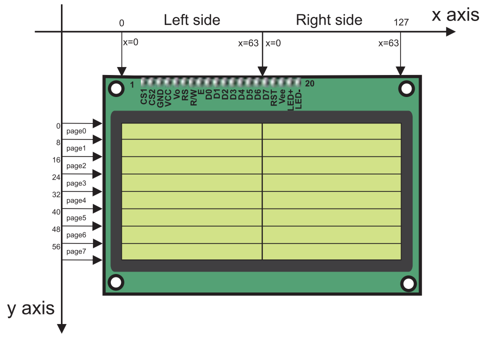
The example demonstrates how to communicate to KS0108 Glcd via the SPI module, using serial to parallel convertor MCP23S17.

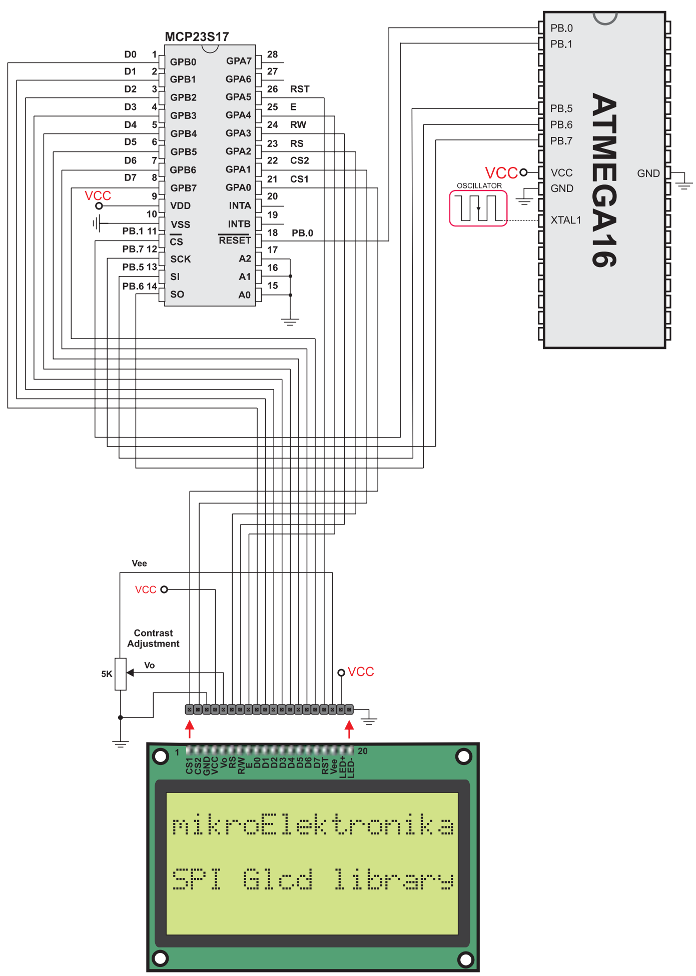
```
const code char truck_bmp[1024];

// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS  at PORTB.B1;

sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections


void Delay2s(){                           // 2 seconds delay function
  Delay_ms(2000);
}

void main() {
  char *someText;
  char counter;
```

```
// If Port Expander Library uses SPI1 module :
   SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV2, _SPI_CLK_HI_TRAIL-
ING);  // Initialize SPI module used with PortExpander
  SPI_Rd_Ptr = SPI1_Read;                    // Pass pointer to SPI Read
function of used SPI module

  // // If Port Expander Library uses SPI2 module :

  // Initialize SPI module used with PortExpander
         //     SPI2_Init_Advanced(_SPI_MASTER,     _SPI_FCY_DIV2,
_SPI_CLK_HI_TRAILING);

  // Pass pointer to SPI Read function of used SPI module
  // SPI_Rd_Ptr = &SPI2_Read;

  SPI_Glcd_Init(0);                          // Initialize Glcd via SPI
  SPI_Glcd_Fill(0x00);                                // Clear Glcd

  while(1) {

  SPI_Glcd_Image(truck_bmp);                          // Draw image
  Delay2s(); Delay2s();

  SPI_Glcd_Fill(0x00);                                // Clear Glcd
  Delay2s;

  SPI_Glcd_Box(62,40,124,56,1);                      // Draw box
  SPI_Glcd_Rectangle(5,5,84,35,1);                  // Draw rectangle
  SPI_Glcd_Line(0, 63, 127, 0,1);                    // Draw line
  Delay2s();

  for(counter = 5; counter < 60; counter+=5 ) {   // Draw horizontal
and vertical line
    Delay_ms(250);
    SPI_Glcd_V_Line(2, 54, counter, 1);
    SPI_Glcd_H_Line(2, 120, counter, 1);
    }
  Delay2s();

  SPI_Glcd_Fill(0x00);                                // Clear Glcd
  SPI_Glcd_Set_Font(Character8x7, 8, 8, 32);    // Choose font, see
__Lib_GlcdFonts.c in Uses folder
  SPI_Glcd_Write_Text("mikroE", 5, 7, 2);       // Write string

for (counter = 1; counter <= 10; counter++)   // Draw circles
    SPI_Glcd_Circle(63,32, 3*counter, 1);
  Delay2s();
```

```
  SPI_Glcd_Box(12,20, 70,63, 2);                  // Draw box
  Delay2s();

  SPI_Glcd_Fill(0xFF);                             // Fill Glcd

  SPI_Glcd_Set_Font(Character8x7, 8, 7, 32);    // Change font
  someText = "8x7 Font";
  SPI_Glcd_Write_Text(someText, 5, 0, 2);       // Write string
  SPI_Glcd_Write_Text(someText, 5, 1, 2);       // Write string
  Delay2s();

  SPI_Glcd_Set_Font(System3x5, 3, 5, 32);       // Change font
  someText = "3X5 CAPITALS ONLY";
  SPI_Glcd_Write_Text(someText, 5, 2, 2);       // Write string
  SPI_Glcd_Write_Text(someText, 5, 3, 2);       // Write string
  Delay2s();

  SPI_Glcd_Set_Font(font5x7, 5, 7, 32);         // Change font
  someText = "5x7 Font";
  SPI_Glcd_Write_Text(someText, 5, 4, 2);       // Write string
  SPI_Glcd_Write_Text(someText, 5, 5, 2);       // Write string
  Delay2s();

  SPI_Glcd_Set_Font(FontSystem5x7_v2, 5, 7, 32); // Change font
  someText = "5x7 Font (v2)";
  SPI_Glcd_Write_Text(someText, 5, 6, 2);       // Write string
  SPI_Glcd_Write_Text(someText, 5, 7, 2);       // Write string
  Delay2s();

    }
}
```

HW Connection





SPI Glcd HW connection

SPI LCD LIBRARY

The mikroC PRO for AVR provides a library for communication with Lcd (with HD44780 compliant controllers) in 4-bit mode via SPI interface.

For creating a custom set of Lcd characters use Lcd Custom Character Tool.

Note: The library uses the SPI module for communication. The user must initialize the SPI module before using the SPI Lcd Library.

Note: This Library is designed to work with the mikroElektronika's Serial Lcd Adapter Board pinout. See schematic at the bottom of this page for details.

External dependencies of SPI Lcd Library

The implementation of SPI Lcd Library routines is based on Port Expander Library routines.

Prior to calling any of this library routines, Spi_Rd_Ptr needs to be initialized with the appropriate SPI_Read routine.

External dependencies are the same as Port Expander Library external dependencies.

Library Routines

- SPI_Lcd_Config
- SPI_Lcd_Out
- SPI_Lcd_Out_Cp
- SPI_Lcd_Chr
- SPI_Lcd_Chr_Cp
- SPI_Lcd_Cmd

SPI_Lcd_Config

<table>
<tr><td>Prototype</td><td><code>void SPI_Lcd_Config(char DeviceAddress);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initializes the Lcd module via SPI interface.

Parameters :

- <code>DeviceAddress</code>: SPI expander hardware address, see schematic at the bottom of this page</td></tr>
<tr><td>Requires</td><td>Global variables :

- <code>SPExpanderCS</code>: Chip Select line
- <code>SPExpanderRST</code>: Reset line
- <code>SPExpanderCS_Direction</code>: Direction of the Chip Select pin
- <code>SPExpanderRST_Direction</code>: Direction of the Reset pin

must be defined before using this function.

The SPI module needs to be initialized. See SPI1_Init and SPI1_Init_Advanced routines.</td></tr>
<tr><td>Example</td><td><pre>
// Port Expander module connections
sbit SPExpanderRST at PORTB.B0;
sbit SPExpanderCS at PORTB.B1;
sbit SPExpanderRST_Direction at DDRB.B0;
sbit SPExpanderCS_Direction at DDRB.B1;
// End Port Expander module connections

void main() {

// If Port Expander Library uses SPI1 module
SPI1_Init();   // Initialize SPI module
used with PortExpander
SPI_Rd_Ptr = SPI1_Read;   // Pass pointer to SPI
Read function of used SPI module
SPI_Lcd_Config(0);   // initialize Lcd over
SPI interface
</pre></td></tr>
</table>

SPI_Lcd_Out

Prototype	`void SPI_Lcd_Out(char row, char column, char *text);`
Returns	Nothing.
Description	Prints text on the Lcd starting from specified position. Both string variables and literals can be passed as a text. Parameters : - `row`: starting position row number - `column`: starting position column number - `text`: text to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd_Config routines.
Example	`// Write text "Hello!" on Lcd starting from row 1, column 3:` `SPI_Lcd_Out(1, 3, "Hello!");`

SPI_Lcd_Out_Cp

Prototype	`void SPI_Lcd_Out_CP(char *text);`
Returns	Nothing.
Description	Prints text on the Lcd at current cursor position. Both string variables and literals can be passed as a text. Parameters : - `text`: text to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd_Config routines.
Example	`// Write text "Here!" at current cursor position:` `SPI_Lcd_Out_CP("Here!");`

SPI_Lcd_Chr

Prototype	`void SPI_Lcd_Chr(char Row, char Column, char Out_Char);`
Returns	Nothing.
Description	Prints character on Lcd at specified position. Both variables and literals can be passed as character. Parameters : - `Row`: writing position row number - `Column`: writing position column number - `Out_Char`: character to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd_Config routines.
Example	`// Write character "i" at row 2, column 3:` `SPI_Lcd_Chr(2, 3, 'i');`

SPI_Lcd_Chr_Cp

Prototype	`void SPI_Lcd_Chr_CP(char Out_Char);`
Returns	Nothing.
Description	Prints character on Lcd at current cursor position. Both variables and literals can be passed as character. Parameters : - `Out_Char`: character to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd_Config routines.
Example	`// Write character "e" at current cursor position:` `SPI_Lcd_Chr_Cp('e');`

SPI_Lcd_Cmd

Prototype	`void SPI_Lcd_Cmd(char out_char);`
Returns	Nothing.
Description	Sends command to Lcd. Parameters : - `out_char`: command to be sent **Note**: Predefined constants can be passed to the function, see Available Lcd Commands.
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd_Config routines.
Example	`// Clear Lcd display:` `SPI_Lcd_Cmd(LCD_CLEAR);`

Available Lcd Commands

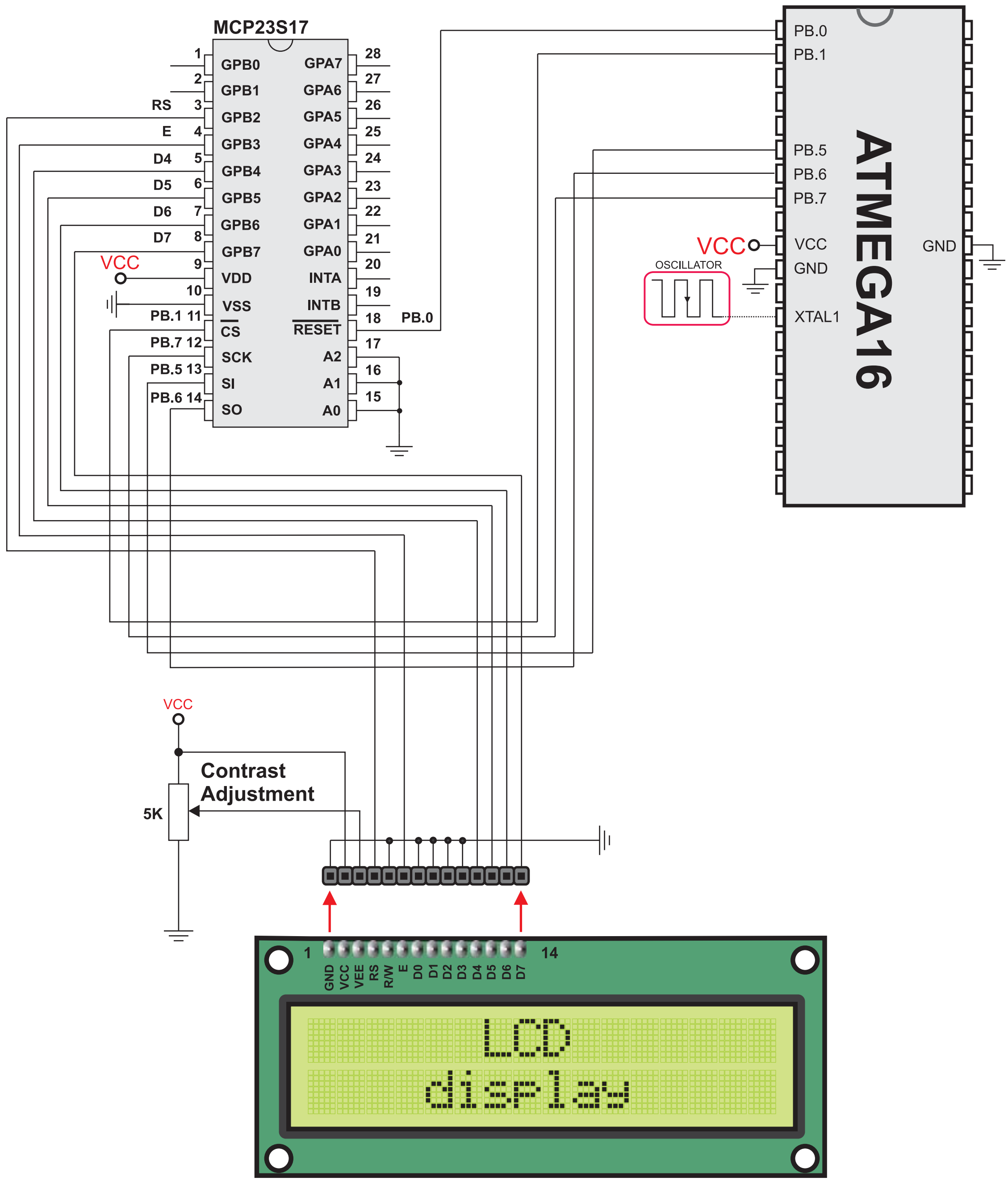
Lcd Command	Purpose
`LCD_FIRST_ROW`	Move cursor to the 1st row
`LCD_SECOND_ROW`	Move cursor to the 2nd row
`LCD_THIRD_ROW`	Move cursor to the 3rd row
`LCD_FOURTH_ROW`	Move cursor to the 4th row
`LCD_CLEAR`	Clear display
`LCD_RETURN_HOME`	Return cursor to home position, returns a shifted display to its original position. Display data RAM is unaffected.
`LCD_CURSOR_OFF`	Turn off cursor
`LCD_UNDERLINE_ON`	Underline cursor on
`LCD_BLINK_CURSOR_ON`	Blink cursor on
`LCD_MOVE_CURSOR_LEFT`	Move cursor left without changing display data RAM
`LCD_MOVE_CURSOR_RIGHT`	Move cursor right without changing display data RAM
`LCD_TURN_ON`	Turn Lcd display on
`LCD_TURN_OFF`	Turn Lcd display off
`LCD_SHIFT_LEFT`	Shift display left without changing display data RAM
`LCD_SHIFT_RIGHT`	Shift display right without changing display data RAM

Library Example

This example demonstrates how to communicate Lcd via the SPI module, using serial to parallel convertor MCP23S17.

```
char *text = "mikroElektronika";

// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS  at PORTB.B1;
sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections


void main() {

  // If Port Expander Library uses SPI1 module
  SPI1_Init();                              // Initialize SPI module
used with PortExpander
  SPI_Rd_Ptr = SPI1_Read;                 // Pass pointer to SPI Read
function of used SPI module

  // // If Port Expander Library uses SPI2 module
  // SPI2_Init();                           // Initialize SPI module
used with PortExpander
  // SPI_Rd_Ptr = SPI2_Read;              // Pass pointer to SPI Read
function of used SPI module

  SPI_Lcd_Config(0);                        // Initialize Lcd over SPI
interface
  SPI_Lcd_Cmd(Lcd_CLEAR);                  // Clear display
  SPI_Lcd_Cmd(Lcd_CURSOR_OFF);             // Turn cursor off
  SPI_Lcd_Out(1,6, "mikroE");              // Print text to Lcd, 1st
row, 6th column
  SPI_Lcd_Chr_CP('!');                     // Append '!'
  SPI_Lcd_Out(2,1, text);                  // Print text to Lcd, 2nd
row, 1st column

  // SPI_Lcd_Out(3,1,"mikroE");            // For Lcd with more than
two rows
  // SPI_Lcd_Out(4,15,"mikroE");           // For Lcd with more than
two rows
}
```

HW Connection



SPI Lcd HW connection

SPI LCD8 (8-BIT INTERFACE) LIBRARY

The mikroC PRO for AVR provides a library for communication with Lcd (with HD44780 compliant controllers) in 8-bit mode via SPI interface.

For creating a custom set of Lcd characters use Lcd Custom Character Tool.

Note: Library uses the SPI module for communication. The user must initialize the SPI module before using the SPI Lcd Library.

Note: This Library is designed to work with mikroElektronika's Serial Lcd/GLcd Adapter Board pinout, see schematic at the bottom of this page for details.

External dependencies of SPI Lcd Library

The implementation of SPI Lcd Library routines is based on Port Expander Library routines.

Prior to calling any of this library routines, Spi_Rd_Ptr needs to be initialized with the appropriate SPI_Read routine.

External dependencies are the same as Port Expander Library external dependencies.

Library Routines

- SPI_Lcd8_Config
- SPI_Lcd8_Out
- SPI_Lcd8_Out_Cp
- SPI_Lcd8_Chr
- SPI_Lcd8_Chr_Cp
- SPI_Lcd8_Cmd

SPI_Lcd8_Config

<table>
<tr><td>Prototype</td><td><code>void SPI_Lcd8_Config(char DeviceAddress);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initializes the Lcd module via SPI interface.

Parameters :

- <code>DeviceAddress</code>: SPI expander hardware address, see schematic at the bottom of this page</td></tr>
<tr><td>Requires</td><td>Global variables :

- <code>SPExpanderCS</code>: Chip Select line
- <code>SPExpanderRST</code>: Reset line
- <code>SPExpanderCS_Direction</code>: Direction of the Chip Select pin
- <code>SPExpanderRST_Direction</code>: Direction of the Reset pin

must be defined before using this function.

The SPI module needs to be initialized. See SPI1_Init and SPI1_Init_Advanced routines.</td></tr>
<tr><td>Example</td><td><pre>
// Port Expander module connections
sbit SPExpanderRST at PORTB.B0;
sbit SPExpanderCS at PORTB.B1;
sbit SPExpanderRST_Direction at DDRB.B0;
sbit SPExpanderCS_Direction at DDRB.B1;
// End Port Expander module connections

...

// If Port Expander Library uses SPI1 module
SPI1_Init();   // Initialize SPI module used with PortExpander
SPI_Rd_Ptr = SPI1_Read;   // Pass pointer to SPI Read function of used SPI module>
SPI_Lcd8_Config(0);   // intialize Lcd in 8bit mode via SPI
</pre></td></tr>
</table>

SPI_Lcd8_Out

Prototype	`void SPI_Lcd8_Out(unsigned short row, unsigned short column, char *text);`
Returns	Nothing.
Description	Prints text on Lcd starting from specified position. Both string variables and literals can be passed as a text. Parameters : - `row:` starting position row number - `column:` starting position column number - `text:` text to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd8_Config routines.
Example	`// Write text "Hello!" on Lcd starting from row 1, column 3:` `SPI_Lcd8_Out(1, 3, "Hello!");`

SPI_Lcd8_Out_Cp

Prototype	`void SPI_Lcd8_Out_CP(char *text);`
Returns	Nothing.
Description	Prints text on Lcd at current cursor position. Both string variables and literals can be passed as a text. Parameters : - `text:` text to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd8_Config routines.
Example	`// Write text "Here!" at current cursor position:` `SPI_Lcd8_Out_Cp("Here!");`

SPI_Lcd8_Chr

Prototype	`void SPI_Lcd8_Chr(unsigned short row, unsigned short column, char out_char);`
Returns	Nothing.
Description	Prints character on Lcd at specified position. Both variables and literals can be passed as character. Parameters : - `row:` writing position row number - `column:` writing position column number - `out_char:` character to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd8_Config routines.
Example	`// Write character "i" at row 2, column 3:` `SPI_Lcd8_Chr(2, 3, 'i');`

SPI_Lcd8_Chr_Cp

Prototype	`void SPI_Lcd8_Chr_CP(char out_char);`
Returns	Nothing.
Description	Prints character on Lcd at current cursor position. Both variables and literals can be passed as character. Parameters : - `out_char`: character to be written
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd8_Config routines.

Example	`Print “e” at current cursor position:`
	
	`// Write character "e" at current cursor position:`
	`SPI_Lcd8_Chr_Cp('e');`

SPI_Lcd8_Cmd

Prototype	`void SPI_Lcd8_Cmd(char out_char);`
Returns	Nothing.
Description	Sends command to Lcd. Parameters : - `out_char`: command to be sent **Note**: Predefined constants can be passed to the function, see Available Lcd Commands.
Requires	Lcd needs to be initialized for SPI communication, see SPI_Lcd8_Config routines.
Example	`// Clear Lcd display:` `SPI_Lcd8_Cmd(Lcd_CLEAR);`

Available Lcd Commands

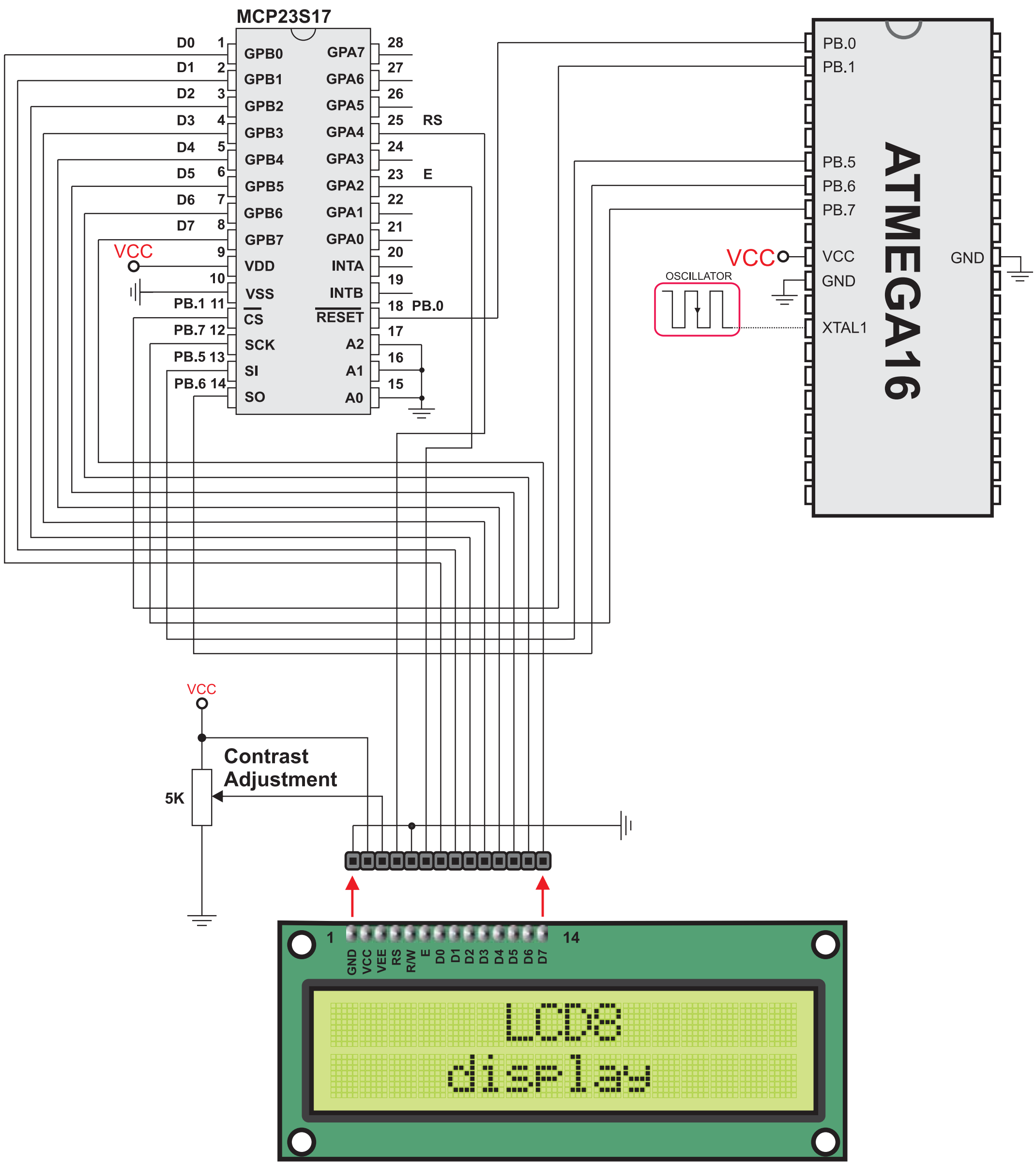
Lcd Command	Purpose
LCD_FIRST_ROW	Move cursor to the 1st row
LCD_SECOND_ROW	Move cursor to the 2nd row
LCD_THIRD_ROW	Move cursor to the 3rd row
LCD_FOURTH_ROW	Move cursor to the 4th row
LCD_CLEAR	Clear display
LCD_RETURN_HOME	Return cursor to home position, returns a shifted display to its original position. Display data RAM is unaffected.
LCD_CURSOR_OFF	Turn off cursor
LCD_UNDERLINE_ON	Underline cursor on
LCD_BLINK_CURSOR_ON	Blink cursor on
LCD_MOVE_CURSOR_LEFT	Move cursor left without changing display data RAM
LCD_MOVE_CURSOR_RIGHT	Move cursor right without changing display data RAM
LCD_TURN_ON	Turn Lcd display on
LCD_TURN_OFF	Turn Lcd display off
LCD_SHIFT_LEFT	Shift display left without changing display data RAM
LCD_SHIFT_RIGHT	Shift display right without changing display data RAM

Library Example

This example demonstrates how to communicate Lcd in 8-bit mode via the SPI module, using serial to parallel convertor MCP23S17.

```
char *text = "mikroE";

// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS  at PORTB.B1;
sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections


void main() {

  // If Port Expander Library uses SPI1 module
  SPI1_Init();                                        // Initialize SPI
module used with PortExpander
  SPI_Rd_Ptr = SPI1_Read;                        // Pass pointer to SPI
Read function of used SPI module

  // // If Port Expander Library uses SPI2 module
  // SPI2_Init();                                       // Initialize SPI
module used with PortExpander
  // SPI_Rd_Ptr = SPI2_Read;                     // Pass pointer to SPI
Read function of used SPI module

  SPI_Lcd8_Config(0);                               // Intialize Lcd in
8bit mode via SPI
  SPI_Lcd8_Cmd(LCD_CLEAR);                        // Clear display
  SPI_Lcd8_Cmd(LCD_CURSOR_OFF);                   // Turn cursor off
  SPI_Lcd8_Out(1,6, text);                         // Print text to Lcd,
1st row, 6th column...
  SPI_Lcd8_Chr_CP('!');                            // Append '!'
  SPI_Lcd8_Out(2,1, "mikroelektronika");       // Print text to Lcd,
2nd row, 1st column...
  SPI_Lcd8_Out(3,1, text);                          // For Lcd modules
with more than two rows
  SPI_Lcd8_Out(4,15, text);                         // For Lcd modules
with more than two rows
}
```

HW Connection



SPI Lcd8 HW connection

SPI T6963C GRAPHIC LCD LIBRARY

The mikroC PRO for AVR provides a library for working with Glcds based on TOSHIBA T6963C controller via SPI interface. The Toshiba T6963C is a very popular Lcd controller for the use in small graphics modules. It is capable of controlling displays with a resolution up to 240x128. Because of its low power and small outline it is most suitable for mobile applications such as PDAs, MP3 players or mobile measurement equipment. Although this controller is small, it has a capability of displaying and merging text and graphics and it manages all interfacing signals to the displays Row and Column drivers.

For creating a custom set of Glcd images use Glcd Bitmap Editor Tool.

Note: The library uses the SPI module for communication. The user must initialize SPI module before using the SPI T6963C Glcd Library.

Note: This Library is designed to work with mikroElektronika's Serial Glcd 240x128 and 240x64 Adapter Boards pinout, see schematic at the bottom of this page for details.

Note: Some mikroElektronika's adapter boards have pinout different from T6369C datasheets. Appropriate relations between these labels are given in the table below:

Adapter Board	T6369C datasheet
RS	C/D
R/W	/RD
E	/WR

External dependencies of SPI T6963C Graphic Lcd Library

The implementation of SPI T6963C Graphic Lcd Library routines is based on Port Expander Library routines.

Prior to calling any of this library routines, Spi_Rd_Ptr needs to be initialized with the appropriate SPI_Read routine.

External dependencies are the same as Port Expander Library external dependencies.

Library Routines

- SPI_T6963C_Config
- SPI_T6963C_WriteData
- SPI_T6963C_WriteCommand
- SPI_T6963C_SetPtr
- SPI_T6963C_WaitReady
- SPI_T6963C_Fill
- SPI_T6963C_Dot
- SPI_T6963C_Write_Char
- SPI_T6963C_Write_Text
- SPI_T6963C_Line
- SPI_T6963C_Rectangle
- SPI_T6963C_Box
- SPI_T6963C_Circle
- SPI_T6963C_Image
- SPI_T6963C_Sprite
- SPI_T6963C_Set_Cursor

Note: The following low level library routines are implemented as macros. These macros can be found in the `SPI_T6963C.h` header file which is located in the SPI T6963C example projects folders.

- SPI_T6963C_ClearBit
- SPI_T6963C_SetBit
- SPI_T6963C_NegBit
- SPI_T6963C_DisplayGrPanel
- SPI_T6963C_DisplayTxtPanel
- SPI_T6963C_SetGrPanel
- SPI_T6963C_SetTxtPanel
- SPI_T6963C_PanelFill
- SPI_T6963C_GrFill
- SPI_T6963C_TxtFill
- SPI_T6963C_Cursor_Height
- SPI_T6963C_Graphics
- SPI_T6963C_Text
- SPI_T6963C_Cursor
- SPI_T6963C_Cursor_Blink

SPI_T6963C_Config

<table>
<tr><td>Prototype</td><td><code>void SPI_T6963C_Config(unsigned int width, unsigned char height, unsigned char fntW, char DeviceAddress, unsigned char wr, unsigned char rd, unsigned char cd, unsigned char rst);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initalizes the Graphic Lcd controller.

Parameters :

- <code>width</code>: width of the Glcd panel
- <code>height</code>: height of the Glcd panel
- <code>fntW</code>: font width
- <code>DeviceAddress</code>: SPI expander hardware address, see schematic at the bottom of this page
- <code>wr</code>: write signal pin on Glcd control port
- <code>rd</code>: read signal pin on Glcd control port
- <code>cd</code>: command/data signal pin on Glcd control port
- <code>rst</code>: reset signal pin on Glcd control port

Display RAM organization:
The library cuts RAM into panels : a complete panel is one graphics panel followed by a text panel (see schematic below).

<pre>
schematic:
+---------------------+ /\
+ GRAPHICS PANEL #0   + |
+   + |
+   + |
+   + |
+---------------------+ | PANEL 0
+ TEXT PANEL #0   + |
+   + \/
+---------------------+ /\
+ GRAPHICS PANEL #1   + |
+   + |
+   + |
+   + |
+---------------------+ | PANEL 1
+ TEXT PANEL #2   + |
+   + |
+---------------------+ \/
</pre></td></tr>
</table>

<table>
<tr><td>Requires</td><td>Global variables :

- <code>SPExpanderCS</code>: Chip Select line
- <code>SPExpanderRST</code>: Reset line
- <code>SPExpanderRST_Direction</code>: Direction of the Chip Select pin
- <code>SPExpanderCS_Direction</code>: Direction of the Reset pin

variables must be defined before using this function.

The SPI module needs to be initialized. See the SPI_Init and SPI_Init_Advanced routines.</td></tr>
<tr><td>Example</td><td>

```
// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS   at PORTB.B1;
sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections


...

// Pass pointer to SPI Read function of used SPI module
SPI_Rd_Ptr = SPI1_Read;

// Initialize SPI module
SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV32, _SPI_CLK_HI_TRAIL-
ING);
SPI_T6963C_Config(240, 64, 8, 0, 0, 1, 3, 4);
```

</td></tr>
</table>

SPI_T6963C_WriteData

Prototype	`void SPI_T6963C_WriteData(unsigned char Ddata);`
Returns	Nothing.
Description	Writes data to T6963C controller via SPI interface. Parameters : - `Ddata`: data to be written
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_WriteData(AddrL);`

SPI_T6963C_WriteCommand

Prototype	`void SPI_T6963C_WriteCommand(unsigned char Ddata);`
Returns	Nothing.
Description	Writes command to T6963C controller via SPI interface. Parameters : - `Ddata`: command to be written
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_WriteCommand(SPI_T6963C_CURSOR_POINTER_SET);`

SPI_T6963C_SetPtr

Prototype	`void SPI_T6963C_SetPtr(unsigned int p, unsigned char c);`
Returns	Nothing.
Description	Sets the memory pointer p for command c. Parameters : - `p`: address where command should be written - `c`: command to be written
Requires	SToshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_SetPtr(T6963C_grHomeAddr + start, T6963C_ADDRESS_POINT-ER_SET);`

SPI_T6963C_WaitReady

Prototype	`void SPI_T6963C_WaitReady(void);`
Returns	Nothing.
Description	Pools the status byte, and loops until Toshiba Glcd module is ready.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_WaitReady();`

SPI_T6963C_Fill

Prototype	`void SPI_T6963C_Fill(unsigned char v, unsigned int start, unsigned int len);`
Returns	Nothing.
Description	Fills controller memory block with given byte. Parameters : - `v:` byte to be written - `start:` starting address of the memory block - `len:` length of the memory block in bytes
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Fill(0x33,0x00FF,0x000F);`

SPI_T6963C_Dot

Prototype	`void SPI_T6963C_Dot(int x, int y, unsigned char color);`
Returns	Nothing.
Description	Draws a dot in the current graphic panel of Glcd at coordinates (x, y). Parameters : - `x:` dot position on x-axis - `y:` dot position on y-axis - `color:` color parameter. Valid values: SPI_T6963C_BLACK and SPI_T6963C_WHITE
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Dot(x0, y0, pcolor);`

SPI_T6963C_Write_Char

<table>
<tr><td>Prototype</td><td><code>void SPI_T6963C_Write_Char(unsigned char c, unsigned char x, unsigned char y, unsigned char mode);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Writes a char in the current text panel of Glcd at coordinates (x, y).

Parameters :

- <code>c:</code> char to be written
- <code>x:</code> char position on x-axis
- <code>y:</code> char position on y-axis
- <code>mode:</code> mode parameter. Valid values: SPI_T6963C_ROM_MODE_OR, SPI_T6963C_ROM_MODE_XOR, SPI_T6963C_ROM_MODE_AND and SPI_T6963C_ROM_MODE_TEXT

Mode parameter explanation:

- OR Mode: In the OR-Mode, text and graphics can be displayed and the data is logically “OR-ed”. This is the most common way of combining text and graphics for example labels on buttons.
- XOR-Mode: In this mode, the text and graphics data are combined via the logical “exclusive OR”. This can be useful to display text in negative mode, i.e. white text on black background.
- AND-Mode: The text and graphic data shown on display are combined via the logical “AND function”.
- TEXT-Mode: This option is only available when displaying just a text. The Text Attribute values are stored in the graphic area of display memory.

For more details see the T6963C datasheet.</td></tr>
<tr><td>Requires</td><td>Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.</td></tr>
<tr><td>Example</td><td><code>SPI_T6963C_Write_Char("A",22,23,AND);</code></td></tr>
</table>

SPI_T6963C_Write_Text

Prototype	`void SPI_T6963C_Write_Text(unsigned char *str, unsigned char x, unsigned char y, unsigned char mode);`
Returns	Nothing.
Description	Writes text in the current text panel of Glcd at coordinates (x, y). Parameters : - `str`: text to be written - `x`: text position on x-axis - `y`: text position on y-axis - `mode`: mode parameter. Valid values: SPI_T6963C_ROM_MODE_OR, SPI_T6963C_ROM_MODE_XOR, SPI_T6963C_ROM_MODE_AND and SPI_T6963C_ROM_MODE_TEXT Mode parameter explanation: - OR Mode: In the OR-Mode, text and graphics can be displayed and the data is logically “OR-ed”. This is the most common way of combining text and graphics for example labels on buttons. - XOR-Mode: In this mode, the text and graphics data are combined via the logical “exclusive OR”. This can be useful to display text in negative mode, i.e. white text on black background. - AND-Mode: The text and graphic data shown on the display are combined via the logical “AND function”. - TEXT-Mode: This option is only available when displaying just a text. The Text Attribute values are stored in the graphic area of display memory. For more details see the T6963C datasheet.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Write_Text("Glcd LIBRARY DEMO, WELCOME !", 0, 0, T6963C_ROM_MODE_EXOR);`

SPI_T6963C_Line

Prototype	`void SPI_T6963C_Line(int x0, int y0, int x1, int y1, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a line from (x0, y0) to (x1, y1). Parameters : - `x0:` x coordinate of the line start - `y0:` y coordinate of the line end - `x1:` x coordinate of the line start - `y1:` y coordinate of the line end - `pcolor:` color parameter. Valid values: SPI_T6963C_BLACK and SPI_T6963C_WHITE
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Line(0, 0, 239, 127, T6963C_WHITE);`

SPI_T6963C_Rectangle

Prototype	`void SPI_T6963C_Rectangle(int x0, int y0, int x1, int y1, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a rectangle on Glcd. Parameters : - `x0:` x coordinate of the upper left rectangle corner - `y0:` y coordinate of the upper left rectangle corner - `x1:` x coordinate of the lower right rectangle corner - `y1:` y coordinate of the lower right rectangle corner - `pcolor:` color parameter. Valid values: SPI_T6963C_BLACK and SPI_T6963C_WHITE
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Rectangle(20, 20, 219, 107, T6963C_WHITE);`

SPI_T6963C_Box

Prototype	`void SPI_T6963C_Box(int x0, int y0, int x1, int y1, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a box on the Glcd Parameters : - `x0:` x coordinate of the upper left box corner - `y0:` y coordinate of the upper left box corner - `x1:` x coordinate of the lower right box corner - `y1:` y coordinate of the lower right box corner - `pcolor:` color parameter. Valid values: SPI_T6963C_BLACK and SPI_T6963C_WHITE
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Box(0, 119, 239, 127, T6963C_WHITE);`

SPI_T6963C_Circle

Prototype	`void SPI_T6963C_Circle(int x, int y, long r, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a circle on the Glcd. Parameters : - `x:` x coordinate of the circle center - `y:` y coordinate of the circle center - `r:` radius size - `pcolor:` color parameter. Valid values: SPI_T6963C_BLACK and SPI_T6963C_WHITE
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Circle(120, 64, 110, T6963C_WHITE);`

SPI_T6963C_Image

Prototype	`void SPI_T6963C_Image(const code char *pic);`
Returns	Nothing.
Description	Displays bitmap on Glcd. Parameters : - `pic:` image to be displayed. Bitmap array can be located in both code and RAM memory (due to the mikroC PRO for AVR pointer to const and pointer to RAM equivalency). Use the mikroC PRO's integrated Glcd Bitmap Editor (menu option **Tools › Glcd Bitmap Editor**) to convert image to a constant array suitable for displaying on Glcd.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Image(my_image);`

SPI_T6963C_Sprite

Prototype	`void SPI_T6963C_Sprite(unsigned char px, unsigned char py, const code char *pic, unsigned char sx, unsigned char sy);`
Returns	Nothing.
Description	Fills graphic rectangle area (px, py) to (px+sx, py+sy) with custom size picture. Parameters : - `px:` x coordinate of the upper left picture corner. Valid values: multiples of the font width - `py:` y coordinate of the upper left picture corner - `pic:` picture to be displayed - `sx:` picture width. Valid values: multiples of the font width - `sy:` picture height **Note:** If `px` and `sx` parameters are not multiples of the font width they will be scaled to the nearest lower number that is a multiple of the font width.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Sprite(76, 4, einstein, 88, 119); // draw a sprite`

SPI_T6963C_Set_Cursor

Prototype	`void SPI_T6963C_Set_Cursor(unsigned char x, unsigned char y);`
Returns	Nothing.
Description	Sets cursor to row x and column y. Parameters : - `x:` cursor position row number - `y:` cursor position column number
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Set_Cursor(cposx, cposy);`

SPI_T6963C_ClearBit

Prototype	`void SPI_T6963C_ClearBit(char b);`
Returns	Nothing.
Description	Clears control port bit(s). Parameters : - `b:` bit mask. The function will clear bit `x` on control port if bit `x` in bit mask is set to 1.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// clear bits 0 and 1 on control port` `SPI_T6963C_ClearBit(0x03);`

SPI_T6963C_SetBit

Prototype	`void SPI_T6963C_SetBit(char b);`
Returns	Nothing.
Description	Sets control port bit(s). Parameters : - `b`: bit mask. The function will set bit `x` on control port if bit `x` in bit mask is set to 1.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// set bits 0 and 1 on control port` `SPI_T6963C_SetBit(0x03);`

SPI_T6963C_NegBit

Prototype	`void SPI_T6963C_NegBit(char b);`
Returns	Nothing.
Description	Negates control port bit(s). Parameters : - `b`: bit mask. The function will negate bit `x` on control port if bit `x` in bit mask is set to 1.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// negate bits 0 and 1 on control port` `SPI_T6963C_NegBit(0x03);`

SPI_T6963C_DisplayGrPanel

Prototype	`void SPI_T6963C_DisplayGrPanel(char n);`
Returns	Nothing.
Description	Display selected graphic panel. Parameters : - `n`: graphic panel number. Valid values: `0` and `1`.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// display graphic panel 1` `SPI_T6963C_DisplayGrPanel(1);`

SPI_T6963C_DisplayTxtPanel

Prototype	`void SPI_T6963C_DisplayTxtPanel(char n);`
Returns	Nothing.
Description	Display selected text panel. Parameters : - `n`: text panel number. Valid values: `0` and `1`.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// display text panel 1` `SPI_T6963C_DisplayTxtPanel(1);`

SPI_T6963C_SetGrPanel

Prototype	`void SPI_T6963C_SetGrPanel(char n);`
Returns	Nothing.
Description	Compute start address for selected graphic panel and set appropriate internal pointers. All subsequent graphic operations will be preformed at this graphic panel. Parameters : - `n`: graphic panel number. Valid values: `0` and `1`.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// set graphic panel 1 as current graphic panel.` `SPI_T6963C_SetGrPanel(1);`

SPI_T6963C_SetTxtPanel

Prototype	`void SPI_T6963C_SetTxtPanel(char n);`
Returns	Nothing.
Description	Compute start address for selected text panel and set appropriate internal pointers. All subsequent text operations will be preformed at this text panel. Parameters : ` - `n`: text panel number. Valid values: `0` and `1`.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// set text panel 1 as current text panel.` `SPI_T6963C_SetTxtPanel(1);`

SPI_T6963C_PanelFill

Prototype	`void SPI_T6963C_PanelFill(unsigned char v);`
Returns	Nothing.
Description	Fill current panel in full (graphic+text) with appropriate value (0 to clear). Parameters : - `v`: value to fill panel with.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`clear current panel` `SPI_T6963C_PanelFill(0);`

SPI_T6963C_GrFill

Prototype	`void SPI_T6963C_GrFill(unsigned char v);`
Returns	Nothing.
Description	Fill current graphic panel with appropriate value (0 to clear). Parameters : - `v`: value to fill graphic panel with.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// clear current graphic panel` `SPI_T6963C_GrFill(0);`

SPI_T6963C_TxtFill

Prototype	`void SPI_T6963C_TxtFill(unsigned char v);`
Returns	Nothing.
Description	Fill current text panel with appropriate value (0 to clear). Parameters : - `v`: this value increased by 32 will be used to fill text panel.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// clear current text panel` `SPI_T6963C_TxtFill(0);`

SPI_T6963C_Cursor_Height

Prototype	`void SPI_T6963C_Cursor_Height(unsigned char n);`
Returns	Nothing.
Description	Set cursor size. Parameters : - `n`: cursor height. Valid values: `0..7`.
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`SPI_T6963C_Cursor_Height(7);`

SPI_T6963C_Graphics

Prototype	`void SPI_T6963C_Graphics(char n);`
Returns	Nothing.
Description	Enable/disable graphic displaying. Parameters : - `n`: graphic enable/disable parameter. Valid values: `0` (disable graphic dispaying) and `1` (enable graphic displaying).
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// enable graphic displaying` `SPI_T6963C_Graphics(1);`

SPI_T6963C_Text

Prototype	`void SPI_T6963C_Text(char n);`
Returns	Nothing.
Description	Enable/disable text displaying. Parameters : - `n`: text enable/disable parameter. Valid values: `0` (disable text dispaying) and `1` (enable text displaying).
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// enable text displaying` `SPI_T6963C_Text(1);`

SPI_T6963C_Cursor

Prototype	`void SPI_T6963C_Cursor(char n);`
Returns	Nothing.
Description	Set cursor on/off. Parameters : - `n`: on/off parameter. Valid values: `0` (set cursor off) and `1` (set cursor on).
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// set cursor on` `SPI_T6963C_Cursor(1);`

SPI_T6963C_Cursor_Blink

Prototype	`void SPI_T6963C_Cursor_Blink(char n);`
Returns	Nothing.
Description	Enable/disable cursor blinking. Parameters : - `n`: cursor blinking enable/disable parameter. Valid values: `0` (disable cursor blinking) and `1` (enable cursor blinking).
Requires	Toshiba Glcd module needs to be initialized. See SPI_T6963C_Config routine.
Example	`// enable cursor blinking` `SPI_T6963C_Cursor_Blink(1);`

Library Example

The following drawing demo tests advanced routines of the SPI T6963C Glcd library. Hardware configurations in this example are made for the T6963C 240x128 display, EasyAVR5 board and ATmega16.

```
#include        "__SPIT6963C.h"

/*
 * bitmap pictures stored in ROM
 */
extern const code char me[] ;
extern const code char einstein[] ;

// Port Expander module connections
sbit  SPExpanderRST at PORTB.B0;
sbit  SPExpanderCS  at PORTB.B1;
sbit  SPExpanderRST_Direction at DDRB.B0;
sbit  SPExpanderCS_Direction  at DDRB.B1;
// End Port Expander module connections


void main() {

 char txt1[] = " EINSTEIN WOULD HAVE LIKED mE";
 char txt[] =  " Glcd LIBRARY DEMO, WELCOME !";
```

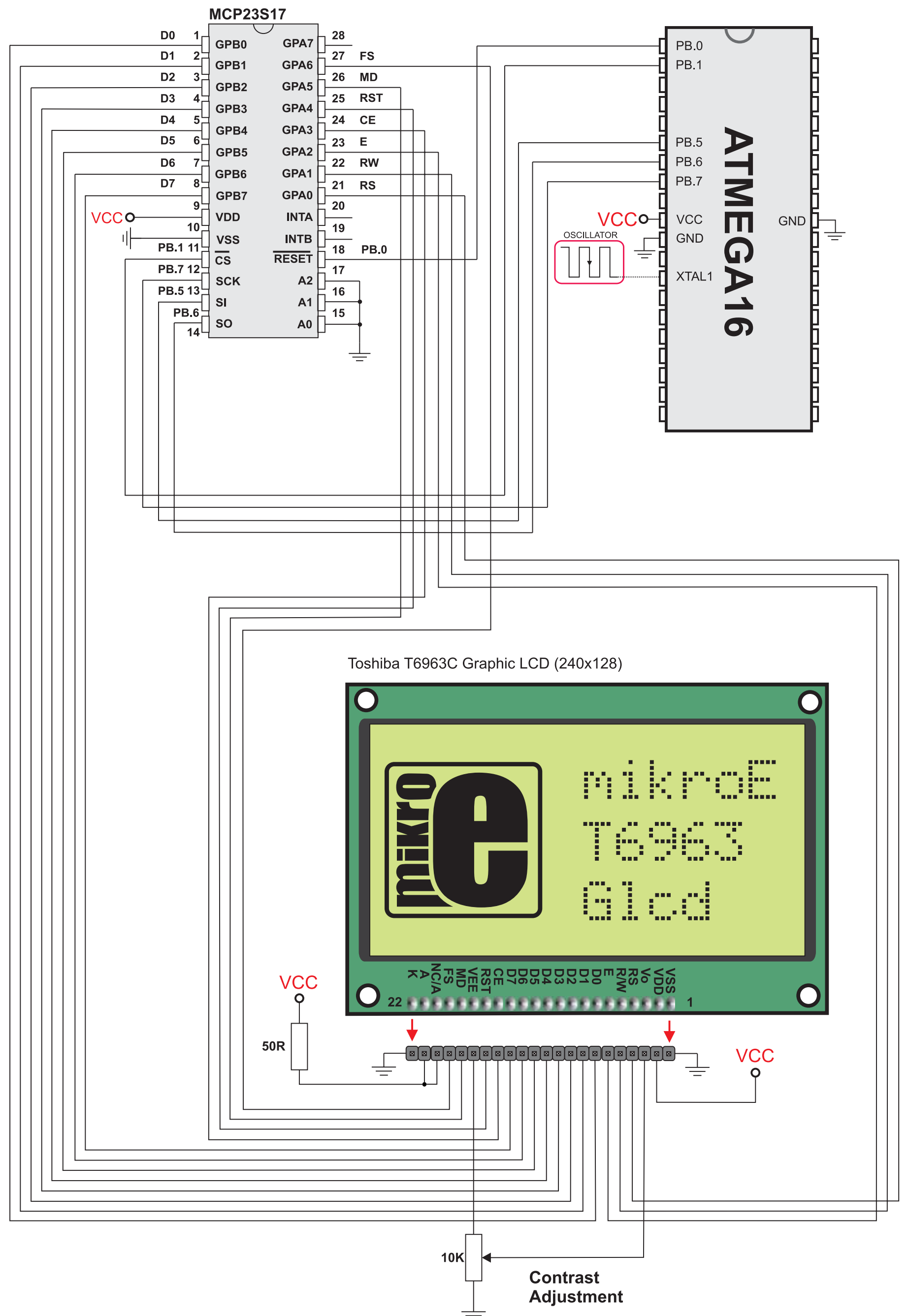
```
unsigned char   panel ;          // current panel
unsigned int    i ;               // general purpose register
unsigned char   curs ;           // cursor visibility
unsigned int    cposx, cposy ;  // cursor x-y position

DDRA = 0x00;                      // configure PORTA as input

  /*
  * init display for 240 pixel width and 128 pixel height
  * 8 bits character width
  * data bus on MCP23S17 portB
  * control bus on MCP23S17 portA
  * bit 2 is !WR
  * bit 1 is !RD
  * bit 0 is !CD
  * bit 4 is RST
  * chip enable, reverse on, 8x8 font internaly set in library
  */

  // Pass pointer to SPI Read function of used SPI module
  SPI_Rd_Ptr = SPI1_Read;

  // Initialize SPI module
  SPI1_Init_Advanced(_SPI_MASTER, _SPI_FCY_DIV32, _SPI_CLK_HI_TRAIL-
ING);

  // // If Port Expander Library uses SPI2 module
  // Pass pointer to SPI Read function of used SPI module
  // SPI_Rd_Ptr = SPI2_Read;             // Pass pointer to SPI Read
function of used SPI module

  // Initialize SPI module used with PortExpander
         //     SPI2_Init_Advanced(_SPI_MASTER,     _SPI_FCY_DIV32,
_SPI_CLK_HI_TRAILING);


  // Initialize SPI Toshiba 240x128
  SPI_T6963C_Config(240, 128, 8, 0, 2, 1, 0, 4) ;
  Delay_ms(1000);
  /*
   * Enable both graphics and text display at the same time
   */
  SPI_T6963C_graphics(1) ;
  SPI_T6963C_text(1) ;

  panel = 0 ;
  i = 0 ;
  curs = 0 ;
  cposx = cposy = 0 ;
```

```
/*
 * Text messages
 */
SPI_T6963C_write_text(txt, 0, 0, SPI_T6963C_ROM_MODE_XOR) ;
SPI_T6963C_write_text(txt1, 0, 15, SPI_T6963C_ROM_MODE_XOR) ;

/*
 * Cursor
 */
SPI_T6963C_cursor_height(8) ;        // 8 pixel height
SPI_T6963C_set_cursor(0, 0) ;        // move cursor to top left
SPI_T6963C_cursor(0) ;               // cursor off

/*
 * Draw rectangles
 */
SPI_T6963C_rectangle(0, 0, 239, 127, SPI_T6963C_WHITE) ;
SPI_T6963C_rectangle(20, 20, 219, 107, SPI_T6963C_WHITE) ;
SPI_T6963C_rectangle(40, 40, 199, 87, SPI_T6963C_WHITE) ;
SPI_T6963C_rectangle(60, 60, 179, 67, SPI_T6963C_WHITE) ;

/*
 * Draw a cross
 */
SPI_T6963C_line(0, 0, 239, 127, SPI_T6963C_WHITE) ;
SPI_T6963C_line(0, 127, 239, 0, SPI_T6963C_WHITE) ;

/*
 * Draw solid boxes
 */
SPI_T6963C_box(0, 0, 239, 8, SPI_T6963C_WHITE) ;
SPI_T6963C_box(0, 119, 239, 127, SPI_T6963C_WHITE) ;

/*
 * Draw circles
 */
SPI_T6963C_circle(120, 64, 10, SPI_T6963C_WHITE) ;
SPI_T6963C_circle(120, 64, 30, SPI_T6963C_WHITE) ;
SPI_T6963C_circle(120, 64, 50, SPI_T6963C_WHITE) ;
SPI_T6963C_circle(120, 64, 70, SPI_T6963C_WHITE) ;
SPI_T6963C_circle(120, 64, 90, SPI_T6963C_WHITE) ;
SPI_T6963C_circle(120, 64, 110, SPI_T6963C_WHITE) ;
SPI_T6963C_circle(120, 64, 130, SPI_T6963C_WHITE) ;

SPI_T6963C_sprite(76, 4, einstein, 88, 119) ;  // Draw a sprite
SPI_T6963C_setGrPanel(1) ;            // Select other graphic panel
SPI_T6963C_image(me) ;   // Fill the graphic screen with a picture

while(1) {                                       // Endless loop
```

```
        /*
         * If PORTA_0 is pressed, toggle the display between graphic
panel 0 and graphic 1
        */
       if(!PINA0) {
         panel++ ;
         panel &= 1 ;
         SPI_T6963C_displayGrPanel(panel) ;
         Delay_ms(300) ;
         }

       /*
        * If PORTA_1 is pressed, display only graphic panel
        */
       else if(!PINA1) {
         SPI_T6963C_graphics(1) ;
         SPI_T6963C_text(0) ;
         Delay_ms(300) ;
         }

       /*
        * If PORTA_2 is pressed, display only text panel
        */
       else if(!PINA2) {
         SPI_T6963C_graphics(0) ;
         SPI_T6963C_text(1) ;
         Delay_ms(300) ;
         }

       /*
        * If PORTA_3 is pressed, display text and graphic panels
        */
       else if(!PINA3) {
         SPI_T6963C_graphics(1) ;
         SPI_T6963C_text(1) ;
         Delay_ms(300) ;
         }

       /*
        * If PORTA_4 is pressed, change cursor
        */
       else if(!PINA4) {
         curs++ ;
         if(curs == 3) curs = 0 ;
         switch(curs) {
            case 0:
             // no cursor
             SPI_T6963C_cursor(0) ;
             break ;
```

```
          case 1:
            // blinking cursor
            SPI_T6963C_cursor(1) ;
            SPI_T6963C_cursor_blink(1) ;
            break ;
          case 2:
            // non blinking cursor
            SPI_T6963C_cursor(1) ;
            SPI_T6963C_cursor_blink(0) ;
            break ;
          }
        Delay_ms(300) ;
        }

      /*
       * Move cursor, even if not visible
       */
      cposx++ ;
      if(cposx == SPI_T6963C_txtCols) {
        cposx = 0 ;
        cposy++ ;
        if(cposy == SPI_T6963C_grHeight / SPI_T6963C_CHARACTER_HEIGHT)
{
          cposy = 0 ;
          }
        }
      SPI_T6963C_set_cursor(cposx, cposy) ;

      Delay_ms(100) ;
      }
}
```

HW Connection



SPI T6963C Glcd HW connection

T6963C GRAPHIC LCD LIBRARY

The mikroC PRO for AVR provides a library for working with GLCDs based on TOSHIBA T6963C controller. The Toshiba T6963C is a very popular LCD controller for the use in small graphics modules. It is capable of controlling displays with a resolution up to 240x128. Because of its low power and small outline it is most suitable for mobile applications such as PDAs, MP3 players or mobile measurement equipment. Although small, this contoller has a capability of displaying and merging text and graphics and it manages all the interfacing signals to the displays Row and Column drivers.

For creating a custom set of GLCD images use GLCD Bitmap Editor Tool.

Note: ChipEnable(CE), FontSelect(FS) and Reverse(MD) have to be set to appropriate levels by the user outside of the `T6963C_Init` function. See the Library Example code at the bottom of this page.

Note: Some mikroElektronika's adapter boards have pinout different from T6369C datasheets. Appropriate relations between these labels are given in the table below:

Adapter Board	T6369C datasheet
RS	C/D
R/W	/RD
E	/WR

External dependencies of T6963C Graphic LCD Library

The following variables must be defined in all projects using T6963C Graphic LCD library:	Description:	Example :
`extern sfr char T6963C_dataPort;`	T6963C Data Port.	`unsigned char sfr T6963C_dataPort at PORTD;`
`extern sfr char T6963C_ctrlPort;`	T6963C Control Port.	`unsigned char sfr T6963C_ctrlPort at PORTC;`
`extern sfr char T6963C_dataPort_Direction;`	Direction of the T6963C Data Port.	`unsigned char sfr T6963C_dataPort_Direction at DDRD;`
`extern sfr char T6963C_ctrlPort_Direction;`	Direction of the T6963C Control Port.	`unsigned char sfr T6963C_ctrlPort_Direction at DDRC;`
`extern sfr sbit T6963C_ctrlwr;`	Write signal.	`sbit T6963C_ctrlwr at PORTC.B2;`
`extern sfr sbit T6963C_ctrlrd;`	Read signal.	`sbit T6963C_ctrlrd at PORTC.B1;`
`extern sfr sbit T6963C_ctrlcd;`	Command/Data signal.	`sbit T6963C_ctrlcd at PORTC.B0;`
`extern sfr sbit T6963C_ctrlrst;`	Reset signal.	`sbit T6963C_ctrlrst at PORTC.B4;`
`extern sfr sbit T6963C_ctrlwr_Direction;`	Direction of the Write pin.	`sbit T6963C_ctrlwr_Direction at DDRC.B2;`
`extern sfr sbit T6963C_ctrlrd_Direction;`	Direction of the Read pin.	`sbit T6963C_ctrlrd_Direction at DDRC.B1;`
`extern sfr sbit T6963C_ctrlcd_Direction;`	Direction of the Data pin.	`sbit T6963C_ctrlcd_Direction at DDRC.B0;`
`extern sfr sbit T6963C_ctrlrst_Direction;`	Direction of the Reset pin.	`sbit T6963C_ctrlrst_Direction at DDRC.B4;`

Library Routines

- T6963C_Init
- T6963C_WriteData
- T6963C_WriteCommand
- T6963C_SetPtr
- T6963C_WaitReady
- T6963C_Fill
- T6963C_Dot
- T6963C_Write_Char
- T6963C_Write_Text
- T6963C_Line
- T6963C_Rectangle
- T6963C_Box
- T6963C_Circle
- T6963C_Image
- T6963C_Sprite
- T6963C_Set_Cursor

Note: The following low level library routines are implemented as macros. These macros can be found in the `T6963C.h` header file which is located in the T6963C example projects folders.

- T6963C_ClearBit
- T6963C_SetBit
- T6963C_NegBit
- T6963C_DisplayGrPanel
- T6963C_DisplayTxtPanel
- T6963C_SetGrPanel
- T6963C_SetTxtPanel
- T6963C_PanelFill
- T6963C_GrFill
- T6963C_TxtFill
- T6963C_Cursor_Height
- T6963C_Graphics
- T6963C_Text
- T6963C_Cursor
- T6963C_Cursor_Blink

T6963C_Init

<table>
<tr><td>Prototype</td><td><code>void T6963C_Init(unsigned int width, unsigned char height, unsigned char fntW);</code></td></tr>
<tr><td>Returns</td><td>Nothing.</td></tr>
<tr><td>Description</td><td>Initalizes the Graphic Lcd controller.

Parameters :

- <code>width</code>: width of the GLCD panel
- <code>height</code>: height of the GLCD panel
- <code>fntW</code>: font width

Display RAM organization:
The library cuts the RAM into panels : a complete panel is one graphics panel followed by a text panel (see schematic below).

<pre>
schematic:
+---------------------+ /\
+ GRAPHICS PANEL #0   + |
+   + |
+   + |
+   + |
+---------------------+ | PANEL 0
+ TEXT PANEL #0   + |
+   + \/
+---------------------+ /\
+ GRAPHICS PANEL #1   + |
+   + |
+   + |
+   + |
+---------------------+ | PANEL 1
+ TEXT PANEL #2   + |
+   + |
+---------------------+ \/
</pre></td></tr>
<tr><td>Requires</td><td>Global variables :

- <code>T6963C_dataPort</code>: Data Port
- <code>T6963C_ctrlPort</code>: Control Port
- <code>T6963C_ctrlwr</code>: Write signal pin
- <code>T6963C_ctrlrd</code>: Read signal pin
- <code>T6963C_ctrlcd</code>: Command/Data signal pin
- <code>T6963C_ctrlrst</code>: Reset signal pin</td></tr>
</table>

Requires	- `T6963C_dataPort_Direction`: Direction of Data Port - `T6963C_ctrlPort_Direction`: Direction of Control Port - `T6963C_ctrlwr_Direction`: Direction of Write signal pin - `T6963C_ctrlrd_Direction`: Direction of Read signal pin - `T6963C_ctrlcd_Direction`: Direction of Command/Data signal pin - `T6963C_ctrlrst_Direction`: Direction of Reset signal pin must be defined before using this function.

Example	`// T6963C module connections`
	`char T6963C_ctrlPort at PORTC;`
	`char T6963C_dataPort at PORTD;`
	`char T6963C_ctrlPort_Direction at DDRC;`
	`char T6963C_dataPort_Direction at DDRD;`
	
	`sbit T6963C_ctrlwr  at PORTC.B2;`
	`sbit T6963C_ctrlrd  at PORTC.B1;`
	`sbit T6963C_ctrlcd  at PORTC.B0;`
	`sbit T6963C_ctrlrst at PORTC.B4;`
	`sbit T6963C_ctrlwr_Direction  at DDRC.B2;`
	`sbit T6963C_ctrlrd_Direction  at DDRC.B1;`
	`sbit T6963C_ctrlcd_Direction  at DDRC.B0;`
	`sbit T6963C_ctrlrst_Direction at DDRC.B4;`
	`// End of T6963C module connections`
	
	`...`
	`// init display for 240 pixel width, 128 pixel height and 8 bits character width`
	`T6963C_init(240, 128, 8) ;`

T6963C_WriteData

Prototype	`void T6963C_WriteData(unsigned char mydata);`
Returns	Nothing.
Description	Writes data to T6963C controller. Parameters : - `mydata:` data to be written
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_WriteData(AddrL);`

T6963C_WriteCommand

Prototype	`void T6963C_WriteCommand(unsigned char mydata);`
Returns	Nothing.
Description	Writes command to T6963C controller. Parameters : - `mydata`: command to be written
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_WriteCommand(T6963C_CURSOR_POINTER_SET);`

T6963C_SetPtr

Prototype	`void T6963C_SetPtr(unsigned int p, unsigned char c);`
Returns	Nothing.
Description	Sets the memory pointer p for command c. Parameters : - `p`: address where command should be written - `c`: command to be written
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_SetPtr(T6963C_grHomeAddr + start, T6963C_ADDRESS_POINTER_SET);`

T6963C_WaitReady

Prototype	`void T6963C_WaitReady(void);`
Returns	Nothing.
Description	Pools the status byte, and loops until Toshiba GLCD module is ready.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_WaitReady();`

T6963C_Fill

Prototype	`void T6963C_Fill(unsigned char v, unsigned int start, unsigned int len);`
Returns	Nothing.
Description	Fills controller memory block with given byte. Parameters : - `v:` byte to be written - `start:` starting address of the memory block - `len:` length of the memory block in bytes
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Fill(0x33,0x00FF,0x000F);`

T6963C_Dot

Prototype	`void T6963C_Dot(int x, int y, unsigned char color);`
Returns	Nothing.
Description	Draws a dot in the current graphic panel of GLCD at coordinates (x, y). Parameters : - `x:` dot position on x-axis - `y:` dot position on y-axis - `color:` color parameter. Valid values: T6963C_BLACK and T6963C_WHITE
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Dot(x0, y0, pcolor);`

T6963C_Write_Char

Prototype	`void T6963C_Write_Char(unsigned char c, unsigned char x, unsigned char y, unsigned char mode);`
Returns	Nothing.
Description	Writes a char in the current text panel of GLCD at coordinates (x, y). Parameters : - `c:` char to be written - `x:` char position on x-axis - `y:` char position on y-axis - `mode:` mode parameter. Valid values: T6963C_ROM_MODE_OR, T6963C_ROM_MODE_XOR, T6963C_ROM_MODE_AND and T6963C_ROM_MODE_TEXT Mode parameter explanation: - OR Mode: In the OR-Mode, text and graphics can be displayed and the data is logically “OR-ed”. This is the most common way of combining text and graphics for example labels on buttons. - XOR-Mode: In this mode, the text and graphics data are combined via the logical “exclusive OR”. This can be useful to display text in the negative mode, i.e. white text on black background. - AND-Mode: The text and graphic data shown on display are combined via the logical “AND function”. - TEXT-Mode: This option is only available when displaying just a text. The Text Attribute values are stored in the graphic area of display memory. For more details see the T6963C datasheet.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Write_Char('A',22,23,AND);`

T6963C_Write_Text

Prototype	`void T6963C_Write_Text(unsigned char *str, unsigned char x, unsigned char y, unsigned char mode);`
Returns	Nothing.
Description	Writes text in the current text panel of GLCD at coordinates (x, y). Parameters : - `str:` text to be written - `x:` text position on x-axis - `y:` text position on y-axis - `mode:` mode parameter. Valid values: T6963C_ROM_MODE_OR, T6963C_ROM_MODE_XOR, T6963C_ROM_MODE_AND and T6963C_ROM_MODE_TEXT Mode parameter explanation: - OR Mode: In the OR-Mode, text and graphics can be displayed and the data is logically “OR-ed”. This is the most common way of combining text and graphics for example labels on buttons. - XOR-Mode: In this mode, the text and graphics data are combined via the logical “exclusive OR”. This can be useful to display text in the negative mode, i.e. white text on black background. - AND-Mode: The text and graphic data shown on display are combined via the logical “AND function”. - TEXT-Mode: This option is only available when displaying just a text. The Text Attribute values are stored in the graphic area of display memory. For more details see the T6963C datasheet.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Write_Text(" GLCD LIBRARY DEMO, WELCOME !", 0, 0, T6963C_ROM_MODE_XOR);`

T6963C_Line

Prototype	`void T6963C_Line(int x0, int y0, int x1, int y1, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a line from (x0, y0) to (x1, y1). Parameters : - `x0:` x coordinate of the line start - `y0:` y coordinate of the line end - `x1:` x coordinate of the line start - `y1:` y coordinate of the line end - `pcolor:` color parameter. Valid values: T6963C_BLACK and T6963C_WHITE
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Line(0, 0, 239, 127, T6963C_WHITE);`

T6963C_Rectangle

Prototype	`void T6963C_Rectangle(int x0, int y0, int x1, int y1, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a rectangle on GLCD. Parameters : - `x0:` x coordinate of the upper left rectangle corner - `y0:` y coordinate of the upper left rectangle corner - `x1:` x coordinate of the lower right rectangle corner - `y1:` y coordinate of the lower right rectangle corner - `pcolor:` color parameter. Valid values: T6963C_BLACK and T6963C_WHITE
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Rectangle(20, 20, 219, 107, T6963C_WHITE);`

T6963C_Box

Prototype	`void T6963C_Box(int x0, int y0, int x1, int y1, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a box on GLCD Parameters : - `x0:` x coordinate of the upper left box corner - `y0:` y coordinate of the upper left box corner - `x1:` x coordinate of the lower right box corner - `y1:` y coordinate of the lower right box corner - `pcolor:` color parameter. Valid values: T6963C_BLACK and T6963C_WHITE
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Box(0, 119, 239, 127, T6963C_WHITE);`

T6963C_Circle

Prototype	`void T6963C_Circle(int x, int y, long r, unsigned char pcolor);`
Returns	Nothing.
Description	Draws a circle on GLCD. Parameters : - `x:` x coordinate of the circle center - `y:` y coordinate of the circle center - `r:` radius size - `pcolor:` color parameter. Valid values: T6963C_BLACK and T6963C_WHITE
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Circle(120, 64, 110, T6963C_WHITE);`

T6963C_Image

Prototype	`void T6963C_Image(const code char *pic);`
Returns	Nothing.
Description	Displays bitmap on GLCD. Parameters : - `pic:` image to be displayed. Bitmap array can be located in both code and RAM memory (due to the mikroC PRO for AVR pointer to const and pointer to RAM equivalency). Use the mikroC PRO's integrated GLCD Bitmap Editor (menu option **Tools › GLCD Bitmap Editor**) to convert image to a constant array suitable for displaying on GLCD.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Image(mc);`

T6963C_Sprite

Prototype	`void T6963C_Sprite(unsigned char px, unsigned char py, const code char *pic, unsigned char sx, unsigned char sy);`
Returns	Nothing.
Description	Fills graphic rectangle area (px, py) to (px+sx, py+sy) with custom size picture. Parameters : - `px:` x coordinate of the upper left picture corner. Valid values: multiples of the font width - `py:` y coordinate of the upper left picture corner - `pic:` picture to be displayed - `sx:` picture width. Valid values: multiples of the font width - `sy:` picture height **Note:** If px and sx parameters are not multiples of the font width they will be scaled to the nearest lower number that is a multiple of the font width.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Sprite(76, 4, einstein, 88, 119); // draw a sprite`

T6963C_Set_Cursor

Prototype	`void T6963C_Set_Cursor(unsigned char x, unsigned char y);`
Returns	Nothing.
Description	Sets cursor to row x and column y. Parameters : - `x:` cursor position row number - `y:` cursor position column number
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Set_Cursor(cposx, cposy);`

T6963C_ClearBit

Prototype	`void T6963C_ClearBit(char b);`
Returns	Nothing.
Description	Clears control port bit(s). Parameters : - `b:` bit mask. The function will clear bit `x` on control port if bit `x` in bit mask is set to 1.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// clear bits 0 and 1 on control port` `T6963C_ClearBit(0x03);`

T6963C_SetBit

Prototype	`void T6963C_SetBit(char b);`
Returns	Nothing.
Description	Sets control port bit(s). Parameters : - `b`: bit mask. The function will set bit `x` on control port if bit `x` in bit mask is set to 1.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// set bits 0 and 1 on control port` `T6963C_SetBit(0x03);`

T6963C_NegBit

Prototype	`void T6963C_NegBit(char b);`
Returns	Nothing.
Description	Negates control port bit(s). Parameters : - `b`: bit mask. The function will negate bit `x` on control port if bit `x` in bit mask is set to 1.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// negate bits 0 and 1 on control port` `T6963C_NegBit(0x03);`

T6963C_DisplayGrPanel

Prototype	`void T6963C_DisplayGrPanel(char n);`
Returns	Nothing.
Description	Display selected graphic panel. Parameters : - `n`: graphic panel number. Valid values: `0` and `1`.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// display graphic panel 1` `T6963C_DisplayGrPanel(1);`

T6963C_DisplayTxtPanel

Prototype	`void T6963C_DisplayTxtPanel(char n);`
Returns	Nothing.
Description	Display selected text panel. Parameters : - `n`: text panel number. Valid values: `0` and `1`.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// display text panel 1` `T6963C_DisplayTxtPanel(1);`

T6963C_SetGrPanel

Prototype	`void T6963C_SetGrPanel(char n);`
Returns	Nothing.
Description	Compute start address for selected graphic panel and set appropriate internal pointers. All subsequent graphic operations will be preformed at this graphic panel. Parameters : - `n`: graphic panel number. Valid values: `0` and `1`.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// set graphic panel 1 as current graphic panel.` `T6963C_SetGrPanel(1);`

T6963C_SetTxtPanel

Prototype	`void T6963C_SetTxtPanel(char n);`
Returns	Nothing.
Description	Compute start address for selected text panel and set appropriate internal pointers. All subsequent text operations will be preformed at this text panel. Parameters : - `n`: text panel number. Valid values: `0` and `1`.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// set text panel 1 as current text panel.` `T6963C_SetTxtPanel(1);`

T6963C_PanelFill

Prototype	`void T6963C_PanelFill(unsigned char v);`
Returns	Nothing.
Description	Fill current panel in full (graphic+text) with appropriate value (0 to clear). Parameters : - `v`: value to fill panel with.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`clear current panel` `T6963C_PanelFill(0);`

T6963C_GrFill

Prototype	`void T6963C_GrFill(unsigned char v);`
Returns	Nothing.
Description	Fill current graphic panel with appropriate value (0 to clear). Parameters : - `v`: value to fill graphic panel with.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// clear current graphic panel` `T6963C_GrFill(0);`

T6963C_TxtFill

Prototype	`void T6963C_TxtFill(unsigned char v);`
Returns	Nothing.
Description	Fill current text panel with appropriate value (0 to clear). Parameters : - `v`: this value increased by 32 will be used to fill text panel.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// clear current text panel` `T6963C_TxtFill(0);`

T6963C_Cursor_Height

Prototype	`void T6963C_Cursor_Height(unsigned char n);`
Returns	Nothing.
Description	Set cursor size. Parameters : - `n:` cursor height. Valid values: `0..7`.
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`T6963C_Cursor_Height(7);`

T6963C_Graphics

Prototype	`void T6963C_Graphics(char n);`
Returns	Nothing.
Description	Enable/disable graphic displaying. Parameters : - `n:` on/off parameter. Valid values: `0` (disable graphic displaying) and `1` (enable graphic displaying).
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// enable graphic displaying` `T6963C_Graphics(1);`

T6963C_Text

Prototype	`void T6963C_Text(char n);`
Returns	Nothing.
Description	Enable/disable text displaying. Parameters : - `n:` on/off parameter. Valid values: `0` (disable text displaying) and `1` (enable text displaying).
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// enable text displaying` `T6963C_Text(1);`

T6963C_Cursor

Prototype	`void T6963C_Cursor(char n);`
Returns	Nothing.
Description	Set cursor on/off. Parameters : - `n:` on/off parameter. Valid values: `0` (set cursor off) and `1` (set cursor on).
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// set cursor on` `T6963C_Cursor(1);`

T6963C_Cursor_Blink

Prototype	`void T6963C_Cursor_Blink(char n);`
Returns	Nothing.
Description	Enable/disable cursor blinking. Parameters : - `n:` on/off parameter. Valid values: `0` (disable cursor blinking) and `1` (enable cursor blinking).
Requires	Toshiba GLCD module needs to be initialized. See the T6963C_Init routine.
Example	`// enable cursor blinking` `T6963C_Cursor_Blink(1);`

Library Example

The following drawing demo tests advanced routines of the T6963C GLCD library. Hardware configurations in this example are made for the T6963C 240x128 display, EasyAVR5 board and ATMEGA16.

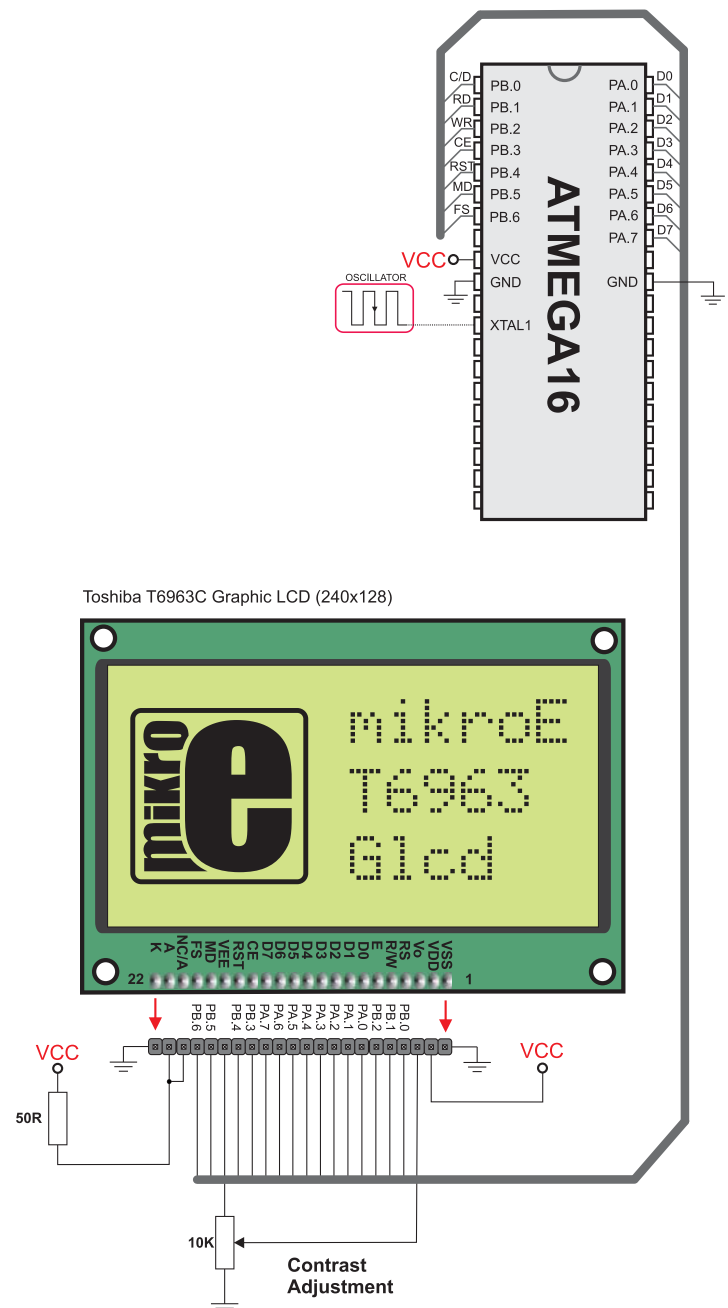
```
#include        "__T6963C.h"

// T6963C module connections
char T6963C_ctrlPort at PORTC;
char T6963C_dataPort at PORTD;
char T6963C_ctrlPort_Direction at DDRC;
char T6963C_dataPort_Direction at DDRD;

sbit T6963C_ctrlwr  at PORTC.B2;
sbit T6963C_ctrlrd  at PORTC.B1;
sbit T6963C_ctrlcd  at PORTC.B0;
sbit T6963C_ctrlrst at PORTC.B4;
sbit T6963C_ctrlwr_Direction  at DDRC.B2;
sbit T6963C_ctrlrd_Direction  at DDRC.B1;
sbit T6963C_ctrlcd_Direction  at DDRC.B0;
sbit T6963C_ctrlrst_Direction at DDRC.B4;

// Signals not used by library, they are set in main function
sbit T6963C_ctrlce at PORTC.B3;
sbit T6963C_ctrlfs at PORTC.B6;
sbit T6963C_ctrlmd at PORTC.B5;
sbit T6963C_ctrlce_Direction  at DDRC.B3;
sbit T6963C_ctrlfs_Direction  at DDRC.B6;
sbit T6963C_ctrlmd_Direction  at DDRC.B5;

// End T6963C module connections

/*
 * bitmap pictures stored in ROM
 */
const code char mikroE_240x128_bmp[];
const code char einstein[];

void main() {
  char txt1[] = " EINSTEIN WOULD HAVE LIKED mE";
  char txt[] =  " GLCD LIBRARY DEMO, WELCOME !";

  unsigned char  panel;          // Current panel
  unsigned int   i;              // General purpose register
  unsigned char  curs;           // Cursor visibility
  unsigned int   cposx, cposy;  // Cursor x-y position
```

```
DDB0 = 0;                        // Set PB0 as input
DDB1 = 0;                        // Set PB1 as input
DDB2 = 0;                        // Set PB2 as input
DDB3 = 0;                        // Set PB3 as input
DDB4 = 0;                        // Set PB4 as input


T6963C_ctrlce_Direction = 1;
T6963C_ctrlce = 0;               // Enable T6963C
T6963C_ctrlfs_Direction = 1;
T6963C_ctrlfs = 0;               // Font Select 8x8
T6963C_ctrlmd_Direction = 1;
T6963C_ctrlmd = 0;               // Column number select

// Initialize T6369C
T6963C_init(240, 128, 8);

/*
 * Enable both graphics and text display at the same time
 */
T6963C_graphics(1);
T6963C_text(1);

panel = 0;
i = 0;
curs = 0;
cposx = cposy = 0;
/*
 * Text messages
 */
T6963C_write_text(txt, 0, 0, T6963C_ROM_MODE_XOR);
T6963C_write_text(txt1, 0, 15, T6963C_ROM_MODE_XOR);

/*
 * Cursor
 */
T6963C_cursor_height(8);        // 8 pixel height
T6963C_set_cursor(0, 0);        // Move cursor to top left
T6963C_cursor(0);                // Cursor off

/*
 * Draw rectangles
 */
T6963C_rectangle(0, 0, 239, 127, T6963C_WHITE);
T6963C_rectangle(20, 20, 219, 107, T6963C_WHITE);
T6963C_rectangle(40, 40, 199, 87, T6963C_WHITE);
T6963C_rectangle(60, 60, 179, 67, T6963C_WHITE);
```

```
  /*
   * Draw a cross
   */
  T6963C_line(0, 0, 239, 127, T6963C_WHITE);
  T6963C_line(0, 127, 239, 0, T6963C_WHITE);

  /*
   * Draw solid boxes
   */
  T6963C_box(0, 0, 239, 8, T6963C_WHITE);
  T6963C_box(0, 119, 239, 127, T6963C_WHITE);

  /*
   * Draw circles
   */
  T6963C_circle(120, 64, 10, T6963C_WHITE);
  T6963C_circle(120, 64, 30, T6963C_WHITE);
  T6963C_circle(120, 64, 50, T6963C_WHITE);
  T6963C_circle(120, 64, 70, T6963C_WHITE);
  T6963C_circle(120, 64, 90, T6963C_WHITE);
  T6963C_circle(120, 64, 110, T6963C_WHITE);
  T6963C_circle(120, 64, 130, T6963C_WHITE);

  T6963C_sprite(76, 4, einstein, 88, 119);         // Draw a sprite

  T6963C_setGrPanel(1);                   // Select other graphic panel

  T6963C_image(mikroE_240x128_bmp);

  for(;;) {                                              // Endless loop
    /*
     * If PB0 is pressed, display only graphic panel
     */
    if(PINB0) {
      T6963C_graphics(1);
      T6963C_text(0);
      Delay_ms(300);
      }

    /*
     * If PB1 is pressed, toggle the display between graphic panel
0 and graphic panel 1
     */
    else if(PINB1) {
      panel++;
      panel &= 1;
      T6963C_displayGrPanel(panel);
      Delay_ms(300);
      }
```

```
        /*
         * If PB2 is pressed, display only text panel
         */
        else if(PINB2) {
          T6963C_graphics(0);
          T6963C_text(1);
          Delay_ms(300);
          }

        /*
         * If PB3 is pressed, display text and graphic panels
         */
        else if(PINB3) {
          T6963C_graphics(1);
          T6963C_text(1);
          Delay_ms(300);
          }

        /*
         * If PB4 is pressed, change cursor
         */
        else if(PINB4) {
          curs++;
          if(curs == 3) curs = 0;
          switch(curs) {
            case 0:
              // no cursor
              T6963C_cursor(0);
              break;
            case 1:
              // blinking cursor
              T6963C_cursor(1);
              T6963C_cursor_blink(1);
              break;
            case 2:
              // non blinking cursor
              T6963C_cursor(1);
              T6963C_cursor_blink(0);
              break;
            }
          Delay_ms(300);
          }

        /*
         * Move cursor, even if not visible
         */
        cposx++;
        if(cposx == T6963C_txtCols) {
          cposx = 0;
          cposy++;
          if(cposy == T6963C_grHeight / T6963C_CHARACTER_HEIGHT) {
            cposy = 0;
            }
          }
        T6963C_set_cursor(cposx, cposy);

        Delay_ms(100);
        }
}
```

HW Connection



T6963C GLCD HW connection

TWI LIBRARY

TWI full master MSSP module is available with a number of AVR MCU models. mikroC PRO for AVR provides library which supports the master TWI mode.

Note: Examples for AVR MCUs with module on other ports can be found in your mikroC for AVR installation folder, subfolder “Examples”.

Library Routines

- TWI_Init
- TWI_Busy
- TWI_Start
- TWI_Stop
- TWI_Read
- TWI_Write
- TWI_Status
- TWI_Close

TWI_Init

Prototype	`void TWI_Init(unsigned long clock);`
Returns	Nothing.
Description	Initializes TWI with desired `clock` (refer to device data sheet for correct values in respect with Fosc). Needs to be called before using other functions of TWI Library. You don’t need to configure ports manually for using the module; library will take care of the initialization.
Requires	Library requires MSSP module on PORTB or PORTC.
Example	`TWI_Init(100000);`

TWI_Busy

Prototype	`char TWI_Busy();`
Returns	Returns 0 if TWI start sequnce is finished, 1 if TWI start sequnce is not finished.
Description	Signalizes the status of TWI bus.
Requires	TWI must be configured before using this function. See TWI_Init.
Example	`if (TWI_Busy == 1) {` `...`

TWI_Start

Prototype	`char TWI_Start();`
Returns	If there is no error function returns 0, otherwise returns 1.
Description	Determines if TWI bus is free and issues START signal.
Requires	TWI must be configured before using this function. See TWI_Init.
Example	`if (TWI_Start == 1) {` `...`

TWI_Read

Prototype	`char TWI_Read(char ack);`
Returns	Returns one byte from the slave.
Description	Reads one byte from the slave, and sends not acknowledge signal if parameter ack is 0, otherwise it sends acknowledge.
Requires	TWI must be configured before using this function. See TWI_Init. Also, START signal needs to be issued in order to use this function. See TWI_Start.
Example	Read data and send not acknowledge signal: `tmp = TWI_Read(0);`

TWI_Write

Prototype	`void TWI_Write(char data_);`
Returns	Nothing.
Description	Sends data byte (parameter `data_`) via TWI bus.
Requires	TWI must be configured before using this function. See TWI_Init. Also, START signal needs to be issued in order to use this function. See TWI_Start.
Example	`TWI_Write(0xA3);`

TWI_Stop

Prototype	`void TWI_Stop();`
Returns	Nothing.
Description	Issues STOP signal to TWI operation.
Requires	TWI must be configured before using this function. See TWI_Init.
Example	`TWI_Stop();`

TWI_Status

Prototype	`char TWI_Status();`
Returns	Returns value of status register (TWSR), the highest 5 bits.
Description	Returns status of TWI.
Requires	TWI must be configured before using this function. See TWI_Init.
Example	`status = TWI_Status();`

TWI_Close

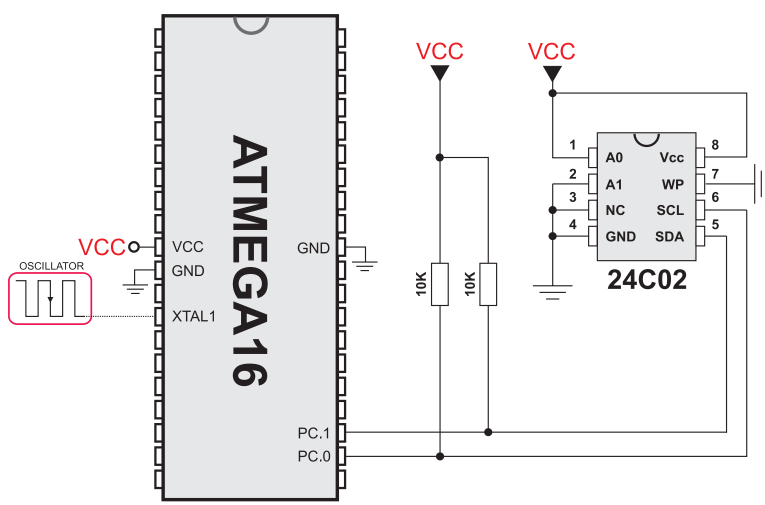
Prototype	`void TWI_Close();`
Returns	Nothing.
Description	Closes TWI connection.
Requires	TWI must be configured before using this function. See TWI_Init.
Example	`TWI_Close();`

Library Example

This code demonstrates use of TWI Library procedures and functions. AVR MCU is connected (SCL, SDA pins) to 24c02 EEPROM. Program sends data to EEPROM (data is written at address 2). Then, we read data via TWI from EEPROM and send its value to PORTA, to check if the cycle was successful. Check the figure below.

```
void main(){
  DDRA = 0xFF;                 // configure PORTA as output

  TWI_Init(100000);            // initialize TWI communication
  TWI_Start();                 // issue TWI start signal
  TWI_Write(0xA2);             // send byte via TWI (device address + W)
  TWI_Write(2);                // send byte (address of EEPROM location)
  TWI_Write(0xAA);             // send data (data to be written)
  TWI_Stop();                  // issue TWI stop signal

  Delay_100ms();

  TWI_Start();                 // issue TWI start signal
  TWI_Write(0xA2);             // send byte via TWI (device address + W)
  TWI_Write(2);                // send byte (data address)
  TWI_Start();                 // issue TWI signal repeated start
  TWI_Write(0xA3);             // send byte (device address + R)
  PORTA = TWI_Read(0u);        // read data (NO acknowledge)
  TWI_Stop();                  // issue TWI stop signal
}
```

HW Connection



Interfacing 24c02 to AVR via TWI

UART LIBRARY

UART hardware module is available with a number of AVR MCUs. mikroC PRO for AVR UART Library provides comfortable work with the Asynchronous (full duplex) mode.

You can easily communicate with other devices via RS-232 protocol (for example with PC, see the figure at the end of the topic – RS-232 HW connection). You need a AVR MCU with hardware integrated UART, for example ATmega16. Then, simply use the functions listed below.

Library Routines

- UARTx_Init
- UARTx_Init_Advanced
- UARTx_Data_Ready
- UARTx_Read
- UARTx_Read_Text
- UARTx_Write
- UARTx_Write_Text

The following routine is for the internal use by compiler only:

UARTx_TX_Idle

Note: AVR MCUs require you to specify the module you want to use. To select the desired UART, simply change the letter x in the prototype for a number from 1 to 4. Number of UART modules per MCU differs from chip to chip. Please, read the appropriate datasheet before utilizing this library.

Example: `UART2_Init()`; initializes UART 2 module.

Note: Some of the AVR MCUs do not support UARTx_Init_Advanced routine. Please, refer to the appropriate datasheet.

UARTx_Init

Prototype	`void UARTx_Init(unsigned long baud_rate);`
Returns	Nothing.
Description	Configures and initializes the UART module. The internal UART module module is set to: - receiver enabled - transmitter enabled - frame size 8 bits - 1 STOP bit - parity mode disabled - asynchronous operation Parameters : - `baud_rate:` requested baud rate Refer to the device data sheet for baud rates allowed for specific Fosc.
Requires	You'll need AVR MCU with hardware UART. `UARTx_Init` needs to be called before using other functions from UART Library.
Example	This will initialize hardware UART1 module and establish the communication at 2400 bps: `UART1_Init(2400);`

UARTx_Init_Advanced

Prototype	`void UARTx_Init_Advanced(unsigned long baud_rate, char parity, char stop_bits);`
Returns	Nothing.
Description	Configures and initializes UART module. Parameter `baud_rate` configures UART module to work on a requested baud rate. Parameters `parity` and `stop_bits` determine the work mode for UART, and can have the following values: (see table below) **Note**: Some MCUs do not support advanced configuration of the UART module. Please consult appropriate daatsheet.
Requires	MCU must have UART module.
Example	`// Initialize hardware UART1 module and establish communication at 9600 bps, 8-bit data, even parity and 2 STOP bits` `UART1_Init_Advanced(9600, _UART_EVENPARITY, _UART_TWO_STOPBITS);`

Mask	Description	Predefined library const
Parity constants:		
`0x00`	`Parity mode disabled`	`_UART_NOPARITY`
`0x20`	`Even parity`	`_UART_EVENPARITY`
`0x30`	`Odd parity`	`_UART_ODDPARITY`
Stop bit constants:		
`0x00`	`1 stop bit`	`_UART_ONE_STOPBIT`
`0x01`	`2 stop bits`	`_UART_TWO_STOPBITS`

UARTx_Data_Ready

Prototype	`char UARTx_Data_Ready();`
Returns	Function returns 1 if data is ready or 0 if there is no data.
Description	Use the function to test if data in receive buffer is ready for reading.
Requires	UART HW module must be initialized and communication established before using this function. See UARTx_Init.

Example	`// If data is ready, read it:`
	`if (UART1_Data_Ready() == 1) {`
	` receive = UART1_Read();`
	` }`

UARTx_Read

Prototype	`char UARTx_Read();`
Returns	Returns the received byte.
Description	Function receives a byte via UART. Use the function UARTx_Data_Ready to test if data is ready first.
Requires	UART HW module must be initialized and communication established before using this function. See UARTx_Init.

Example	`// If data is ready, read it:`
	`if (UART1_Data_Ready() == 1) {`
	` receive = UART1_Read();`
	` }`

UARTx_Read_Text

Prototype	`void UARTx_Read_Text(char *Output, char *Delimiter, char Attempts);`
Returns	Nothing.
Description	Reads characters received via UART until the delimiter sequence is detected. The read sequence is stored in the parameter `output`; delimiter sequence is stored in the parameter `delimiter`. This is a blocking call: the delimiter sequence is expected, otherwise the procedure exits (if the delimiter is not found). Parameterv Attempts defines number of received characters in which Delimiter sequence is expected. If Attempts is set to 255, this routine will continuously try to detect the Delimiter sequence.
Requires	UART HW module must be initialized and communication established before using this function. See UARTx_Init.

Example	Read text until the sequence “OK” is received, and send back what’s been received:
	<pre>UART1_Init(4800); // initialize UART module
	Delay_ms(100);
	
	 while (1) {
	   if (UART1_Data_Ready() == 1) { // if data is received
	     UART1_Read_Text(output, "delim", 10); // reads text until 'delim' is found
	     UART1_Write_Text(output); // sends back text
	 }
	}</pre>

UARTx_Write

Prototype	`void UARTx_Write(char _data);`
Returns	Nothing.
Description	The function transmits a byte via the UART module. Parameters : - `_data`: data to be sent
Requires	UART HW module must be initialized and communication established before using this function. See UARTx_Init.

Example	`unsigned char _data = 0x1E;`
	`...`
	`UART1_Write(_data);`

UARTx_Write_Text

Prototype	`void UARTx_Write_Text(char * UART_text);`
Returns	Nothing.
Description	Sends text (parameter `UART_text`) via UART. Text should be zero terminated.
Requires	UART HW module must be initialized and communication established before using this function. See UARTx_Init.

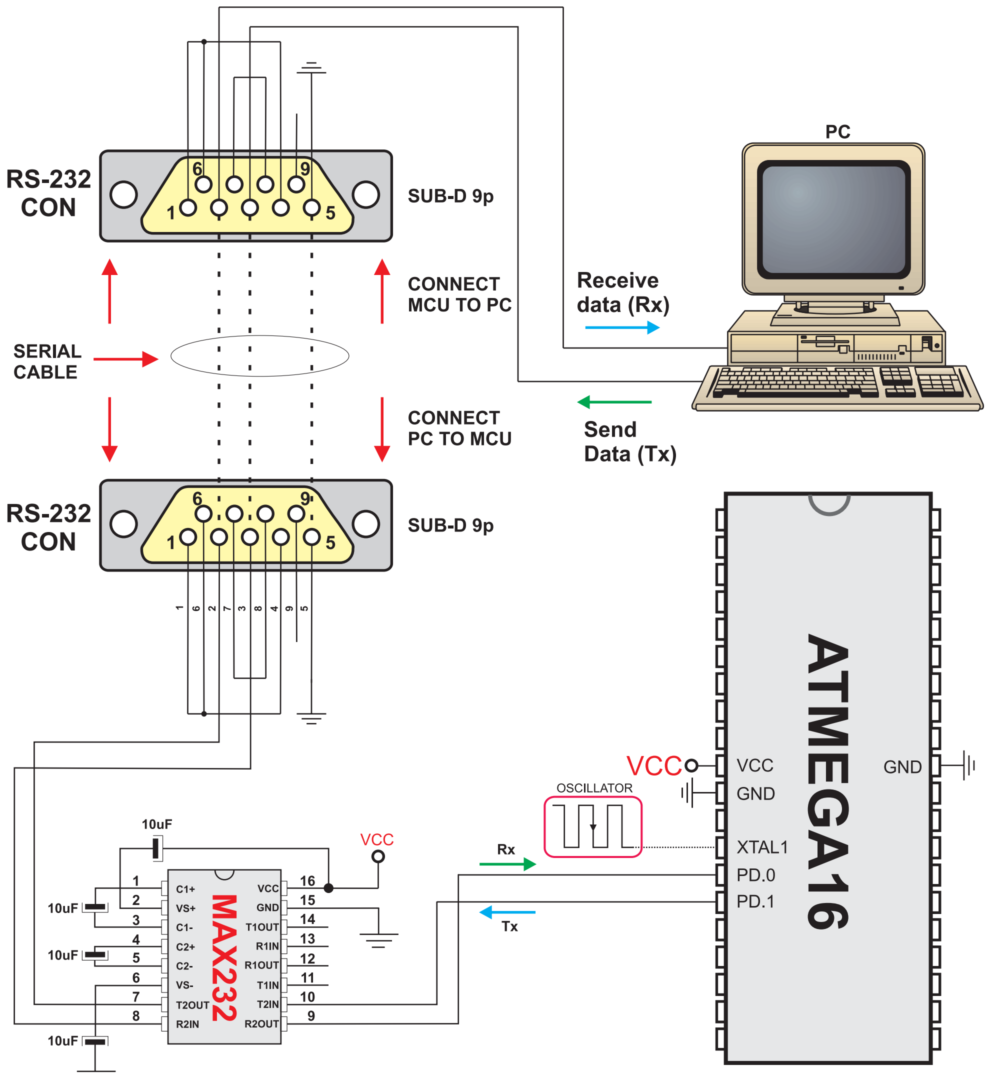
Example	Read text until the sequence “OK” is received, and send back what’s been received:
	
	`UART1_Init(4800);                    // initialize UART module`
	`Delay_ms(100);`
	
	` while (1) {`
	`   if (UART1_Data_Ready() == 1) {         // if data is received`
	`     UART1_Read_Text(output, "delim", 10); // reads text until 'delim' is found`
	`     UART1_Write_Text(output);              // sends back text`
	` }`
	`}`

Library Example

The example demonstrates a simple data exchange via UART. When AVR MCU receives data, it immediately sends it back. If AVR is connected to the PC (see the figure below), you can test the example from the mikroC PRO for AVR terminal for RS-232 communication, menu choice **Tools › Terminal.**

```
char uart_rd;

void main() {

    UART1_Init(9600);             // initialize UART module at 9600 bps
    Delay_ms(100);                // wait for UART module to stabilize

    while (1) {                        // endless loop
      if (UART1_Data_Ready()) {      // if data is received,
        uart_rd = UART1_Read();      //   read the received data,
        UART1_Write(uart_rd);        //   and send data via UART
      }
  }
}
```

HW Connection



RS-232 HW connection

ANSI C CTYPE LIBRARY

The mikroC PRO for AVR provides a set of standard ANSI C library functions for testing and mapping characters.

Note: Not all of the standard functions have been included.

Note: The functions have been mostly implemented according to the ANSI C standard, but certain functions have been modified in order to facilitate AVR programming. Be sure to skim through the description before using standard C functions.

Library Functions

- isalnum
- isalpha
- iscntrl
- isdigit
- isgraph
- islower
- ispunct
- isspace
- isupper
- isxdigit
- toupper
- tolower

isalnum

Prototype	`unsigned short isalnum(char character);`
Description	Function returns 1 if the `character` is alphanumeric (A-Z, a-z, 0-9), otherwise returns zero.

isalpha

Prototype	`unsigned short isalpha(char character);`
Description	Function returns 1 if the `character` is alphabetic (A-Z, a-z), otherwise returns zero.

iscntrl

Prototype	`unsigned short iscntrl(char character);`
Description	Function returns 1 if the `character` is a control or delete character(decimal 0-31 and 127), otherwise returns zero.

isdigit

Prototype	`unsigned short isdigit(char character);`
Description	Function returns 1 if the `character` is a digit (0-9), otherwise returns zero.

isgraph

Prototype	`unsigned short isgraph(char character);`
Description	Function returns 1 if the `character` is a printable, excluding the space (decimal 32), otherwise returns zero.

islower

Prototype	`int islower(char character);`
Description	Function returns 1 if the `character` is a lowercase letter (a-z), otherwise returns zero.

ispunct

Prototype	`unsigned short ispunct(char character);`
Description	Function returns 1 if the `character` is a punctuation (decimal 32-47, 58-63, 91-96, 123-126), otherwise returns zero.

isspace

Prototype	`unsigned short isspace(char character);`
Description	Function returns 1 if the character is a white space (space, tab, CR, HT, VT, NL, FF), otherwise returns zero.

isupper

Prototype	`unsigned short isupper(char character);`
Description	Function returns 1 if the character is an uppercase letter (A-Z), otherwise returns zero.

isxdigit

Prototype	`unsigned short isxdigit(char character);`
Description	Function returns 1 if the `character` is a hex digit (0-9, A-F, a-f), otherwise returns zero.

toupper

Prototype	`unsigned short toupper(char character);`
Description	If the `character` is a lowercase letter (a-z), the function returns an uppercase letter. Otherwise, the function returns an unchanged input parameter.

tolower

Prototype	`unsigned short tolower(char character);`
Description	If the `character` is an uppercase letter (A-Z), function returns a lowercase letter. Otherwise, function returns an unchanged input parameter.

ANSI C MATH LIBRARY

The mikroC PRO for AVR provides a set of standard ANSI C library functions for floating point math handling.

Note: Not all of the standard functions have been included.

Note: The functions have been mostly implemented according to the ANSI C standard, but certain functions have been modified in order to facilitate AVR programming. Be sure to skim through the description before using standard C functions.

Library Functions

- acos
- asin
- atan
- atan2
- ceil
- cos
- cosh
- eval_poly
- exp
- fabs
- floor
- frexp
- ldexp
- log
- log10
- modf
- pow
- sin
- sinh
- sqrt
- tan
- tanh

acos

Prototype	`double acos(double x);`
Description	Function returns the arc cosine of parameter `x`; that is, the value whose cosine is x. The input parameter `x` must be between -1 and 1 (inclusive). The return value is in radians, between 0 an π (inclusive).

asin

Prototype	`double asin(double x);`
Description	Function returns the arc sine of parameter `x`; that is, the value whose sine is x. The input parameter `x` must be between -1 and 1 (inclusive). The return value is in radians, between - π/2 and π /2 (inclusive).

atan

Prototype	`double atan(double f);`
Description	Function computes the arc tangent of parameter `f`; that is, the value whose tangent is f. The return value is in radians, between - π/2 and π /2 (inclusive).

atan2

Prototype	`double atan2(double y, double x);`
Description	This is the two-argument arc tangent function. It is similar to computing the arc tangent of `y/x`, except that the signs of both arguments are used to determine the quadrant of the result and `x` is permitted to be zero. The return value is in radians, between - π and π (inclusive).

ceil

Prototype	`double ceil(double x);`
Description	Function returns value of parameter x rounded up to the next whole number.

cos

Prototype	`double cos(double f);`
Description	Function returns the cosine of `f` in radians. The return value is from -1 to 1.

cosh

Prototype	`double cosh(double x);`
Description	Function returns the hyperbolic cosine of `x`, defined mathematically as $(e^x+e^{-x})/2$. If the value of x is too large (if overflow occurs), the function fails.

eval_poly

Prototype	`static double eval_poly(double x, const double code * d, int n);`
Description	Function Calculates polynom for number `x`, with coefficients stored in `d[]`, for degree `n`.

exp

Prototype	`double exp(double x);`
Description	Function returns the value of e — the base of natural logarithms — raised to the power `x` (i.e. e^x).

fabs

Prototype	`double fabs(double d);`
Description	Function returns the absolute (i.e. positive) value of `d`.

floor

Prototype	`double floor(double x);`
Description	Function returns the value of parameter `x` rounded down to the nearest integer.

frexp

Prototype	`double frexp(double value, int *eptr);`
Description	Function splits a floating-point value into a normalized fraction and an integral power of 2. The return value is the normalized fraction and the integer exponent is stored in the object pointed to by `eptr`.

ldexp

Prototype	`double ldexp(double value, int newexp);`
Description	Function returns the result of multiplying the floating-point number `num` by 2 raised to the power `n` (i.e. returns `x * 2n`).

log

Prototype	`double log(double x);`
Description	Function returns the natural logarithm of `x` (i.e. $\log_e(x)$).

log10

Prototype	`double log10(double x);`
Description	Function returns the base-10 logarithm of `x` (i.e. $\log_{10}(x)$).

modf

Prototype	`double modf(double val, double * iptr);`
Description	Returns argument `val` split to the fractional part (function return val) and integer part (in number iptr).

pow

Prototype	`double pow(double x, double y);`
Description	Function returns the value of `x` raised to the power `y` (i.e. x^y). If x is negative, the function will automatically cast y into `unsigned long`.

sin

Prototype	`double sin(double f);`
Description	Function returns the sine of `f` in radians. The return value is from -1 to 1.

sinh

Prototype	`double sinh(double x);`
Description	Function returns the hyperbolic sine of x, defined mathematically as $(e^x-e^{-x})/2$. If the value of x is too large (if overflow occurs), the function fails.

sqrt

Prototype	`double sqrt(double x);`
Description	Function returns the non negative square root of `x`.

tan

Prototype	`double tan(double x);`
Description	Function returns the tangent of `x` in radians. The return value spans the allowed range of floating point in the mikroC PRO for AVR.

tanh

Prototype	`double tanh(double x);`
Description	Function returns the hyperbolic tangent of x, defined mathematically as sinh(x)/cosh(x).

ANSI C STDLIB LIBRARY

The mikroC PRO for AVR provides a set of standard ANSI C library functions of general utility.

Note: Not all of the standard functions have been included.

Note: Functions have been mostly implemented according to the ANSI C standard, but certain functions have been modified in order to facilitate AVR programming. Be sure to skim through the description before using standard C functions.

Library Functions

- abs
- atof
- atoi
- atol
- div
- ldiv
- uldiv
- labs
- max
- min
- rand
- srand
- xtoi

abs

Prototype	`int abs(int a);`
Description	Function returns the absolute (i.e. positive) value of `a`.

atof

Prototype	`double atof(char *s)`
Description	Function converts the input string `s` into a double precision value and returns the value. Input string `s` should conform to the floating point literal format, with an optional whitespace at the beginning. The string will be processed one character at a time, until the function reaches a character which it doesn't recognize (including a null character).

atoi

Prototype	`int atoi(char *s);`
Description	Function converts the input string `s` into an integer value and returns the value. The input string `s` should consist exclusively of decimal digits, with an optional whitespace and a sign at the beginning. The string will be processed one character at a time, until the function reaches a character which it doesn't recognize (including a null character).

atol

Prototype	`long atol(char *s)`
Description	Function converts the input string `s` into a long integer value and returns the value. The input string `s` should consist exclusively of decimal digits, with an optional whitespace and a sign at the beginning. The string will be processed one character at a time, until the function reaches a character which it doesn't recognize (including a null character).

div

Prototype	`div_t div(int number, int denom);`
Description	Function computes the result of division of the numerator `number` by the denominator `denom`; the function returns a structure of type `div_t` comprising quotient (`quot`) and remainder (`rem`), see Div Structures.

ldiv

Prototype	`ldiv_t ldiv(long number, long denom);`
Description	Function is similar to the div function, except that the arguments and result structure members all have type long. Function computes the result of division of the numerator `number` by the denominator `denom`; the function returns a structure of type `ldiv_t` comprising quotient (`quot`) and remainder (`rem`), see Div Structures.

uldiv

Prototype	`uldiv_t uldiv(unsigned long number, unsigned long denom);`
Description	Function is similar to the div function, except that the arguments and result structure members all have type `unsigned long`. Function computes the result of division of the numerator `number` by the denominator `denom`; the function returns a structure of type `uldiv_t` comprising quotient (`quot`) and remainder (`rem`), see Div Structures.

labs

Prototype	`long labs(long x);`
Description	Function returns the absolute (i.e. positive) value of long integer `x`.

max

Prototype	`int max(int a, int b);`
Description	Function returns greater of the two integers, `a` and `b`.

min

Prototype	`int min(int a, int b);`
Description	Function returns lower of the two integers, `a` and `b`.

rand

Prototype	`int rand();`
Description	Function returns a sequence of pseudo-random numbers between 0 and 32767. The function will always produce the same sequence of numbers unless srand is called to seed the start point.

srand

Prototype	`void srand(unsigned x);`
Description	Function uses `x` as a starting point for a new sequence of pseudo-random numbers to be returned by subsequent calls to rand. No values are returned by this function.

xtoi

Prototype	`unsigned xtoi(register char *s);`
Description	Function converts the input string `s` consisting of hexadecimal digits into an integer value. The input parameter s should consist exclusively of hexadecimal digits, with an optional whitespace and a sign at the beginning. The string will be processed one character at a time, until the function reaches a character which it doesn't recognize (including a null character).

Div Structures

```
typedef struct divstruct {
            int quot;
            int rem;
} div_t;


typedef struct ldivstruct {
            long quot;
            long rem;
} ldiv_t;


typedef struct uldivstruct {
            unsigned long quot;
            unsigned long rem;
} uldiv_t;
```

ANSI C STRING LIBRARY

The mikroC PRO for AVR provides a set of standard ANSI C library functions useful for manipulating strings and RAM memory.

Note: Not all of the standard functions have been included.

Note: Functions have been mostly implemented according to the ANSI C standard, but certain functions have been modified in order to facilitate AVR programming. Be sure to skim through the description before using standard C functions.

Library Functions

- memchr
- memcmp
- memcpy
- memmove
- memset
- strcat
- strchr
- strcmp
- strcpy
- strlen
- strncat
- strncpy
- strspn
- strncmp
- strstr
- strcspn
- strpbrk
- strrchr

memchr

Prototype	`void *memchr(void *p, char n, unsigned int v);`
Description	Function locates the first occurrence of `n` in the initial `v` bytes of memory area starting at the address `p`. The function returns the pointer to this location or 0 if the n was not found. For parameter `p` you can use either a numerical value (literal/variable/constant) indicating memory address or a dereferenced value of an object, for example `&mystring` or `&P0`.

memcmp

Prototype	`int memcmp(void *s1, void *s2, int n);`
Description	Function compares the first `n` characters of objects pointed to by `s1` and `s2` and returns zero if the objects are equal, or returns a difference between the first differing characters (in a left-to-right evaluation). Accordingly, the result is greater than zero if the object pointed to by `s1` is greater than the object pointed to by `s2` and vice versa.

memcpy

Prototype	`void *memcpy(void *d1, void *s1, int n);`
Description	Function copies `n` characters from the object pointed to by `s2` into the object pointed to by `d1`. If copying takes place between objects that overlap, the behavior is undefined. The function returns address of the object pointed to by `d1`.

memmove

Prototype	`void *memmove(void *to, void *from, register int n);`
Description	Function copies `n` characters from the object pointed to by from into the object pointed to by to. Unlike memcpy, the memory areas `to` and `from` may overlap. The function returns address of the object pointed to by `to`.

memset

Prototype	`void *memset(void *p1, char character, int n)`
Description	Function copies the value of the `character` into each of the first `n` characters of the object pointed by `p1`. The function returns address of the object pointed to by `p1`.

strcat

Prototype	`char *strcat(char *to, char *from);`
Description	Function appends a copy of the string `from` to the string `to`, overwriting the null character at the end of to. Then, a terminating null character is added to the result. If copying takes place between objects that overlap, the behavior is undefined. `to` string must have enough space to store the result. The function returns address of the object pointed to by `to`.

strchr

Prototype	`char *strchr(char *ptr, char chr);`
Description	Function locates the first occurrence of character `chr` in the string `ptr`. The function returns a pointer to the first occurrence of character `chr`, or a null pointer if `chr` does not occur in `ptr`. The terminating null character is considered to be a part of the string.

strcmp

Prototype	`int strcmp(char *s1, char *s2);`
Description	Function compares strings `s1` and `s2` and returns zero if the strings are equal, or returns a difference between the first differing characters (in a left-to-right evaluation). Accordingly, the result is greater than zero if `s1` is greater than `s2` and vice versa.

strcpy

Prototype	`char *strcpy(char *to, char *from);`
Description	Function copies the string `from` into the string `to`. If copying is successful, the function returns `to`. If copying takes place between objects that overlap, the behavior is undefined.

strlen

Prototype	`int strlen(char *s);`
Description	Function returns the length of the string `s` (the terminating null character does not count against string's length).

strncat

Prototype	`char *strncat(char *to, char *from, int size);`
Description	Function appends not more than `size` characters from the string `from` to `to`. The initial character of `from` overwrites the null character at the end of `to`. The terminating null character is always appended to the result. The function returns `to`.

strncpy

Prototype	`char *strncpy(char *to, char *from, int size);`
Description	Function copies not more than `size` characters from string `from` to `to`. If copying takes place between objects that overlap, the behavior is undefined. If `from` is shorter than `size` characters, then `to` will be padded out with null characters to make up the difference. The function returns the resulting string `to`.

strspn

Prototype	`int strspn(char *str1, char *str2);`
Description	Function returns the length of the maximum initial segment of `str1` which consists entirely of characters from `str2`. The terminating null character at the end of the string is not compared.

Strncmp

Prototype	`int strncmp(char *s1, char *s2, char len);`

Description	Function lexicographically compares not more than len characters (characters that follow the null character are not compared) from the string pointed by `s1` to the string pointed by `s2`. The function returns a value indicating the `s1` and `s2` relationship:
	
	`Value     Meaning`
	`< 0       s1 "less than" s2`
	`= 0       s1 "equal to" s2`
	`> 0       s1 "greater than" s2`

Strstr

Prototype	`char *strstr(char *s1, char *s2);`
Description	Function locates the first occurrence of the string `s2` in the string `s1` (excluding the terminating null character). The function returns pointer to first occurrence of `s2` in `s1`; if no string was found, function returns `0`. If `s2` is a null string, the function returns `0`.

Strcspn

Prototype	`char *strcspn(char * s1, char *s2);`
Description	Function computes the length of the maximum initial segment of the string pointed to by `s1` that consists entirely of characters that are not in the string pointed to by `s2`. The function returns the length of the initial segment.

Strpbrk

Prototype	`char *strpbrk(char * s1, char *s2);`
Description	Function searches `s1` for the first occurrence of any character from the string `s2`. The terminating null character is not included in the search. The function returns pointer to the matching character in `s1`. If `s1` contains no characters from `s2`, the function returns `0`.

Strrchr

Prototype	`char *strrchr(char * ptr, unsigned int chr);`
Description	Function searches the string `ptr` for the last occurrence of character `chr`. The null character terminating `ptr` is not included in the search. The function returns pointer to the last `chr` found in `ptr`; if no matching character was found, function returns `0`.

BUTTON LIBRARY

The Button library contains miscellaneous routines useful for a project development.

External dependecies of Button Library

The following variable must be defined in all projects using Button library:	Description:	Example :
`extern sbit Button_Pin;`	Declares button pins.	`sbit Button_Pin at PINB.B0;`
`extern sbit Button_Pin_Direction;`	Declares direction of the button.	`sbit Button_Pin_Direction at DDRB.B0;`

Library Routines

- Button

Button

Prototype	`unsigned short Button(unsigned short time, unsigned short active_state)`
Returns	- `255` if the pin was in the active state for given period. - `0` otherwise
Description	The function eliminates the influence of contact flickering upon pressing a button (debouncing). The Button pin is tested just after the function call and then again after the debouncing period has expired. If the pin was in the active state in both cases then the function returns 255 (true). Parameters : - `time`: debouncing period in milliseconds - `active_state`: determines what is considered as active state. Valid values: `0` (logical zero) and `1` (logical one)
Requires	Global variables : - `Button_Pin`: Button pin line - `Button_Pin_Direction`: Direction of the button pin must be defined before using this function.
Example	On every PB0 one-to-zero transition PORTC is inverted : (see code below)

```
// Button connections
sbit Button_Pin     at PINB.B0; //Input pin, PINx register is used
sbit Button_Pin_Direction at DDRB.B0;
// End Button connections

bit oldstate;                              // Old state flag

void main() {

  Button_Pin_Direction = 0;               // Set pin as input

  DDRC   = 0xFF;                          // Configure PORTC as output
  PORTC  = 0xAA;                           // Initial PORTC value

  oldstate = 0;

  do {
    if (Button(1, 1)) {                   // Detect logical one
      oldstate = 1;                        // Update flag
    }
    if (oldstate && Button(1, 0)) { //Detect one-to-zero transition
      PORTC = ~PORTC;                      // Invert PORTC
      oldstate = 0;                        // Update flag
    }
  } while(1);                              // Endless loop
}
```

CONVERSIONS LIBRARY

The mikroC PRO for AVR Conversions Library provides routines for numerals to strings and BCD/decimal conversions.

Library Routines

You can get text representation of numerical value by passing it to one of the following routines:

- ByteToStr
- ShortToStr
- WordToStr
- IntToStr
- LongToStr
- LongWordToStr
- FloatToStr

The following functions convert decimal values to BCD and vice versa:

- Dec2Bcd
- Bcd2Dec16
- Dec2Bcd16

ByteToStr

Prototype	`void ByteToStr(unsigned short input, char *output);`
Returns	Nothing.
Description	Converts input byte to a string. The output string has fixed width of 4 characters including null character at the end (string termination). The output string is right justified and remaining positions on the left (if any) are filled with blanks. Parameters : - `input`: byte to be converted - `output`: destination string
Requires	Destination string should be at least 4 characters in length.

Example	`unsigned short t = 24;`
	`char txt[ 4] ;`
	`...`
	`ByteToStr(t, txt);   // txt is " 24" (one blank here)`

ShortToStr

Prototype	`void ShortToStr(short input, char *output);`
Returns	Nothing.
Description	Converts input signed short number to a string. The output string has fixed width of 5 characters including null character at the end (string termination). The output string is right justified and remaining positions on the left (if any) are filled with blanks. Parameters : - `input`: signed short number to be converted - `output`: destination string
Requires	Destination string should be at least 5 characters in length.

Example	`short t = -24;`
	`char txt[ 5] ;`
	`...`
	`ShortToStr(t, txt);   // txt is " -24" (one blank here)`

WordToStr

Prototype	`void WordToStr(unsigned input, char *output);`
Returns	Nothing.
Description	Converts input word to a string. The output string has fixed width of 6 characters including null character at the end (string termination). The output string is right justified and the remaining positions on the left (if any) are filled with blanks. Parameters : - `input`: word to be converted - `output`: destination string
Requires	Destination string should be at least 6 characters in length.

Example	`unsigned t = 437;`
	`char txt[ 6] ;`
	`...`
	`WordToStr(t, txt);  // txt is "  437" (two blanks here)`

IntToStr

Prototype	`void IntToStr(int input, char *output);`
Returns	Nothing.
Description	Converts input signed integer number to a string. The output string has fixed width of 7 characters including null character at the end (string termination). The output string is right justified and the remaining positions on the left (if any) are filled with blanks. Parameters : - `input`: signed integer number to be converted - `output`: destination string
Requires	Destination string should be at least 7 characters in length.

Example	`int j = -4220;`
	`char txt[ 7] ;`
	`...`
	`IntToStr(j, txt);  // txt is " -4220" (one blank here)`

LongToStr

Prototype	`void LongToStr(long input, char *output);`
Returns	Nothing.
Description	Converts input signed long integer number to a string. The output string has fixed width of 12 characters including null character at the end (string termination). The output string is right justified and the remaining positions on the left (if any) are filled with blanks. Parameters : - `input`: signed long integer number to be converted - `output`: destination string
Requires	Destination string should be at least 12 characters in length.

Example	`long jj = -3700000;`
	`char txt[12];`
	`...`
	`LongToStr(jj, txt);`
	`// txt is "   -3700000" (three blanks here)`

LongWordToStr

Prototype	`void LongWordToStr(unsigned long input, char *output);`
Returns	Nothing.
Description	Converts input unsigned long integer number to a string. The output string has fixed width of 11 characters including null character at the end (string termination). The output string is right justified and the remaining positions on the left (if any) are filled with blanks. Parameters : - `input`: unsigned long integer number to be converted - `output`: destination string
Requires	Destination string should be at least 11 characters in length.

Example	`unsigned long jj = 3700000;`
	`char txt[11];`
	`...`
	`LongToStr(jj, txt);`
	`// txt is "   3700000" (three blanks here)`

FloatToStr

Prototype	`unsigned char FloatToStr(float fnum, unsigned char *str);`
Returns	- 3 if input number is NaN - 2 if input number is -INF - 1 if input number is +INF - 0 if conversion was successful
Description	Converts a floating point number to a string. Parameters : - `fnum`: floating point number to be converted - `str`: destination string The output string is left justified and null terminated after the last digit. **Note**: Given floating point number will be truncated to 7 most significant digits before conversion.
Requires	Destination string should be at least 14 characters in length.

Example	`float ff1 = -374.2;`
	`float ff2 = 123.456789;`
	`float ff3 = 0.000001234;`
	`char txt[15];`
	`...`
	`FloatToStr(ff1, txt);   // txt is "-374.2"`
	`FloatToStr(ff2, txt);   // txt is "123.4567"`
	`FloatToStr(ff3, txt);   // txt is "1.234e-6"`

Dec2Bcd

Prototype	`unsigned short Dec2Bcd(unsigned short decnum);`
Returns	Converted BCD value.
Description	Converts input unsigned short integer number to its appropriate BCD representation. Parameters : - `decnum`: unsigned short integer number to be converted
Requires	Nothing.

Example	`unsigned short a, b;`
	`...`
	`a = 22;`
	`b = Dec2Bcd(a);     // b equals 34`

Bcd2Dec16

Prototype	`unsigned Bcd2Dec16(unsigned bcdnum);`
Returns	Converted decimal value.
Description	Converts 16-bit BCD numeral to its decimal equivalent. Parameters : - `bcdnum`: 16-bit BCD numeral to be converted
Requires	Nothing.

Example	`unsigned a, b;`
	`...`
	`a = 0x1234;          // a equals 4660`
	`b = Bcd2Dec16(a);     // b equals 1234`

Dec2Bcd16

Prototype	`unsigned Dec2Bcd16(unsigned decnum);`
Returns	Converted BCD value.
Description	Converts unsigned 16-bit decimal value to its BCD equivalent. Parameters : - `decnum` unsigned 16-bit decimal number to be converted
Requires	Nothing.

Example	`unsigned a, b;`
	`...`
	`a = 2345;`
	`b = Dec2Bcd16(a);     // b equals 9029`

SPRINT LIBRARY

The mikroC PRO for AVR provides the standard ANSI C Sprintf function for easy data formatting.

Note: In addition to ANSI C standard, the Sprint Library also includes two limited versions of the sprintf function (sprinti and sprintl). These functions take less ROM and RAM and may be more convenient for use in some cases.

Functions

- sprintf
- sprintl
- sprinti

sprintf

Prototype	`sprintf(char *wh, const char *f,...);`
Returns	The function returns the number of characters actually written to destination string.
Description	`sprintf` is used to format data and print them into destination string. Parameters : - `wh:` destination string - `f:` format string The `f` argument is a format string and may be composed of characters, escape sequences, and format specifications. Ordinary characters and escape sequences are copied to the destination string in the order in which they are interpreted. Format specifications always begin with a percent sign (`%`) and require additional arguments to be included in the function call. The format string is read from left to right. The first format specification encountered refers to the first argument after f and then converts and outputs it using the format specification. The second format specification accesses the second argument after `f,` and so on. If there are more arguments than format specifications, then these extra arguments are ignored. Results are unpredictable if there are not enough arguments for the format specifications. The format specifications have the following format: `% [flags] [width] [.precision] [{ l | L }] conversion_type`

Description

Each field in the format specification can be a single character or a number which specifies a particular format option. The `conversion_type` field is where a single character specifies that the argument is interpreted as a character, string, number, or pointer, as shown in the following table:

`conversion_type`	**Argument Type**	**Output Format**
`d`	`int`	Signed decimal number
`u`	`unsigned int`	Unsigned decimal number
`o`	`unsigned int`	Unsigned octal number
`x`	`unsigned int`	Unsigned hexadecimal number using 0123456789abcdef
`X`	`unsigned int`	Unsigned hexadecimal number using 0123456789ABCEDF
`f`	`double`	Floating-point number using the format [-]dddd.dddd
`e`	`double`	Floating-point number using the format [-]d.dddde[-]dd
`E`	`double`	Floating-point number using the format [-]d.ddddE[-]dd
`g`	`double`	Floating-point number using either e or f format, whichever is more compact for the specified value and precision
`c`	`int`	int is converted to unsigned char, and the resulting character is written
`s`	`char *`	String with a terminating null character
`p`	`void *`	Pointer value, the X format is used
`%`	<none>	A % is written. No argument is converted. The complete conversion specification shall be %%.

The `flags` field is where a single character is used to justify the output and to print +/- signs and blanks, decimal points, and octal and hexadecimal prefixes, as shown in the following table.

Description

`flags`	**Meaning**
`-`	Left justify the output in the specified field width.
`+`	Prefix the output value with + or - sign if the output is a signed type.
`space (' ')`	Prefix the output value with a blank if it is a signed positive value. Otherwise, no blank is prefixed
`#`	Prefixes a non-zero output value with `0`, `0x`, or `0X` when used with `o`, `x`, and `X` field types, respectively. When used with `e`, `E`, `f`, `g`, and `G` field types, the `#` flag forces the output value to include a decimal point. The # flag is ignored in all other cases.
`*`	Ignore format specifier.

The `width` field is a non-negative number that specifies the minimum number of printed characters. If a number of characters in the output value is less than width, then blanks are added on the left or right (when the - flag is specified) to pad to the minimum width. If width is prefixed with 0, then zeros are padded instead of blanks. The `width` field never truncates a field. If a length of the output value exceeds the specified width, all characters are output.

The `precision` field is a non-negative number that specifies a number of characters to print, number of significant digits or number of decimal places. The precision field can cause truncation or rounding of the output value in the case of a floating-point number as specified in the following table.

`flags`	**Meaning of the `precision` field**
`d, u, o, x, X`	The precision field is where you specify a minimum number of digits that will be included in the output value. Digits are not truncated if the number of digits in the argument exceeds that defined in the precision field. If a number of digits in the argument is less than the precision field, the output value is padded on the left with zeros.
`f`	The precision field is where you specify a number of digits to the right of the decimal point. The last digit is rounded.
`e, E`	The precision field is where you specify a number of digits to the right of the decimal point. The last digit is rounded.
`g`	The precision field is where you specify a maximum number of significant digits in the output value.
`c, C`	The precision field has no effect on these field types.
`s`	The precision field is where you specify a maximum number of characters in the output value. Excess characters are not output.

Description	The optional characters `l` or `L` may immediately precede `conversion_type` to respectively specify long versions of the integer types `d, i, u, o, x,` and `X`. You must ensure that the argument type matches that of the format specification. You can use type casts to ensure that the proper type is passed to `sprintf`.

sprintl

Prototype	`sprintl(char  *wh, const char *f,...);`
Returns	The function returns the number of characters actually written to destination string.
Description	The same as sprintf, except it doesn't support float-type numbers.

sprinti

Prototype	`sprinti(char  *wh, const char *f,...);`
Returns	The function returns the number of characters actually written to destination string.
Description	The same as sprintf, except it doesn't support long integers and float-type numbers.

Library Example

This is a demonstration of the standard C library sprintf routine usage. Three different representations of the same floating poing number obtained by using the sprintf routine are sent via UART.

```
double ww = -1.2587538e+1;
char  buffer[15];

// Function for sending string to UART
void UartWriteText(char *txt) {
  while(*txt)
    Uart_Write(*txt++);
}

// Function for sending const string to UART
void UartWriteConstText(const char *txt) {
  while(*txt)
    Uart_Write(*txt++);
}

void main(){

  Uart_Init(4800);                          // Initialize UART mod-
ule at 4800 bps
  Delay_ms(10);

   UartWriteConstText("Floating point number representation"); //
Write message on UART

  sprintf(buffer, "%12e", ww);               // Format ww and store
it to buffer
  UartWriteConstText("\r\ne format:");      // Write message on UART
  UartWriteText(buffer);                     // Write buffer on UART

  sprintf(buffer, "%12f", ww);               // Format ww and store
it to buffer
  UartWriteConstText("\r\nf format:");      // Write message on UART
  UartWriteText(buffer);                     // Write buffer on UART

  sprintf(buffer, "%12g", ww);               // Format ww and store
it to buffer
  UartWriteConstText("\r\ng format:");      // Write message on UART
  UartWriteText(buffer);                     // Write buffer on UART
}
```

TIME LIBRARY

The Time Library contains functions and type definitions for time calculations in the UNIX time format which counts the number of seconds since the "epoch". This is very convenient for programs that work with time intervals: the difference between two UNIX time values is a real-time difference measured in seconds.

What is the epoch?
Originally it was defined as the beginning of 1970 GMT. (January 1, 1970 Julian day) GMT, Greenwich Mean Time, is a traditional term for the time zone in England.

The **TimeStruct** type is a structure type suitable for time and date storage. Type declaration is contained in `timelib.h` which can be found in the mikroC PRO for AVR Time Library Demo example folder.

Library Routines

- Time_dateToEpoch
- Time_epochToDate
- Time_dateDiff

Time_dateToEpoch

Prototype	`long Time_dateToEpoch(TimeStruct *ts);`
Returns	Number of seconds since January 1, 1970 0h00mn00s.
Description	This function returns the unix time : number of seconds since January 1, 1970 0h00mn00s. Parameters : - `ts`: time and date value for calculating unix time.
Requires	Nothing.

Example	`#include "timelib.h"`
	`...`
	`TimeStruct ts1;`
	`long epoch ;`
	`...`
	`/*`
	` * what is the epoch of the date in ts ?`
	` */`
	`epoch = Time_dateToEpoch(&ts1) ;`

Time_epochToDate

Prototype	`void Time_epochToDate(long e, TimeStruct *ts);`
Returns	Nothing.
Description	Converts the unix time to time and date. Parameters : - `e:` unix time (seconds since unix epoch) - `ts:` time and date structure for storing conversion output
Requires	Nothing.

Example	`#include "timelib.h"`
	`...`
	`TimeStruct ts2;`
	`long epoch ;`
	`...`
	`/*`
	` * what date is epoch 1234567890 ?`
	` */`
	`epoch = 1234567890 ;`
	`Time_epochToDate(epoch, &ts2) ;`

Time_dateDiff

Prototype	`long Time_dateDiff(TimeStruct *t1, TimeStruct *t2);`
Returns	Time difference in seconds as a signed long.
Description	This function compares two dates and returns time difference in seconds as a signed long. Result is positive if `t1` is before `t2`, result is null if `t1` is the same as `t2` and result is negative if `t1` is after `t2`. Parameters : - `t1:` time and date structure (the first comparison parameter) - `t2:` time and date structure (the second comparison parameter) Note: This function is implemented as macro in the timelib.h header file which can be found in the mikroC PRO for AVR Time Library Demo example folder.
Requires	Nothing.

Example	`#include "timelib.h"`
	`...`
	`TimeStruct ts1, ts2;`
	`long diff ;`
	`...`
	`/*`
	` * how many seconds between these two dates contained in ts1 and ts2 buffers?`
	` */`
	` diff = Time_dateDiff(&ts1, &ts2) ;`

Library Example

This example demonstrates Time Library usage.

```
#include        "timelib.h"

TimeStruct ts1, ts2 ;
long epoch ;
long diff ;

void main() {
  ts1.ss = 0 ;
  ts1.mn = 7 ;
  ts1.hh = 17 ;
  ts1.md = 23 ;
  ts1.mo = 5 ;
  ts1.yy = 2006 ;

  /*
   * What is the epoch of the date in ts ?
   */
  epoch = Time_dateToEpoch(&ts1) ;


  /*
   * What date is epoch 1234567890 ?
   */
  epoch = 1234567890 ;
  Time_epochToDate(epoch, &ts2) ;

  /*
   * How much seconds between this two dates ?
   */
  diff = Time_dateDiff(&ts1, &ts2) ;
}
```

TRIGONOMETRY LIBRARY

The mikroC PRO for AVR implements fundamental trigonometry functions. These functions are implemented as look-up tables. Trigonometry functions are implemented in integer format in order to save memory.

Library Routines

- sinE3
- cosE3

sinE3

Prototype	`int sinE3(unsigned angle_deg);`
Returns	The function returns the sine of input parameter.
Description	The function calculates sine multiplied by 1000 and rounded to the nearest integer: `result = round(sin(angle_deg)*1000)` Parameters : - `angle_deg`: input angle in degrees **Note**: Return value range: `-1000..1000.`
Requires	Nothing.

Example	`int res;`
	`...`
	`res = sinE3(45);   // result is 707`

cosE3

Prototype	`int cosE3(unsigned angle_deg);`
Returns	The function returns the cosine of input parameter.
Description	The function calculates cosine multiplied by 1000 and rounded to the nearest integer: `result = round(cos(angle_deg)*1000)` Parameters : - `angle_deg`: input angle in degrees **Note**: Return value range: `-1000..1000`.
Requires	Nothing.

Example	`int res;`
	`...`
	`res = cosE3(196);   // result is -193`

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