MPLAB® C18 C COMPILER LIBRARIES

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Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our web site (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXXA”, where “XXXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE on-line help. Select the Help menu, and then Topics to open a list of available on-line help files.

INTRODUCTION

The purpose of this document is to provide detailed information on the libraries and precompiled object files that may be used with Microchip’s MPLAB® C18 C Compiler.

DOCUMENT LAYOUT

The document layout is as follows:

- **Chapter 1: Overview** – describes the libraries and precompiled object files available.
- **Chapter 2: Hardware Peripheral Functions** – describes each hardware peripheral library function.
- **Chapter 3: Software Peripheral Library** – describes each software peripheral library function.
- **Chapter 4: General Software Library** – describes each general software library function.
- **Chapter 5: Math Library** – discusses the math library functions.
- **Glossary** – A glossary of terms used in this guide.
- **Index** – Cross-reference listing of terms, features and sections of this document.

CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	*MPLAB® IDE User's Guide*
Courier font:		
Plain Courier	Sample source code	#define START
	Filenames	autoexec.bat
	File paths	c:\mcc18\h
	Keywords	_asm, _endasm, static
	Command-line options	-Opa+, -Opa-
Italic Courier	A variable argument	*file*.o, where *file* can be any valid filename
0b*nnnn*	A binary number where *n* is a binary digit	0b00100, 0b10
0x*nnnn*	A hexadecimal number where *n* is a hexadecimal digit	0xFFFF, 0x007A
Square brackets [ ]	Optional arguments	mcc18 [options] *file* [options]
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	errorlevel {0|1}
Ellipses...	Replaces repeated text	var_name [, var_name...]
	Represents code supplied by user	void main (void) { ... }

RECOMMENDED READING

For more information on included libraries and precompiled object files for the compilers, the operation of MPLAB IDE and the use of other tools, the following are recommended reading.

readme.c18

For the latest information on using MPLAB C18 C Compiler, read the readme.c18 file (ASCII text) included with the software. This readme file contains update information that may not be included in this document.

readme.xxx

For the latest information on other Microchip tools (MPLAB IDE, MPLINK™ linker, etc.), read the associated readme files (ASCII text file) included with the software.

MPLAB® C18 C Compiler Getting Started Guide (DS51295)

Describes how to install the MPLAB C18 compiler, how to write simple programs and how to use the MPLAB IDE with the compiler.

MPLAB® C18 C Compiler User's Guide (DS51288)

Comprehensive guide that describes the operation and features of Microchip's MPLAB C18 C compiler for PIC18 devices.

MPLAB® IDE Quick Start Guide (DS51281)

Describes how to set up the MPLAB IDE software and use it to create projects and program devices.

MPASM™ Assembler, MPLINK™ Object Linker, and MPLIB™ Object Librarian User's Guide (DS33014)

Describes how to use the Microchip PICmicro® microcontroller (MCU) assembler (MPASM), linker (MPLINK) and librarian (MPLIB).

PICmicro® 18C MCU Family Reference Manual (DS39500)

Focuses on the Enhanced MCU family of devices. The operation of the Enhanced MCU family architecture and peripheral modules is explained but does not cover the specifics of each device.

PIC18 Device Data Sheets and Application Notes

Data sheets describe the operation and electrical specifications of PIC18 devices. Application notes describe how to use PIC18 devices.

To obtain any of the above listed documents, visit the Microchip web site (www.microchip.com) to retrieve these documents in Adobe Acrobat (.pdf) format.

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The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers and other language tools. These include the MPLAB C18 and MPLAB C30 C compilers; MPASM™ and MPLAB ASM30 assemblers; MPLINK™ and MPLAB LINK30 object linkers; and MPLIB™ and MPLAB LIB30 object librarians.
- **Emulators** – The latest information on Microchip in-circuit emulators.This includes the MPLAB ICE 2000 and MPLAB ICE 4000.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debugger, MPLAB ICD 2.
- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB SIM simulator, MPLAB IDE Project Manager and general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the MPLAB PM3 and PRO MATE® II device programmers and the PICSTART® Plus and PICkit® development programmers.

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Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support
- Development Systems Information Line

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: http://support.microchip.com

In addition, there is a Development Systems Information Line which lists the latest versions of Microchip's development systems software products. This line also provides information on how customers can receive currently available upgrade kits.

The Development Systems Information Line numbers are:

1-800-755-2345 – United States and most of Canada

1-480-792-7302 – Other International Locations

Chapter 1. Overview

1.1 INTRODUCTION

This chapter gives an overview of the MPLAB C18 library files and precompiled object files that can be included in an application.

1.2 MPLAB C18 LIBRARIES OVERVIEW

A library is a collection of functions grouped for reference and ease of linking. See the *MPASM™ Assembler, MPLINK™ Object Linker, MPLIB*™ Object Librarian User's Guide (DS33014) for more information about creating and maintaining libraries.

The MPLAB C18 libraries are included in the lib subdirectory of the installation. These can be linked directly into an application using the MPLINK linker.

These files were precompiled in the c:\mcc18\src directory at Microchip. The directory src\traditional contains the files for Non-extended mode and src\extended contains the files for Extended mode. If you chose **not** to install the compiler and related files in the c:\mcc18 directory, source code from the libraries will not show in the linker listing file and cannot be stepped through when using MPLAB IDE.

To include the library code in the .lst file and to be able to single step through library functions, follow the instructions in **Section 1.3.3**, **Section 1.4.3** and **Section 1.5.3** to rebuild the libraries using the supplied batch files (.bat) found in the src, src\traditional and src\extended directories.

1.3 START-UP CODE

1.3.1 Overview

Three versions of start-up code are provided with MPLAB C18, with varying levels of initialization. The c018*.o object files are for use with the compiler operating in the Non-extended mode. The c018*_e.o object files are for use with the compiler when operating in Extended mode. In increasing order of complexity, they are:

c018.o/c018_e.o initializes the C software stack and jumps to the start of the application function, main().

c018i.o/c018i_e.o performs all of the same tasks as c018.o/c018_e.o and also assigns the appropriate values to initialized data prior to calling the user's application. Initialization is required if global or static variables are set to a value when they are defined. This is the start-up code that is included in the linker script files that are provided with MPLAB C18.

c018iz.o/c018iz_e.o performs all of the same tasks as c018i.o/c018i_e.o and also assigns zero to all uninitialized variables, as is required for strict ANSI compliance.

1.3.2 Source Code

The source code for the start-up routines may be found in the `src\traditional\startup` and `src\extended\startup` subdirectories of the compiler installation.

1.3.3 Rebuilding

The batch file `makestartup.bat` may be used to rebuild the start-up code and copy the generated object files to the `lib` directory.

Before rebuilding the start-up code with `makestartup.bat`, verify that MPLAB C18 (`mcc18.exe`) is in your path.

1.4 PROCESSOR-INDEPENDENT LIBRARY

1.4.1 Overview

The standard C library (`clib.lib` or `clib_e.lib`) provides functions that are supported by the core PIC18 architecture: those that are supported across all processors in the family. These functions are described in the following chapters:

- General Software Library, Chapter 4.
- Math Libraries, Chapter 5.

1.4.2 Source Code

The source code for the functions in the standard C library may be found in the following subdirectories of the compiler installation:

- `src\traditional\math`
- `src\extended\math`
- `src\traditional\delays`
- `src\extended\delays`
- `src\traditional\stdclib`
- `src\extended\stdclib`

1.4.3 Rebuilding

The batch file `makeclib.bat` may be used to rebuild the processor-independent library. Before invoking this batch file, verify that the following tools are in your path:

- MPLAB C18 (`mcc18.exe`)
- MPASM assembler (`mpasm.exe`)
- MPLIB librarian (`mplib.exe`)

Also prior to rebuilding the standard C library, be sure that the environment variable `MCC_INCLUDE` is set to the path of the MPLAB C18 include files (e.g., `c:\mcc18\h`).

1.5 PROCESSOR-SPECIFIC LIBRARIES

1.5.1 Overview

The processor-specific library files contain definitions that may vary across individual members of the PIC18 family. This includes all of the peripheral routines and the Special Function Register (SFR) definitions. The peripheral routines that are provided include both those designed to use the hardware peripherals and those that implement a peripheral interface using general purpose I/O lines. The functions included in the processor-specific libraries are described in the following chapters:

- **Chapter 2. "Hardware Peripheral Functions"**
- **Chapter 3. "Software Peripheral Library"**

The processor-specific libraries are named:

`p`*processor*`.lib` – Non-extended mode processor-specific library

`p`*processor*`_e.lib` – Extended mode processor-specific library

For example, the library file for the PIC18F4620 is named `p18f4620.lib` for the Non-extended version of the library and `p18f4620_e.lib` for the Extended version of the library.

1.5.2 Source Code

The source code for the processor-specific libraries may be found in the following subdirectories of the compiler installation:

- `src\traditional\pmc`
- `src\extended\pmc`
- `src\traditional\proc`
- `src\extended\proc`

1.5.3 Rebuilding

The batch file `makeplib.bat` may be used to rebuild the processor-specific libraries. Before invoking this batch file, verify that the following tools are in your path:

- MPLAB C18 (`mcc18.exe`)
- MPASM assembler (`mpasm.exe`)
- MPLIB librarian (`mplib.exe`)

Also prior to invoking `makeplib.bat`, be sure that the environment variable `MCC_INCLUDE` is set to the path of the MPLAB C18 include files (e.g., `c:\mcc18\h`).

NOTES:

Chapter 2. Hardware Peripheral Functions

2.1 INTRODUCTION

This chapter documents the hardware peripheral functions found in the processor-specific libraries. The source code for all of these functions is included with MPLAB C18 in the `src\traditional\pmc` and `src\extended\pmc` subdirectories of the compiler installation.

See the *MPASM™ Assembler, MPLINK™ Object Linker, MPLIB*™ Object Librarian User's Guide (DS33014) for more information about managing libraries using the MPLIB librarian.

The following peripherals are supported by MPLAB C18 library routines:

- A/D Converter (**Section 2.2 "A/D Converter Functions"**)
- Input Capture (**Section 2.3 "Input Capture Functions"**)
- I^{2}C™ (**Section 2.4 "I^{2}C™ Functions"**)
- I/O Ports (**Section 2.5 "I/O Port Functions"**)
- Microwire (**Section 2.6 "Microwire Functions"**)
- Pulse-Width Modulation (PWM) (**Section 2.7 "Pulse-Width Modulation Functions"**)
- SPI™ (**Section 2.8 "SPI™ Functions"**)
- Timer (**Section 2.9 "Timer Functions"**)
- USART (**Section 2.10 "USART Functions"**)

2.2 A/D CONVERTER FUNCTIONS

The A/D peripheral is supported with the following functions:

TABLE 2-1: A/D CONVERTER FUNCTIONS

Function	Description
`BusyADC`	Is A/D converter currently performing a conversion?
`CloseADC`	Disable the A/D converter.
`ConvertADC`	Start an A/D conversion.
`OpenADC`	Configure the A/D convertor.
`ReadADC`	Read the results of an A/D conversion.
`SetChanADC`	Select A/D channel to be used.

2.2.1 Function Descriptions

BusyADC

Function: Is the A/D converter currently performing a conversion?

Include: `adc.h`

Prototype: `char BusyADC( void );`

Remarks: This function indicates if the A/D peripheral is in the process of converting a value.

Return Value: 1 if the A/D peripheral is performing a conversion.
0 if the A/D peripheral isn't performing a conversion.

File Name: `adcbusy.c`

CloseADC

Function: Disable the A/D converter.

Include: `adc.h`

Prototype: `void CloseADC( void );`

Remarks: This function disables the A/D convertor and A/D interrupt mechanism.

File Name: `adcclose.c`

ConvertADC

Function: Starts the A/D conversion process.

Include: `adc.h`

Prototype: `void ConvertADC( void );`

Remarks: This function starts an A/D conversion. The `BusyADC()` function may be used to detect completion of the conversion.

File Name: `adcconv.c`

OpenADC
PIC18CXX2, PIC18FXX2, PIC18FXX8, PIC18FXX39

Function: Configure the A/D convertor.

Include: `adc.h`

Prototype:

```
void OpenADC( unsigned char config,
              unsigned char config2 );
```

Arguments: ***config***
A bitmask that is created by performing a bitwise AND operation ('`&`') with a value from each of the categories listed below. These values are defined in the file `adc.h`.

A/D clock source:

`ADC_FOSC_2`	Fosc / 2
`ADC_FOSC_4`	Fosc / 4
`ADC_FOSC_8`	Fosc / 8
`ADC_FOSC_16`	Fosc / 16
`ADC_FOSC_32`	Fosc / 32
`ADC_FOSC_64`	Fosc / 64
`ADC_FOSC_RC`	Internal RC Oscillator

A/D result justification:

`ADC_RIGHT_JUST`	Result in Least Significant bits
`ADC_LEFT_JUST`	Result in Most Significant bits

OpenADC
PIC18CXX2, PIC18FXX2, PIC18FXX8, PIC18FXX39 (Continued)

A/D voltage reference source:

`ADC_8ANA_0REF`	VREF+=VDD, VREF-=VSS, All analog channels
`ADC_7ANA_1REF`	AN3=VREF+, All analog channels except AN3
`ADC_6ANA_2REF`	AN3=VREF+, AN2=VREF
`ADC_6ANA_0REF`	VREF+=VDD, VREF-=VSS
`ADC_5ANA_1REF`	AN3=VREF+, VREF-=VSS
`ADC_5ANA_0REF`	VREF+=VDD, VREF-=VSS
`ADC_4ANA_2REF`	AN3=VREF+, AN2=VREF-
`ADC_4ANA_1REF`	AN3=VREF+
`ADC_3ANA_2REF`	AN3=VREF+, AN2=VREF-
`ADC_3ANA_0REF`	VREF+=VDD, VREF-=VSS
`ADC_2ANA_2REF`	AN3=VREF+, AN2=VREF-
`ADC_2ANA_1REF`	AN3=VREF+
`ADC_1ANA_2REF`	AN3=VREF+, AN2=VREF-, AN0=A
`ADC_1ANA_0REF`	AN0 is analog input
`ADC_0ANA_0REF`	All digital I/O

config2

A bitmask that is created by performing a bitwise AND operation (‘&’) with a value from each of the categories listed below. These values are defined in the file `adc.h`.

Channel:

`ADC_CH0`	Channel 0
`ADC_CH1`	Channel 1
`ADC_CH2`	Channel 2
`ADC_CH3`	Channel 3
`ADC_CH4`	Channel 4
`ADC_CH5`	Channel 5
`ADC_CH6`	Channel 6
`ADC_CH7`	Channel 7

A/D Interrupts:

`ADC_INT_ON`	Interrupts enabled
`ADC_INT_OFF`	Interrupts disabled

Remarks: This function resets the A/D peripheral to the POR state and configures the A/D-related Special Function Registers (SFRs) according to the options specified.

File Name: `adcopen.c`

Code Example:

```
OpenADC( ADC_FOSC_32    &
         ADC_RIGHT_JUST &
         ADC_1ANA_0REF,
         ADC_CH0        &
         ADC_INT_OFF    );
```

OpenADC PIC18C658/858, PIC18C601/801, PIC18F6X20, PIC18F8X20

Function: Configure the A/D convertor.

Include: `adc.h`

Prototype:

```
void OpenADC( unsigned char config,
              unsigned char config2 );
```

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation ('`&`') with a value from each of the categories listed below. These values are defined in the file `adc.h`.

A/D clock source:

`ADC_FOSC_2`	FOSC / 2
`ADC_FOSC_4`	FOSC / 4
`ADC_FOSC_8`	FOSC / 8
`ADC_FOSC_16`	FOSC / 16
`ADC_FOSC_32`	FOSC / 32
`ADC_FOSC_64`	FOSC / 64
`ADC_FOSC_RC`	Internal RC Oscillator

A/D result justification:

`ADC_RIGHT_JUST`	Result in Least Significant bits
`ADC_LEFT_JUST`	Result in Most Significant bits

A/D port configuration:

`ADC_0ANA`	All digital	
`ADC_1ANA`	analog:AN0	digital:AN1-AN15
`ADC_2ANA`	analog:AN0-AN1	digital:AN2-AN15
`ADC_3ANA`	analog:AN0-AN2	digital:AN3-AN15
`ADC_4ANA`	analog:AN0-AN3	digital:AN4-AN15
`ADC_5ANA`	analog:AN0-AN4	digital:AN5-AN15
`ADC_6ANA`	analog:AN0-AN5	digital:AN6-AN15
`ADC_7ANA`	analog:AN0-AN6	digital:AN7-AN15
`ADC_8ANA`	analog:AN0-AN7	digital:AN8-AN15
`ADC_9ANA`	analog:AN0-AN8	digital:AN9-AN15
`ADC_10ANA`	analog:AN0-AN9	digital:AN10-AN15
`ADC_11ANA`	analog:AN0-AN10	digital:AN11-AN15
`ADC_12ANA`	analog:AN0-AN11	digital:AN12-AN15
`ADC_13ANA`	analog:AN0-AN12	digital:AN13-AN15
`ADC_14ANA`	analog:AN0-AN13	digital:AN14-AN15
`ADC_15ANA`	All analog	

config2

A bitmask that is created by performing a bitwise AND operation ('`&`') with a value from each of the categories listed below. These values are defined in the file `adc.h.`

OpenADC PIC18C658/858, PIC18C601/801, PIC18F6X20, PIC18F8X20 (Continued)

Channel:

`ADC_CH0`	Channel 0
`ADC_CH1`	Channel 1
`ADC_CH2`	Channel 2
`ADC_CH3`	Channel 3
`ADC_CH4`	Channel 4
`ADC_CH5`	Channel 5
`ADC_CH6`	Channel 6
`ADC_CH7`	Channel 7
`ADC_CH8`	Channel 8
`ADC_CH9`	Channel 9
`ADC_CH10`	Channel 10
`ADC_CH11`	Channel 11
`ADC_CH12`	Channel 12
`ADC_CH13`	Channel 13
`ADC_CH14`	Channel 14
`ADC_CH15`	Channel 15

A/D Interrupts:

`ADC_INT_ON`	Interrupts enabled
`ADC_INT_OFF`	Interrupts disabled

A/D VREF+ configuration:

`ADC_VREFPLUS_VDD`	VREF+ = AVDD
`ADC_VREFPLUS_EXT`	VREF+ = external

A/D VREF- configuration:

`ADC_VREFMINUS_VSS`	VREF- = AVSS
`ADC_VREFMINUS_EXT`	VREF- = external

Remarks: This function resets the A/D-related registers to the POR state and then configures the clock, result format, voltage reference, port and channel.

File Name: `adcopen.c`

Code Example:

```
OpenADC( ADC_FOSC_32    &
         ADC_RIGHT_JUST &
         ADC_14ANA,
         ADC_CH0        &
         ADC_INT_OFF    );
```

OpenADC
All Other Processors

Function: Configure the A/D convertor.

Include: `adc.h`

Prototype:

```
void OpenADC(unsigned char config,
             unsigned char config2 ,
             unsigned char portconfig);
```

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation (‘&’) with a value from each of the categories listed below. These values are defined in the file adc.h.

A/D clock source:

ADC_FOSC_2	FOSC / 2
ADC_FOSC_4	FOSC / 4
ADC_FOSC_8	FOSC / 8
ADC_FOSC_16	FOSC / 16
ADC_FOSC_32	FOSC / 32
ADC_FOSC_64	FOSC / 64
ADC_FOSC_RC	Internal RC Oscillator

A/D result justification:

ADC_RIGHT_JUST	Result in Least Significant bits
ADC_LEFT_JUST	Result in Most Significant bits

A/D acquisition time select:

ADC_0_TAD	0 Tad
ADC_2_TAD	2 Tad
ADC_4_TAD	4 Tad
ADC_6_TAD	6 Tad
ADC_8_TAD	8 Tad
ADC_12_TAD	12 Tad
ADC_16_TAD	16 Tad
ADC_20_TAD	20 Tad

config2

A bitmask that is created by performing a bitwise AND operation (‘&’) with a value from each of the categories listed below. These values are defined in the file adc.h.

Channel:

ADC_CH0	Channel 0
ADC_CH1	Channel 1
ADC_CH2	Channel 2
ADC_CH3	Channel 3
ADC_CH4	Channel 4
ADC_CH5	Channel 5
ADC_CH6	Channel 6
ADC_CH7	Channel 7
ADC_CH8	Channel 8
ADC_CH9	Channel 9
ADC_CH10	Channel 10
ADC_CH11	Channel 11
ADC_CH12	Channel 12
ADC_CH13	Channel 13
ADC_CH14	Channel 14
ADC_CH15	Channel 15

OpenADC
All Other Processors (Continued)

A/D Interrupts:

`ADC_INT_ON`	Interrupts enabled
`ADC_INT_OFF`	Interrupts disabled

A/D voltage configuration:

`ADC_VREFPLUS_VDD`	VREF+ = AVDD
`ADC_VREFPLUS_EXT`	VREF+ = external
`ADC_VREFMINUS_VDD`	VREF- = AVDD
`ADC_VREFMINUS_EXT`	VREF- = external

portconfig

The value of portconfig is any value from 0 to 127 inclusive for the PIC18F1220/1320 and 0 to 15 inclusive for all other processors. This is the value of bits 0 through 6 or bits 0 through 3 of the ADCON1 register, which are the port configuration bits.

Remarks: This function resets the A/D-related registers to the POR state and then configures the clock, result format, voltage reference, port and channel.

File Name: `adcopen.c`

Code Example:

```
OpenADC( ADC_FOSC_32    &
         ADC_RIGHT_JUST &
         ADC_12_TAD,
         ADC_CH0        &
         ADC_INT_OFF, 15  );
```

ReadADC

Function: Read the result of an A/D conversion.

Include: `adc.h`

Prototype: `int ReadADC( void );`

Remarks: This function reads the 16-bit result of an A/D conversion.

Return Value: This function returns the 16-bit signed result of the A/D conversion. Based on the configuration of the A/D converter (e.g., using the `OpenADC()` function), the result will be contained in the Least Significant or Most Significant bits of the 16-bit result.

File Name: `adcread.c`

SetChanADC

Function: Select the channel used as input to the A/D converter.

Include: `adc.h`

Prototype: `void SetChanADC( unsigned char channel );`

Arguments: ***`channel`***

One of the following values (defined in `adc.h`):

`ADC_CH0`	Channel 0
`ADC_CH1`	Channel 1
`ADC_CH2`	Channel 2
`ADC_CH3`	Channel 3
`ADC_CH4`	Channel 4
`ADC_CH5`	Channel 5
`ADC_CH6`	Channel 6
`ADC_CH7`	Channel 7
`ADC_CH8`	Channel 8
`ADC_CH9`	Channel 9
`ADC_CH10`	Channel 10
`ADC_CH11`	Channel 11

Remarks: Selects the pin that will be used as input to the A/D converter.

File Name: `adcsetch.c`

Code Example: `SetChanADC( ADC_CH0 );`

2.2.2 Example Use of the A/D Converter Routines

```
#include <p18C452.h>
#include <adc.h>
#include <stdlib.h>
#include <delays.h>

int result;

void main( void )
{
  // configure A/D convertor
  OpenADC( ADC_FOSC_32 & ADC_RIGHT_JUST & ADC_8ANA_0REF,
           ADC_CH0 & ADC_INT_OFF );

  Delay10TCYx( 5 );      // Delay for 50TCY
  ConvertADC();          // Start conversion
  while( BusyADC() );    // Wait for completion
  result = ReadADC();    // Read result
  CloseADC();            // Disable A/D converter
}
```

2.3 INPUT CAPTURE FUNCTIONS

The capture peripheral is supported with the following functions:

TABLE 2-2: INPUT CAPTURE FUNCTIONS

Function	Description
`CloseCapture`***x***	Disable capture peripheral ***x.***
`OpenCapture`***x***	Configure capture peripheral ***x.***
`ReadCapture`***x***	Read a value from capture peripheral ***x.***
`CloseECapture`***x***(1)	Disable enhanced capture peripheral ***x.***
`OpenECapture`***x***(1)	Configure enhanced capture peripheral ***x.***
`ReadECapture`***x***(1)	Read a value from enhanced capture peripheral ***x.***

Note 1: The enhanced capture functions are only available on those devices with an ECCPxCON register.

2.3.1 Function Descriptions

CloseCapture1
CloseCapture2
CloseCapture3
CloseCapture4
CloseCapture5
CloseECapture1

Function: Disable input capture *x*.

Include: `capture.h`

Prototype:

```
void CloseCapture1( void );
void CloseCapture2( void );
void CloseCapture3( void );
void CloseCapture4( void );
void CloseCapture5( void );
void CloseECapture1( void );
```

Remarks: This function disables the interrupt corresponding to the specified input capture.

File Name:

```
cp1close.c
cp2close.c
cp3close.c
cp4close.c
cp5close.c
ep1close.c
```

OpenCapture1
OpenCapture2
OpenCapture3
OpenCapture4
OpenCapture5
OpenECapture1

Function: Configure and enable input capture *x*.

Include: `capture.h`

Prototype:

```
void OpenCapture1( unsigned char config );
void OpenCapture2( unsigned char config );
void OpenCapture3( unsigned char config );
void OpenCapture4( unsigned char config );
void OpenCapture5( unsigned char config );
void OpenECapture1( unsigned char config );
```

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `capture.h`:

Enable CCP Interrupts:

`CAPTURE_INT_ON`	Interrupts Enabled
`CAPTURE_INT_OFF`	Interrupts Disabled

Interrupt Trigger (replace *x* with CCP module number):

`Cx_EVERY_FALL_EDGE`	Interrupt on every falling edge
`Cx_EVERY_RISE_EDGE`	Interrupt on every rising edge
`Cx_EVERY_4_RISE_EDGE`	Interrupt on every 4th rising edge
`Cx_EVERY_16_RISE_EDGE`	Interrupt on every 16th rising edge
`EC1_EVERY_FALL_EDGE`	Interrupt on every falling edge (enhanced)
`EC1_EVERY_RISE_EDGE`	Interrupt on every rising edge (enhanced)
`EC1_EVERY_4_RISE_EDGE`	Interrupt on every 4th rising edge (enhanced)
`EC1_EVERY_16_RISE_EDGE`	Interrupt on every 16th rising edge (enhanced)

Remarks: This function first resets the capture module to the POR state and then configures the input capture for the specified edge detection.

The capture functions use a structure, defined in `capture.h`, to indicate overflow status of each of the capture modules. This structure is called `CapStatus` and has the following bit fields:

```
Cap1OVF
Cap2OVF
Cap3OVF
Cap4OVF
Cap5OVF
ECap1OVF
```

In addition to opening the capture, the appropriate timer module must be enabled before any of the captures will operate. See the data sheet for CCP and timer interconnect configurations and **Section 2.9 “Timer Functions”** for the arguments used with CCP in OpenTimer3.

OpenCapture1
OpenCapture2
OpenCapture3
OpenCapture4
OpenCapture5
OpenECapture1 (Continued)

File Name:

```
cp1open.c
cp2open.c
cp3open.c
cp4open.c
cp5open.c
ep1open.c
```

Code Example:

```
OpenCapture1( CAPTURE_INT_ON &
              C1_EVERY_4_RISE_EDGE );
```

ReadCapture1
ReadCapture2
ReadCapture3
ReadCapture4
ReadCapture5
ReadECapture1

Function: Read the result of a capture event from the specified input capture.

Include: `capture.h`

Prototype:

```
unsigned int ReadCapture1( void );
unsigned int ReadCapture2( void );
unsigned int ReadCapture3( void );
unsigned int ReadCapture4( void );
unsigned int ReadCapture5( void );
unsigned int ReadECapture1( void );
```

Remarks: This function reads the value of the respective input capture’s SFRs.

Return Value: This function returns the result of the capture event.

File Name:

```
cp1read.c
cp2read.c
cp3read.c
cp4read.c
cp5read.c
ep1read.c
```

2.3.2 Example Use of the Capture Routines

This example demonstrates the use of the capture library routines in a “polled” (not interrupt-driven) environment.

```
#include <p18C452.h>
#include <capture.h>
#include <timers.h>
#include <usart.h>
#include <stdlib.h>

void main(void)
{
  unsigned int result;
  char str[7];

  // Configure Capture1
  OpenCapture1( C1_EVERY_4_RISE_EDGE &
                CAPTURE_INT_OFF );

  // Configure Timer3
  OpenTimer3( TIMER_INT_OFF &
              T3_SOURCE_INT );

  // Configure USART
  OpenUSART( USART_TX_INT_OFF  &
             USART_RX_INT_OFF  &
             USART_ASYNCH_MODE &
             USART_EIGHT_BIT   &
             USART_CONT_RX,
             25 );

  while(!PIR1bits.CCP1IF);  // Wait for event
  result = ReadCapture1(); // read result
  ultoa(result,str);       // convert to string

  // Write the string out to the USART if
  // an overflow condition has not occurred.
  if(!CapStatus.Cap1OVF)
  {
    putsUSART(str);
  }

  // Clean up
  CloseCapture1();
  CloseTimer3();
  CloseUSART();
}
```

2.4 I^{2}C™ FUNCTIONS

The following routines are provided for devices with a single I^{2}C peripheral:

TABLE 2-3: SINGLE I^{2}C™ PERIPHERAL FUNCTIONS

Function	Description
`AckI2C`	Generate I^{2}C™ bus *Acknowledge* condition.
`CloseI2C`	Disable the SSP module.
`DataRdyI2C`	Is the data available in the I^{2}C buffer?
`getcI2C`	Read a single byte from the I^{2}C bus.
`getsI2C`	Read a string from the I^{2}C bus operating in master I^{2}C mode.
`IdleI2C`	Loop until I^{2}C bus is idle.
`NotAckI2C`	Generate I^{2}C bus *Not Acknowledge* condition.
`OpenI2C`	Configure the SSP module.
`putcI2C`	Write a single byte to the I^{2}C bus.
`putsI2C`	Write a string to the I^{2}C bus operating in either Master or Slave mode.
`ReadI2C`	Read a single byte from the I^{2}C bus.
`RestartI2C`	Generate an I^{2}C bus *Restart* condition.
`StartI2C`	Generate an I^{2}C bus *Start* condition.
`StopI2C`	Generate an I^{2}C bus *Stop* condition.
`WriteI2C`	Write a single byte to the I^{2}C bus.

The following routines are provided for devices with multiple I^{2}C peripherals:

TABLE 2-4: MULTIPLE I^{2}C™ PERIPHERAL FUNCTIONS

Function	Description
`AckI2C`***x***	Generate I^{2}C***x*** bus *Acknowledge* condition.
`CloseI2C`***x***	Disable the SS ***x*** module.
`DataRdyI2C`***x***	Is the data available in the I^{2}C***x*** buffer?
`getcI2C`***x***	Read a single byte from the I^{2}C***x*** bus.
`getsI2C`***x***	Read a string from the I^{2}C***x*** bus operating in master I^{2}C mode.
`IdleI2C`***x***	Loop until I^{2}C***x*** bus is idle.
`NotAckI2C`***x***	Generate I^{2}C***x*** bus *Not Acknowledge* condition.
`OpenI2C`***x***	Configure the SSP***x*** module.
`putcI2C`***x***	Write a single byte to the I^{2}C***x*** bus.
`putsI2C`***x***	Write a string to the I^{2}C***x*** bus operating in either Master or Slave mode.
`ReadI2C`***x***	Read a single byte from the I^{2}C***x*** bus.
`RestartI2C`***x***	Generate an I^{2}C***x*** bus *Restart* condition.
`StartI2C`***x***	Generate an I^{2}C***x*** bus *Start* condition.
`StopI2C`***x***	Generate an I^{2}C***x*** bus *Stop* condition.
`WriteI2C`***x***	Write a single byte to the I^{2}C***x*** bus.

The following functions are also provided for interfacing with an EE memory device such as the Microchip 24LC01B using the I^{2}C interface:

TABLE 2-5: INTERFACE FUNCTIONS FOR EE MEMORY DEVICES

Function	Description
`EEAckPolling`***x***	Generate the Acknowledge polling sequence.
`EEByteWrite`***x***	Write a single byte.
`EECurrentAddRead`***x***	Read a single byte from the next location.
`EEPageWrite`***x***	Write a string of data.
`EERandomRead`***x***	Read a single byte from an arbitrary address.
`EESequentialRead`***x***	Read a string of data.

2.4.1 Function Descriptions

AckI2C
AckI2C1
AckI2C2

Function: Generate I^{2}C bus *Acknowledge* condition.

Include: `i2c.h`

Prototype:

```
void AckI2C( void );
void AckI2C1( void );
void AckI2C2( void );
```

Remarks: This function generates an I^{2}C***x*** bus *Acknowledge* condition.

File Name:

```
i2c_ack.c
i2c1ack.c
i2c2ack.c
```

CloseI2C
CloseI2C1
CloseI2C2

Function: Disable the SSP***x*** module.

Include: `i2c.h`

Prototype:

```
void CloseI2C( void );
void CloseI2C1( void );
void CloseI2C2( void );
```

Remarks: This function disables the SSP***x*** module.

File Name:

```
i2c_close.c
i2c1close.c
i2c2close.c
```

DataRdyI2C
DataRdyI2C1
DataRdyI2C2

Function: Is data available in the I^{2}C*x* buffer?

Include: `i2c.h`

Prototype:

```
unsigned char DataRdyI2C( void );
unsigned char DataRdyI2C1( void );
unsigned char DataRdyI2C2( void );
```

Remarks: Determines if there is a byte to be read in the SSP***x*** buffer.

Return Value: 1 if there is data in the SSP***x*** buffer
0 if there is no data in the SSP***x*** buffer

File Name:

```
i2c_dtrd.c
i2c1dtrd.c
i2c2dtrd.c
```

Code Example:

```
if (DataRdyI2C())
{
  var = getcI2C();
}
```

getcI2C
getcI2C1
getcI2C2

getcI2C*x* is defined as ReadI2C*x*. *See* **ReadI2C*x***.

getsI2C
getsI2C1
getsI2C2

Function: Read a fixed length string from the I^{2}C***x*** bus operating in master I^{2}C mode.

Include: `i2c.h`

Prototype:

```
unsigned char getsI2C(
            unsigned char  * rdptr,
            unsigned char    length );
unsigned char getsI2C1(
            unsigned char  * rdptr,
            unsigned char    length );
unsigned char getsI2C2(
            unsigned char  * rdptr,
            unsigned char    length );
```

Arguments: ***`rdptr`***
Character type pointer to PICmicro MCU RAM for storage of data read from I^{2}C device.
`length`
Number of bytes to read from I^{2}C***x*** device.

Remarks: This routine reads a predefined data string length from the I^{2}C***x*** bus.

getsI2C
getsI2C1
getsI2C2 (Continued)

Return Value: 0 if all bytes have been sent
-1 if a bus collision has occurred

File Name:

```
i2c_gets.c
i2c1gets.c
i2c2gets.c
```

Code Example:

```
unsigned char string[15];
getsI2C(string, 15);
```

IdleI2C
IdleI2C1
IdleI2C2

Function: Loop until I^2C***x*** bus is Idle.

Include: `i2c.h`

Prototype: `void IdleI2C( void );`

Remarks: This function checks the state of the I^2C peripheral and waits for the bus to become available. The `IdleI2C` function is required since the hardware I^2C peripheral does not allow for spooling of bus sequences. The I^2C peripheral must be in an Idle state before an I^2C operation can be initiated or a write collision will be generated.

File Name: `idlei2c.c`

NotAckI2C
NotAckI2C1
NotAckI2C2

Function: Generate I^2C***x*** bus *Not Acknowledge* condition.

Include: `i2c.h`

Prototype:

```
void NotAckI2C( void );
void NotAckI2C1( void );
void NotAckI2C2( void );
```

Remarks: This function generates an I^2C***x*** bus *Not Acknowledge* condition.

File Name:

```
i2c_nack.c
i2c1nack.c
i2c2nack.c
```

OpenI2C
OpenI2C1
OpenI2C2

Function: Configure the SSP***x*** module.

Include: `i2c.h`

Prototype:

```
void OpenI2C( unsigned char sync_mode,
              unsigned char slew );
void OpenI2C1( unsigned char sync_mode,
              unsigned char slew );
void OpenI2C2( unsigned char sync_mode,
              unsigned char slew );
```

Arguments: ***sync_mode***

One of the following values, defined in `i2c.h`:

`SLAVE_7`	I^{2}C Slave mode, 7-bit address
`SLAVE_10`	I^{2}C Slave mode, 10-bit address
`MASTER`	I^{2}C Master mode

slew

One of the following values, defined in `i2c.h`:

`SLEW_OFF`	Slew rate disabled for 100 kHz mode
`SLEW_ON`	Slew rate enabled for 400 kHz mode

Remarks: `OpenI2C`***x*** resets the SSP***x*** module to the POR state and then configures the module for Master/Slave mode and the selected slew rate.

File Name:

```
i2c_open.c
i2c1open.c
i2c2open.c
```

Code Example:

```
OpenI2C(MASTER, SLEW_ON);
```

putcI2C
putcI2C1
putcI2C2

putcI2Cx is defines as WriteI2Cx. *See* **WriteI2C*x***.

putsI2C
putsI2C1
putsI2C2

Function: Write a data string to the I^{2}C***x*** bus operating in either Master or Slave mode.

Include: `i2c.h`

Prototype:

```
unsigned char putsI2C(
                unsigned char *wrptr );
unsigned char putsI2C1(
                unsigned char *wrptr );
unsigned char putsI2C2(
                unsigned char *wrptr );
```

Arguments: ***`wrptr`***
Pointer to data that will be written to the I^{2}C bus.

Remarks: This routine writes a data string to the I^{2}C***x*** bus until a null character is reached. The null character itself is not transmitted. This routine can operate in both Master or Slave mode.

Return Value: **Master I^{2}C mode:**
0 if the null character was reached in the data string
-2 if the slave I^{2}C***x*** device responded with a *NOT ACK*
-3 if a write collision occurred
Slave I^{2}C mode:
0 if the null character was reached in the data string
-2 if the master I^{2}C***x*** device responded with a *NOT ACK* which terminated the data transfer

File Name:

```
i2c_puts.c
i2c1puts.c
i2c2puts.c
```

Code Example:

```
unsigned char string[] = “data to send”;
putsI2C(string);
```

ReadI2C
ReadI2C1
ReadI2C2
getcI2C
getcI2C1
getcI2C2

Function: Read a single byte from the I^{2}C***x*** bus.

Include: `i2c.h`

Prototype:

```
unsigned char ReadI2C ( void );
unsigned char ReadI2C1 ( void );
unsigned char ReadI2C2 ( void );
unsigned char getcI2C ( void );
unsigned char getcI2C1 ( void );
unsigned char getcI2C2 ( void );
```

Remarks: This function reads in a single byte from the I^{2}C***x*** bus. getcI2C*x* is defined to be ReadI2C*x* in i2c.h.

Return Value: The data byte read from the I^{2}C***x*** bus.

ReadI2C
ReadI2C1
ReadI2C2
getcI2C
getcI2C1
getcI2C2 (Continued)

File Name:

```
i2c_read.c
i2c1read.c
i2c2read.c
# define in i2c.h
# define in i2c.h
# define in i2c.h
```

Code Example:

```
unsigned char value;
value = ReadI2C();
```

RestartI2C
RestartI2C1
RestartI2C2

Function: Generate an I^{2}C***x*** bus *Restart* condition.

Include: `i2c.h`

Prototype:

```
void RestartI2C( void );
void RestartI2C1( void );
void RestartI2C2( void );
```

Remarks: This function generates an I^{2}C***x*** bus *Restart* condition.

File Name:

```
i2c_rstr.c
i2c1rstr.c
i2c2rstr.c
```

StartI2C
StartI2C1
StartI2C2

Function: Generate an I^{2}C***x*** bus *Start* condition.

Include: `i2c.h`

Prototype:

```
void StartI2C( void );
void StartI2C1( void );
void StartI2C2( void );
```

Remarks: This function generates a I^{2}C***x*** bus *Start* condition.

File Name:

```
i2c_start.c
i2c1start.c
i2c2start.c
```

StopI2C
StopI2C1
StopI2C2

Function: Generate I^{2}C***x*** bus *Stop* condition.

Include: `i2c.h`

Prototype:

```
void StopI2C( void );
void StopI2C1( void );
void StopI2C2( void );
```

Remarks: This function generates an I^{2}C***x*** bus *Stop* condition.

File Name:

```
i2c_stop.c
i2c1stop.c
i2c2stop.c
```

WriteI2C
WriteI2C1
WriteI2C2
putcI2C
putcI2C1
putcI2C2

Function: Write a single byte to the I^{2}C***x*** bus device.

Include: `i2c.h`

Prototype:

```
unsigned char WriteI2C(
      unsigned char data_out );
unsigned char WriteI2C1(
      unsigned char data_out );
unsigned char WriteI2C2(
      unsigned char data_out );
unsigned char putcI2C(
      unsigned char data_out );
unsigned char putcI2C1(
      unsigned char data_out );
unsigned char putcI2C2(
      unsigned char data_out );
```

Arguments: ***data_out***
A single data byte to be written to the I^{2}C***x*** bus device.

Remarks: This function writes out a single data byte to the I^{2}C***x*** bus device.
putcI2C*x* is defined to be WriteI2C*x* in i2c.h.

Return Value: 0 if the write was successful
-1 if there was a write collision

File Name:

```
i2c_write.c
i2c1write.c
i2c2write.c
#define in i2c.h
#define in i2c.h
#define in i2c.h
```

Code Example:

```
WriteI2C('a');
```

2.4.2 EE Memory Device Interface Function Descriptions

EEAckPolling
EEAckPolling1
EEAckPolling2

Function: Generate the Acknowledge polling sequence for Microchip EE I^{2}C memory devices.

Include: `i2c.h`

Prototype:

```
unsigned char EEAckPolling(
     unsigned char control );
unsigned char EEAckPolling1(
     unsigned char control );
unsigned char EEAckPolling2(
     unsigned char control );
```

Arguments: ***control***
EEPROM control / bus device select address byte.

Remarks: This function is used to generate the Acknowledge polling sequence for EE I^{2}C memory devices that utilize Acknowledge polling.

Return Value: 0 if there were no errors
-1 if there was a bus collision error
-3 if there was a write collision error

File Name:
`i2c_ecap.c`
`i2c1ecap.c`
`i2c2ecap.c`

Code Example:

```
temp = EEAckPolling(0xA0);
```

EEByteWrite
EEByteWrite1
EEByteWrite2

Function: Write a single byte to the I^{2}C***x*** bus.

Include: `i2c.h`

Prototype:

```
unsigned char EEByteWrite(
     unsigned char control,
     unsigned char address,
     unsigned char data );
unsigned char EEByteWrite1(
     unsigned char control,
     unsigned char address,
     unsigned char data );
unsigned char EEByteWrite2(
     unsigned char control,
     unsigned char address,
     unsigned char data );
```

Arguments: ***control***
EEPROM control / bus device select address byte.
address
EEPROM internal address location.
data
Data to write to EEPROM address specified in function parameter address.

EEByteWrite
EEByteWrite1
EEByteWrite2 (Continued)

Remarks: This function writes a single data byte to the I^{2}C***x*** bus. This routine can be used for any Microchip I^{2}C EE memory device which requires only 1 byte of address information.

Return Value:
0 if there were no errors
-1 if there was a bus collision error
-2 if there was a NOT ACK error
-3 if there was a write collision error

File Name:

```
i2c_ecbw.c
i2c1ecbw.c
i2c2ecbw.c
```

Code Example:

```
temp = EEByteWrite(0xA0, 0x30, 0xA5);
```

EECurrentAddRead
EECurrentAddRead1
EECurrentAddRead2

Function: Read a single byte from the I^{2}C***x*** bus.

Include: `i2c.h`

Prototype:

```
unsigned int EECurrentAddRead(
     unsigned char control );
unsigned int EECurrentAddRead1(
     unsigned char control );
unsigned int EECurrentAddRead2(
     unsigned char control );
```

Arguments:
control
EEPROM control / bus device select address byte.

Remarks: This function reads in a single byte from the I^{2}C***x*** bus. The address location of the data to read is that of the current pointer within the I^{2}C EE device. The memory device contains an address counter that maintains the address of the last word accessed, incremented by one.

Return Value:
-1 if a bus collision error occurred
-2 if a NOT ACK error occurred
-3 if a write collision error occurred
Otherwise, the result is returned as an unsigned 16-bit quantity. Since the buffer itself is only 8-bits wide, this means that the Most Significant Byte will be zero and the Least Significant Byte will contain the read buffer contents.

File Name:

```
i2c_eecr.c
i2c1eecr.c
i2c2eecr.c
```

Code Example:

```
temp = EECurrentAddRead(0xA1);
```

EEPageWrite
EEPageWrite1
EEPageWrite2

Function: Write a string of data to the EE device from the I^{2}C***x*** bus.

Include: `i2c.h`

Prototype:

```
unsigned char EEPageWrite(
     unsigned char control,
     unsigned char address,
     unsigned char * wrptr );
unsigned char EEPageWrite1(
     unsigned char control,
     unsigned char address,
     unsigned char * wrptr );
unsigned char EEPageWrite2(
     unsigned char control,
     unsigned char address,
     unsigned char * wrptr );
```

Arguments:

control
EEPROM control / bus device select address byte.
address
EEPROM internal address location.
wrptr
Character type pointer in PICmicro MCU RAM. The data objects pointed to by *wrptr* will be written to the EE device.

Remarks: This function writes a null terminated string of data to the I^{2}C EE memory device. The null character itself is not transmitted.

Return Value: 0 if there were no errors
-1 if there was a bus collision error
-2 if there was a NOT ACK error
-3 if there was a write collision error

File Name:
`i2c_eepw.c`
`i2c1eepw.c`
`i2c2eepw.c`

Code Example:

```
temp = EEPageWrite(0xA0, 0x70, wrptr);
```

EERandomRead
EERandomRead1
EERandomRead2

Function: Read a single byte from the I^{2}C*x* bus.

Include: `i2c.h`

Prototype:

```
unsigned int EERandomRead(
     unsigned char control,
     unsigned char address );
unsigned int EERandomRead1(
     unsigned char control,
     unsigned char address );
unsigned int EERandomRead2(
     unsigned char control,
     unsigned char address );
```

Arguments: ***control***
EEPROM control / bus device select address byte.
address
EEPROM internal address location.

Remarks: This function reads in a single byte from the I^{2}C*x* bus. The routine can be used for Microchip I^{2}C EE memory devices which only require 1 byte of address information.

Return Value: The return value contains the value read in the Least Significant Byte and the error condition in the Most Significant Byte. The error condition is:
-1 if there was a bus collision error
-2 if there was a NOT ACK error
-3 if there was a write collision error

File Name:

```
i2c_eerr.c
i2c1eerr.c
i2c2eerr.c
```

Code Example:

```
unsigned int temp;
temp = EERandomRead(0xA0,0x30);
```

EESequentialRead
EESequentialRead1
EESequentialRead2

Function: Read a string of data from the I^{2}C***x*** bus.

Include: `i2c.h`

Prototype:

```
unsigned char EESequentialRead(
     unsigned char control,
     unsigned char address,
     unsigned char * rdptr,
     unsigned char length );
unsigned char EESequentialRead1(
     unsigned char control,
     unsigned char address,
     unsigned char * rdptr,
     unsigned char length );
unsigned char EESequentialRead2(
     unsigned char control,
     unsigned char address,
     unsigned char * rdptr,
     unsigned char length );
```

Arguments:

`control`
EEPROM control / bus device select address byte.

`address`
EEPROM internal address location.

`rdptr`
Character type pointer to PICmicro MCU RAM area for placement of data read from EEPROM device.

`length`
Number of bytes to read from EEPROM device.

Remarks: This function reads in a predefined string length of data from the I^{2}C***x*** bus. The routine can be used for Microchip I^{2}C EE memory devices which only require 1 byte of address information.

Return Value:
0 if there were no errors
-1 if there was a bus collision error
-2 if there was a NOT ACK error
-3 if there was a write collision error

File Name:
`i2c_eesr.c`
`i2c1eesr.c`
`i2c2eesr.c`

Code Example:

```
unsigned char err;
err = EESequentialRead(0xA0,
                       0x70,
                       rdptr,
                       15);
```

2.4.3 Example of Use

The following is a simple code example illustrating the SSP module configured for I^{2}C master communication. The routine illustrates I^{2}C communications with a Microchip 24LC01B I^{2}C EE memory device.

```
#include "p18cxx.h"
#include "i2c.h"

unsigned char arraywr[] = {1,2,3,4,5,6,7,8,0};
unsigned char arrayrd[20];

//***************************************************
void main(void)
{
  OpenI2C(MASTER, SLEW_ON);// Initialize I2C module
  SSPADD = 9;              //400kHz Baud clock(9) @16MHz
                           //100kHz Baud clock(39) @16MHz

  while(1)
  {
    EEByteWrite(0xA0, 0x30, 0xA5);
    EEAckPolling(0xA0);
    EECurrentAddRead(0xA0);
    EEPageWrite(0xA0, 0x70, arraywr);
    EEAckPolling(0xA0);
    EESequentialRead(0xA0, 0x70, arrayrd, 20);
    EERandomRead(0xA0,0x30);
  }
}
```

2.5 I/O PORT FUNCTIONS

PORTB is supported with the following functions:

TABLE 2-6: I/O PORT FUNCTIONS

Function	Description
ClosePORTB	Disable the interrupts and internal pull-up resistors for PORTB.
CloseRB*x*INT	Disable interrupts for PORTB pin *x* .
DisablePullups	Disable the internal pull-up resistors on PORTB.
EnablePullups	Enable the internal pull-up resistors on PORTB.
OpenPORTB	Configure the interrupts and internal pull-up resistors on PORTB.
OpenRB*x*INT	Enable interrupts for PORTB pin *x* .

2.5.1 Function Descriptions

ClosePORTB

Function:	Disable the interrupts and internal pull-up resistors for `PORTB`.
Include:	`portb.h`
Prototype:	`void ClosePORTB( void );`
Remarks:	This function disables the `PORTB` interrupt-on-change and the internal pull-up resistors.
File Name:	`pbclose.c`

CloseRB0INT
CloseRB1INT
CloseRB2INT

Function:	Disable the interrupts for the specified `PORTB` pin.
Include:	`portb.h`

Prototype:	`void CloseRB0INT( void );`
	`void CloseRB1INT( void );`
	`void CloseRB2INT( void );`

Remarks:	This function disables the `PORTB` interrupt-on-change.

File Name:	`rb0close.c`
	`rb1close.c`
	`rb2close.c`

DisablePullups

Function:	Disable the internal pull-up resistors on `PORTB`.
Include:	`portb.h`
Prototype:	`void DisablePullups( void );`
Remarks:	This function disables the internal pull-up resistors on `PORTB`.
File Name:	`pulldis.c`

EnablePullups

Function:	Enable the internal pull-up resistors on `PORTB`.
Include:	`portb.h`
Prototype:	`void EnablePullups( void );`
Remarks:	This function enables the internal pull-up resistors on `PORTB`.
File Name:	`pullen.c`

OpenPORTB

Function: Configure the interrupts and internal pull-up resistors on PORTB.

Include: portb.h

Prototype: `void OpenPORTB( unsigned char config);`

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation ('&') with a value from each of the categories listed below. These values are defined in the file portb.h.

Interrupt-on-change:

PORTB_CHANGE_INT_ON	Interrupt enabled
PORTB_CHANGE_INT_OFF	Interrupt disabled

Enable Pullups:

PORTB_PULLUPS_ON	pull-up resistors enabled
PORTB_PULLUPS_OFF	pull-up resistors disabled

Remarks: This function configures the interrupts and internal pull-up resistors on PORTB.

File Name: pbopen.c

Code Example:

```
OpenPORTB( PORTB_CHANGE_INT_ON & PORTB_PULLUPS_ON);
```

OpenRB0INT
OpenRB1INT
OpenRB2INT

Function: Enable interrupts for the specified PORTB pin.

Include: portb.h

Prototype:

```
void OpenRB0INT( unsigned char config );
void OpenRB1INT( unsigned char config );
void OpenRB2INT( unsigned char config );
```

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation ('&') with a value from each of the categories listed below. These values are defined in the file portb.h.

Interrupt-on-change:

PORTB_CHANGE_INT_ON	Interrupt enabled
PORTB_CHANGE_INT_OFF	Interrupt disabled

Interrupt-on-edge:

RISING_EDGE_INT	Interrupt on rising edge
FALLING_EDGE_INT	Interrupt on falling edge

Enable Pullups:

PORTB_PULLUPS_ON	pull-up resistors enabled
PORTB_PULLUPS_OFF	pull-up resistors disabled

Remarks: This function configures the interrupts and internal pull-up resistors on PORTB.

File Name:

rb0open.c
rb1open.c
rb2open.c

Code Example:

```
OpenRB0INT( PORTB_CHANGE_INT_ON & RISING_EDGE_INT &
PORTB_PULLUPS_ON);
```

2.6 MICROWIRE FUNCTIONS

The following routines are provided for devices with a single Microwire peripheral:

TABLE 2-7: SINGLE MICROWIRE PERIPHERAL FUNCTIONS

Function	Description
`CloseMwire`	Disable the SSP module used for Microwire communication.
`DataRdyMwire`	Indicate completion of the internal write cycle.
`getcMwire`	Read a byte from the Microwire device.
`getsMwire`	Read a string from the Microwire device.
`OpenMwire`	Configure the SSP module for Microwire use.
`putcMwire`	Write a byte to the Microwire device.
`ReadMwire`	Read a byte from the Microwire device.
`WriteMwire`	Write a byte to the Microwire device.

The following routines are provided for devices with multiple Microwire peripherals:

TABLE 2-8: MULTIPLE MICROWIRE PERIPHERAL FUNCTIONS

Function	Description
`CloseMwire`***x***	Disable the SSP***x*** module used for Microwire communication.
`DataRdyMwire`***x***	Indicate completion of the internal write cycle.
`getcMwire`***x***	Read a byte from the Microwire device.
`getsMwire`***x***	Read a string from the Microwire device.
`OpenMwire`***x***	Configure the SSP***x*** module for Microwire use.
`putcMwire`***x***	Write a byte to the Microwire device.
`ReadMwire`***x***	Read a byte from the Microwire device.
`WriteMwire`***x***	Write a byte to the Microwire device.

2.6.1 Function Descriptions

CloseMwire
CloseMwire1
CloseMwire2

Function: Disable the SSP***x*** module.

Include: `mwire.h`

Prototype:

```
void CloseMwire( void );
void CloseMwire1( void );
void CloseMwire2( void );
```

Remarks: Pin I/O returns under control of the `TRISC` and `LATC` register settings.

File Name:

```
mw_close.c
mw1close.c
mw2close.c
```

DataRdyMwire
DataRdyMwire1
DataRdyMwire2

Function: Indicate whether the Microwire***x*** device has completed the internal write cycle.

Include: `mwire.h`

Prototype:

```
unsigned char DataRdyMwire( void );
unsigned char DataRdyMwire1( void );
unsigned char DataRdyMwire2( void );
```

Remarks: Determines if Microwire***x*** device is ready.

Return Value: 1 if the Microwire***x*** device is ready
0 if the internal write cycle is not complete or a bus error occurred

File Name:

```
mw_drdy.c
mw1drdy.c
mw2drdy.c
```

Code Example:

```
while (!DataRdyMwire());
```

getcMwire
getcMwire1
getcMwire2

getcMwire*x* is defined as ReadMwire*x*. *See* **ReadMwire*x***.

getsMwire
getsMwire1
getsMwire2

Function: Read a string from the Microwire***x*** device.

Include: `mwire.h`

Prototype:

```
void getsMwire( unsigned char * rdptr,
                unsigned char length);
void getsMwire1( unsigned char * rdptr,
                unsigned char length);
void getsMwire2( unsigned char * rdptr,
                unsigned char length);
```

Arguments: ***rdptr***
Pointer to PICmicro MCU RAM for placement of data read from Microwire***x*** device.
length
Number of bytes to read from Microwire***x*** device.

Remarks: This function is used to read a predetermined length of data from a Microwire***x*** device. Before using this function, a Read***x*** command with the appropriate address must be issued.

File Name:

```
mw_gets.c
mw1gets.c
mw2gets.c
```

Code Example:

```
unsigned char arryrd[LENGTH];
putcMwire(READ);
putcMwire(address);
getsMwire(arrayrd, LENGTH);
```

OpenMwire
OpenMwire1
OpenMwire2

Function: Configure the SSP***x*** module.

Include: `mwire.h`

Prototype:
```
void OpenMwire(
        unsigned char sync_mode );
```

Arguments: ***`sync_mode`***

One of the following values defined in `mwire.h`:

`MWIRE_FOSC_4`	clock = FOSC/4
`MWIRE_FOSC_16`	clock = FOSC/16
`MWIRE_FOSC_64`	clock = FOSC/64
`MWIRE_FOSC_TMR2`	clock = TMR2 output/2

Remarks: `OpenMwire`***x*** resets the SSP***x*** module to the `POR` state and then configures the module for Microwire communications.

File Name:
```
mw_open.c
mw1open.c
mw2open.c
```

Code Example:
```
OpenMwire(MWIRE_FOSC_16);
```

putcMwire
putcMwire1
putcMwire2

putcMwire*x* is defined as WriteMwire*x*. *See* **WriteMwire*x***.

ReadMwire
ReadMwire1
ReadMwire2
getcMwire
getcMwire1
getcMwire2

Function: Read a byte from a Microwire***x*** device.

Include: `mwire.h`

Prototype:

```
unsigned char ReadMwire(
        unsigned char high_byte,
        unsigned char low_byte );
unsigned char ReadMwire1(
        unsigned char high_byte,
        unsigned char low_byte );
unsigned char ReadMwire2(
        unsigned char high_byte,
        unsigned char low_byte );
unsigned char getcMwire(
        unsigned char high_byte,
        unsigned char low_byte );
unsigned char getcMwire1(
        unsigned char high_byte,
        unsigned char low_byte );
unsigned char getcMwire2(
        unsigned char high_byte,
        unsigned char low_byte );
```

Arguments:

`high_byte`
First byte of 16-bit instruction word.

`low_byte`
Second byte of 16-bit instruction word.

Remarks: This function reads in a single byte from a Microwire***x*** device. The Start bit, opcode and address compose the high and low bytes passed into this function. getcMwire*x* is defined to be ReadMwire*x* in mwire.h.

Return Value: The return value is the data byte read from the Microwire***x*** device.

File Name:

```
mw_read.c
mw1read.c
mw2read.c
#define in mwire.h
#define in mwire.h
#define in mwire.h
```

Code Example:

```
ReadMwire(0x03, 0x00);
```

WriteMwire
WriteMwire1
WriteMwire2
putcMwire
putcMwire1
putcMwire2

Function: This function is used to write out a single data byte (one character).

Include: `mwire.h`

Prototype:

```
unsigned char WriteMwire(
        unsigned char data_out );
unsigned char WriteMwire1(
        unsigned char data_out );
unsigned char WriteMwire2(
        unsigned char data_out );
unsigned char putcMwire(
        unsigned char data_out );
unsigned char putcMwire1(
        unsigned char data_out );
unsigned char putcMwire2(
        unsigned char data_out );
```

Arguments: ***`data_out`***
Single byte of data to write to Microwire***x*** device.

Remarks: This function writes out single data byte to a Microwire***x*** device utilizing the SSP***x*** module. putcMwire*x* is defined to be WriteMwire*x* in mwire.h.

Return Value: 0 if the write was successful
-1 if there was a write collision

File Name:

```
mw_write.c
mw1write.c
mw2write.c
#define in mwire.h
#define in mwire.h
#define in mwire.h
```

Code Example: `WriteMwire(0x55);`

2.6.2 Example of Use

The following is a simple code example illustrating the SSP module communicating with a Microchip 93LC66 Microwire EE memory device.

```
#include "p18cxxx.h"
#include "mwire.h"

// 93LC66 x 8
// FUNCTION Prototypes
void main(void);
void ew_enable(void);
void erase_all(void);
void busy_poll(void);
void write_all(unsigned char data);
void byte_read(unsigned char address);
void read_mult(unsigned char address,
               unsigned char *rdptr,
               unsigned char length);
void write_byte(unsigned char address,
                unsigned char data);

// VARIABLE Definitions
unsigned char arrayrd[20];
unsigned char var;

// DEFINE 93LC66 MACROS -- see datasheet for details
#define  READ   0x0C
#define  WRITE  0x0A
#define  ERASE  0x0E
#define  EWEN1  0x09
#define  EWEN2  0x80
#define  ERAL1  0x09
#define  ERAL2  0x00
#define  WRAL1  0x08
#define  WRAL2  0x80
#define  EWDS1  0x08
#define  EWDS2  0x00
#define  W_CS   LATCbits.LATC2

void main(void)
{
  TRISCbits.TRISC2 = 0;
  W_CS = 0;               //ensure CS is negated
  OpenMwire(MWIRE_FOSC_16);     //enable SSP peripheral
  ew_enable();            //send erase/write enable
  write_byte(0x13, 0x34); //write byte (address, data)
  busy_poll();
  Nop();
  byte_read(0x13);        //read single byte (address)
  read_mult(0x10, arrayrd, 10); //read multiple bytes
  erase_all();                  //erase entire array
  CloseMwire();                 //disable SSP peripheral
}
```

```
void ew_enable(void)
{
   W_CS = 1;         //assert chip select
   putcMwire(EWEN1); //enable write command byte 1
   putcMwire(EWEN2); //enable write command byte 2
   W_CS = 0;         //negate chip select
}
void busy_poll(void)
{
  W_CS = 1;
  while(! DataRdyMwire() );
  W_CS = 0;
}

void write_byte(unsigned char address,
                unsigned char data)
{
  W_CS = 1;
  putcMwire(WRITE);    //write command
  putcMwire(address);  //address
  putcMwire(data);     //write single byte
  W_CS = 0;
}

void byte_read(unsigned char address)
{
  W_CS = 1;
  getcMwire(READ,address);  //read one byte
  W_CS = 0;
}

void read_mult(unsigned char address,
               unsigned char *rdptr,
               unsigned char length)
{
  W_CS = 1;
  putcMwire(READ);          //read command
  putcMwire(address);       //address (A7 - A0)
  getsMwire(rdptr, length); //read multiple bytes
  W_CS = 0;
}

void erase_all(void)
{
  W_CS = 1;
  putcMwire(ERAL1); //erase all command byte 1
  putcMwire(ERAL2); //erase all command byte 2
  W_CS = 0;
}
```

2.7 PULSE-WIDTH MODULATION FUNCTIONS

The PWM peripheral is supported with the following functions:

TABLE 2-9: PWM FUNCTIONS

Function	Description
`ClosePWMx`	Disable PWM channel ***x***.
`OpenPWMx`	Configure PWM channel ***x***.
`SetDCPWMx`	Write a new duty cycle value to PWM channel ***x***.
`SetOutputPWMx`	Sets the PWM output configuration bits for ECCP ***x***.
`CloseEPWMx`(1)	Disable enhanced PWM channel ***x***.
`OpenEPWMx`(1)	Configure enhanced PWM channel ***x***.
`SetDCEPWMx`(1)	Write a new duty cycle value to enhanced PWM channel ***x***.
`SetOutputEPWMx`(1)	Sets the enhanced PWM output configuration bits for ECCP ***x***.

Note 1: The enhanced PWM functions are only available on those devices with an ECCPxCON register.

2.7.1 Function Descriptions

ClosePWM1
ClosePWM2
ClosePWM3
ClosePWM4
ClosePWM5
CloseEPWM1

Function: Disable PWM channel.

Include: `pwm.h`

Prototype:

```
void ClosePWM1( void );
void ClosePWM2( void );
void ClosePWM3( void );
void ClosePWM4( void );
void ClosePWM5( void );
void CloseEPWM1( void );
```

Remarks: This function disables the specified PWM channel.

File Name:

```
pw1close.c
pw2close.c
pw3close.c
pw4close.c
pw5close.c
ew1close.c
```

OpenPWM1
OpenPWM2
OpenPWM3
OpenPWM4
OpenPWM5
OpenEPWM1

Function: Configure PWM channel.

Include: `pwm.h`

Prototype:

```
void OpenPWM1( char period );
void OpenPWM2( char period );
void OpenPWM3( char period );
void OpenPWM4( char period );
void OpenPWM5( char period );
void OpenEPWM1( char period );
```

Arguments: ***period***

Can be any value from 0x00 to 0xff. This value determines the PWM frequency by using the following formula:
PWM period =[(***period***) + 1] x 4 x TOSC x TMR2 prescaler

Remarks: This function configures the specified PWM channel for period and for time base. PWM uses only Timer2.

In addition to opening the PWM, Timer2 must also be opened with an **OpenTimer2(...)** statement before the PWM will operate.

File Name:

```
pw1open.c
pw2open.c
pw3open.c
pw4open.c
pw5open.c
ew1open.c
```

Code Example:

```
OpenPWM1(0xff);
```

SetDCPWM1
SetDCPWM2
SetDCPWM3
SetDCPWM4
SetDCPWM5
SetDCEPWM1

Function: Write a new duty cycle value to the specified PWM channel duty-cycle registers.

Include: `pwm.h`

Prototype:

```
void SetDCPWM1( unsigned int dutycycle );
void SetDCPWM2( unsigned int dutycycle );
void SetDCPWM3( unsigned int dutycycle );
void SetDCPWM4( unsigned int dutycycle );
void SetDCPWM5( unsigned int dutycycle );
void SetDCEPWM1( unsigned int dutycycle );
```

Arguments: ***`dutycycle`***

The value of *dutycycle* can be any 10-bit number. Only the lower 10-bits of *dutycycle* are written into the duty cycle registers. The duty cycle, or more specifically the high time of the PWM waveform, can be calculated from the following formula:

PWM x Duty cycle = (DCx<9:0>) x TOSC

where DCx<9:0> is the 10-bit value specified in the call to this function.

Remarks: This function writes the new value for *dutycycle* to the specified PWM channel duty cycle registers.

The maximum resolution of the PWM waveform can be calculated from the period using the following formula:

Resolution (bits) = log(FOSC/Fpwm) / log(2)

File Name:

```
pw1setdc.c
pw2setdc.c
pw3setdc.c
pw4setdc.c
pw5setdc.c
ew1setdc.c
```

Code Example:

```
SetDCPWM1(0);
```

SetOutputPWM1
SetOutputPWM2
SetOutputPWM3
SetOutputEPWM1

Function: Sets the PWM output configuration bits for ECCP.

Include: `pwm.h`

Prototype:

```
void SetOutputPWM1 (
        unsigned char outputconfig,
        unsigned char outputmode);
void SetOutputPWM2 (
        unsigned char outputconfig,
        unsigned char outputmode);
void SetOutputPWM3 (
        unsigned char outputconfig,
        unsigned char outputmode);
void SetOutputEPWM1 (
        unsigned char outputconfig,
        unsigned char outputmode);
```

Arguments: ***outputconfig***

The value of outputconfig can be any one of the following values (defined in `pwm.h`):

`SINGLE_OUT`	single output
`FULL_OUT_FWD`	full-bridge output forward
`HALF_OUT`	half-bridge output
`FULL_OUT_REV`	full-bridge output reverse

outputmode

The value of outputmode can be any one of the following values (defined in pwm.h):

`PWM_MODE_1`	P1A and P1C active-high, P1B and P1D active-high
`PWM_MODE_2`	P1A and P1C active-high, P1B and P1D active-low
`PWM_MODE_3`	P1A and P1C active-low, P1B and P1D active-high
`PWM_MODE_4`	P1A and P1C active-low, P1B and P1D active-low

Remarks: This is only applicable to those devices with Extended or Enhanced CCP (ECCP).

File Name:

```
pw1setoc.c
pw2setoc.c
pw3setoc.c
ew1setoc.c
```

Code Example:

```
SetOutputPWM1 (SINGLE_OUT, PWM_MODE_1);
```

2.8 SPI™ FUNCTIONS

The following routines are provided for devices with a single SPI peripheral:

TABLE 2-10: SINGLE SPI™ PERIPHERAL FUNCTIONS

Function	Description
`CloseSPI`	Disable the SSP module used for SPI™ communications.
`DataRdySPI`	Determine if a new value is available from the SPI buffer.
`getcSPI`	Read a byte from the SPI bus.
`getsSPI`	Read a string from the SPI bus.
`OpenSPI`	Initialize the SSP module used for SPI communications.
`putcSPI`	Write a byte to the SPI bus.
`putsSPI`	Write a string to the SPI bus.
`ReadSPI`	Read a byte from the SPI bus.
`WriteSPI`	Write a byte to the SPI bus.

The following routines are provided for devices with multiple SPI peripherals:

TABLE 2-11: MULTIPLE SPI™ PERIPHERAL FUNCTIONS

Function	Description
`CloseSPI`***x***	Disable the SSP***x*** module used for SPI™ communications.
`DataRdySPI`***x***	Determine if a new value is available from the SPI***x*** buffer.
`getcSPI`***x***	Read a byte from the SPI***x*** bus.
`getsSPI`***x***	Read a string from the SPI***x*** bus.
`OpenSPI`***x***	Initialize the SSP***x*** module used for SPI communications.
`putcSPI`***x***	Write a byte to the SPI***x*** bus.
`putsSPI`***x***	Write a string to the SPI***x*** bus.
`ReadSPI`***x***	Read a byte from the SPI***x*** bus.
`WriteSPI`***x***	Write a byte to the SPI***x*** bus.

2.8.1 Function Descriptions

CloseSPI
CloseSPI1
CloseSPI2

Function:	Disable the SSP***x*** module.
Include:	`spi.h`

Prototype:	`void CloseSPI( void );`
	`void CloseSPI1( void );`
	`void CloseSPI2( void );`

Remarks:	This function disables the SSP***x*** module. Pin I/O returns under the control of the appropriate `TRIS` and `LAT` registers.

File Name:	`spi_clos.c`
	`spi1clos.c`
	`spi2clos.c`

DataRdySPI
DataRdySPI1
DataRdySPI2

Function:	Determine if the `SSPBUF`***x*** contains data.
Include:	`spi.h`

Prototype:	`unsigned char DataRdySPI( void );`
	`unsigned char DataRdySPI1( void );`
	`unsigned char DataRdySPI2( void );`

Remarks:	This function determines if there is a byte to be read from the `SSPBUF`***x*** register.
Return Value:	0 if there is no data in the `SSPBUF`***x*** register 1 if there is data in the `SSPBUF`***x*** register

File Name:	`spi_dtrd.c`
	`spi1dtrd.c`
	`spi2dtrd.c`

Code Example:	`while (!DataRdySPI());`

getcSPI
getcSPI1
getcSPI2

getcSPI*x* is defined as ReadSPI*x*. *See* **ReadSPI*x*.**

getsSPI
getsSPI1
getsSPI2

Function: Read a string from the SPI***x*** bus.

Include: `spi.h`

Prototype:

```
void getsSPI( unsigned char *rdptr,
              unsigned char length );
void getsSPI1( unsigned char *rdptr,
              unsigned char length );
void getsSPI2( unsigned char *rdptr,
              unsigned char length );
```

Arguments:

rdptr
Pointer to location to store data read from SPI***x*** device.

length
Number of bytes to read from SPI***x*** device.

Remarks: This function reads in a predetermined data string length from the SPI***x*** bus.

File Name:

`spi_gets.c`
`spi1gets.c`
`spi2gets.c`

Code Example:

```
unsigned char wrptr[10];
getsSPI(wrptr, 10);
```

OpenSPI
OpenSPI1
OpenSPI2

Function: Initialize the SSP***x*** module.

Include: `spi.h`

Prototype:

```
void OpenSPI( unsigned char sync_mode,
              unsigned char bus_mode,
              unsigned char smp_phase);
void OpenSPI1( unsigned char sync_mode,
              unsigned char bus_mode,
              unsigned char smp_phase);
void OpenSPI2( unsigned char sync_mode,
              unsigned char bus_mode,
              unsigned char smp_phase);
```

Arguments:

sync_mode
One of the following values, defined in spi.h:

`SPI_FOSC_4`	SPI Master mode, clock = FOSC/4
`SPI_FOSC_16`	SPI Master mode, clock = FOSC/16
`SPI_FOSC_64`	SPI Master mode, clock = FOSC/64
`SPI_FOSC_TMR2`	SPI Master mode, clock = TMR2 output/2
`SLV_SSON`	SPI Slave mode, /SS pin control enabled
`SLV_SSOFF`	SPI Slave mode, /SS pin control disabled

bus_mode
One of the following values, defined in `spi.h`:

`MODE_00`	Setting for SPI bus Mode 0,0
`MODE_01`	Setting for SPI bus Mode 0,1
`MODE_10`	Setting for SPI bus Mode 1,0
`MODE_11`	Setting for SPI bus Mode 1,1

OpenSPI
OpenSPI1
OpenSPI2 (Continued)

	smp_phase One of the following values, defined in `spi.h`: `SMPEND` Input data sample at end of data out `SMPMID` Input data sample at middle of data out
Remarks:	This function sets up the SSP***x*** module for use with a SPI***x*** bus device.

File Name:	`spi_open.c`
	`spi1open.c`
	`spi2open.c`

Code Example:	`OpenSPI(SPI_FOSC_16, MODE_00, SMPEND);`

putcSPI
putcSPI1
putcSPI2

putcSPI*x* is defined as WriteSPI*x*. *See* **WriteSPI*x***.

putsSPI
putsSPI1
putsSPI2

Function:	Write a string to the SPI***x*** bus.
Include:	`spi.h`

Prototype:	`void putsSPI( unsigned char *`*`wrptr`*` );`
	`void putsSPI1( unsigned char *`*`wrptr`*` );`
	`void putsSPI2( unsigned char *`*`wrptr`*` );`

Arguments:	***wrptr*** Pointer to value that will be written to the SPI***x*** bus.
Remarks:	This function writes out a data string to the SPI***x*** bus device. The routine is terminated by reading a null character in the data string (the null character is not written to the bus).

File Name:	`spi_puts.c`
	`spi1puts.c`
	`spi2puts.c`

Code Example:	`unsigned char wrptr[] = “Hello!”;`
	`putsSPI(wrptr);`

ReadSPI
ReadSPI1
ReadSPI2
getcSPI
getcSPI1
getcSPI2

Function: Read a byte from the SPI***x*** bus.

Include: `spi.h`

Prototype:

```
unsigned char ReadSPI( void );
unsigned char ReadSPI1( void );
unsigned char ReadSPI2( void );
unsigned char getcSPI( void );
unsigned char getcSPI1( void );
unsigned char getcSPI2( void );
```

Remarks: This function initiates a SPI***x*** bus cycle for the acquisition of a byte of data. getcSPI*x* is defined to be ReadSPI*x* in spi.h.

Return Value: This function returns a byte of data read during a SPI***x*** read cycle.

File Name:

```
spi_read.c
spi1read.c
spi2read.c
#define in spi.h
#define in spi.h
#define in spi.h
```

Code Example:

```
char x;
x = ReadSPI();
```

WriteSPI
WriteSPI1
WriteSPI2
putcSPI
putcSPI1
putcSPI2

Function: Write a byte to the SPI***x*** bus.

Include: `spi.h`

Prototype:

```
unsigned char WriteSPI(
             unsigned char data_out );
unsigned char WriteSPI1(
             unsigned char data_out );
unsigned char WriteSPI2(
             unsigned char data_out );
unsigned char putcSPI(
             unsigned char data_out );
unsigned char putcSPI1(
             unsigned char data_out );
unsigned char putcSPI2(
             unsigned char data_out );
```

Arguments: ***`data_out`***
Value to be written to the SPI***x*** bus.

Remarks: This function writes a single data byte out and then checks for a write collision. putcSPI*x* is defined to be WriteSPI*x* in spi.h.

Return Value: 0 if no write collision occurred
-1 if a write collision occurred

File Name:

```
spi_writ.c
spi1writ.c
spi2writ.c
#define in spi.h
#define in spi.h
#define in spi.h
```

Code Example: `WriteSPI(‘a’);`

2.8.2 Example of Use

The following example demonstrates the use of an SSP module to communicate with a Microchip 25C080 SPI EE memory device.

```
#include <p18cxxx.h>
#include <spi.h>

// FUNCTION Prototypes
void main(void);
void set_wren(void);
void busy_polling(void);
unsigned char status_read(void);
void status_write(unsigned char data);
void byte_write(unsigned char addhigh,
                unsigned char addlow,
                unsigned char data);
void page_write(unsigned char addhigh,
                unsigned char addlow,
                unsigned char *wrptr);
void array_read(unsigned char addhigh,
                unsigned char addlow,
                unsigned char *rdptr,
                unsigned char count);
unsigned char byte_read(unsigned char addhigh,
                        unsigned char addlow);

// VARIABLE Definitions
unsigned char arraywr[] = {1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,0};

//25C040/080/160 page write size
unsigned char arrayrd[16];
unsigned char var;

#define SPI_CS  LATCbits.LATC2

//**************************************************
void main(void)
{
  TRISCbits.TRISC2 = 0;
  SPI_CS = 1;  // ensure SPI memory device
               // Chip Select is reset
  OpenSPI(SPI_FOSC_16, MODE_00, SMPEND);
  set_wren();
  status_write(0);

  busy_polling();
  set_wren();
  byte_write(0x00, 0x61, 'E');

  busy_polling();
  var = byte_read(0x00, 0x61);

  set_wren();
  page_write(0x00, 0x30, arraywr);
  busy_polling();

  array_read(0x00, 0x30, arrayrd, 16);
  var = status_read();
  CloseSPI();
  while(1);
}

void set_wren(void)
{
  SPI_CS = 0;               //assert chip select
  var = putcSPI(SPI_WREN);  //send write enable command
  SPI_CS = 1;               //negate chip select
}

void page_write (unsigned char addhigh,
                 unsigned char addlow,
                 unsigned char *wrptr)
{
  SPI_CS = 0;                 //assert chip select
  var = putcSPI(SPI_WRITE);   //send write command
  var = putcSPI(addhigh);     //send high byte of address
  var = putcSPI(addlow);      //send low byte of address
  putsSPI(wrptr);             //send data byte
  SPI_CS = 1;                 //negate chip select
}

void array_read (unsigned char addhigh,
                 unsigned char addlow,
                 unsigned char *rdptr,
                 unsigned char count)
{
  SPI_CS = 0;              //assert chip select
  var = putcSPI(SPI_READ); //send read command
  var = putcSPI(addhigh);  //send high byte of address
  var = putcSPI(addlow);   //send low byte of address
  getsSPI(rdptr, count);   //read multiple bytes
  SPI_CS = 1;
}

void byte_write (unsigned char addhigh,
                 unsigned char addlow,
                 unsigned char data)
{
  SPI_CS = 0;               //assert chip select
  var = putcSPI(SPI_WRITE); //send write command
  var = putcSPI(addhigh);   //send high byte of address
  var = putcSPI(addlow);    //send low byte of address
  var = putcSPI(data);      //send data byte
  SPI_CS = 1;               //negate chip select
}

unsigned char byte_read (unsigned char addhigh,
                         unsigned char addlow)
{
  SPI_CS = 0;               //assert chip select
  var = putcSPI(SPI_READ);  //send read command
  var = putcSPI(addhigh);   //send high byte of address
  var = putcSPI(addlow);    //send low byte of address
  var = getcSPI();          //read single byte
  SPI_CS = 1;
  return (var);
}
```

```
unsigned char status_read (void)
{
  SPI_CS = 0;              //assert chip select
  var = putcSPI(SPI_RDSR); //send read status command
  var = getcSPI();         //read data byte
  SPI_CS = 1;              //negate chip select
  return (var);
}

void status_write (unsigned char data)
{
  SPI_CS = 0;
  var = putcSPI(SPI_WRSR); //write status command
  var = putcSPI(data);     //status byte to write
  SPI_CS = 1;              //negate chip select
}

void busy_polling (void)
{
  do
  {
    SPI_CS = 0;              //assert chip select
    var = putcSPI(SPI_RDSR); //send read status command
    var = getcSPI();         //read data byte
    SPI_CS = 1;              //negate chip select
  } while (var & 0x01);      //stay in loop until !busy
}
```

2.9 TIMER FUNCTIONS

The timer peripherals are supported with the following functions:

TABLE 2-12: TIMER FUNCTIONS

Function	Description
`CloseTimerx`	Disable timer ***x***.
`OpenTimerx`	Configure and enable timer ***x***.
`ReadTimerx`	Read the value of timer ***x***.
`WriteTimerx`	Write a value into timer ***x***.

2.9.1 Function Descriptions

CloseTimer0
CloseTimer1
CloseTimer2
CloseTimer3
CloseTimer4

Function: Disable the specified timer.

Include: `timers.h`

Prototype:

```
void CloseTimer0( void );
void CloseTimer1( void );
void CloseTimer2( void );
void CloseTimer3( void );
void CloseTimer4( void );
```

Remarks: This function disables the interrupt and the specified timer.

File Name:

```
t0close.c
t1close.c
t2close.c
t3close.c
t4close.c
```

OpenTimer0

Function: Configure and enable timer0.

Include: `timers.h`

Prototype: `void OpenTimer0( unsigned char config );`

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `timers.h`.

Enable Timer0 Interrupt:

`TIMER_INT_ON`	Interrupt enabled
`TIMER_INT_OFF`	Interrupt disabled

Timer Width:

`T0_8BIT`	8-bit mode
`T0_16BIT`	16-bit mode

Clock Source:

`T0_SOURCE_EXT`	External clock source (I/O pin)
`T0_SOURCE_INT`	Internal clock source (TOSC)

External Clock Trigger (for `T0_SOURCE_EXT`):

`T0_EDGE_FALL`	External clock on falling edge
`T0_EDGE_RISE`	External clock on rising edge

Prescale Value:

`T0_PS_1_1`	1:1 prescale
`T0_PS_1_2`	1:2 prescale
`T0_PS_1_4`	1:4 prescale
`T0_PS_1_8`	1:8 prescale
`T0_PS_1_16`	1:16 prescale
`T0_PS_1_32`	1:32 prescale
`T0_PS_1_64`	1:64 prescale
`T0_PS_1_128`	1:128 prescale
`T0_PS_1_256`	1:256 prescale

Remarks: This function configures timer0 according to the options specified and then enables it.

File Name: `t0open.c`

Code Example:

```
OpenTimer0( TIMER_INT_OFF &
            T0_8BIT &
            T0_SOURCE_INT &
            T0_PS_1_32 );
```

OpenTimer1

Function: Configure and enable timer1.

Include: `timers.h`

Prototype: `void OpenTimer1( unsigned char` ***`config`*** `);`

Arguments: ***`config`***

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `timers.h`.

Enable Timer1 Interrupt:

`TIMER_INT_ON`	Interrupt enabled
`TIMER_INT_OFF`	Interrupt disabled

Timer Width:

`T1_8BIT_RW`	8-bit mode
`T1_16BIT_RW`	16-bit mode

Clock Source:

`T1_SOURCE_EXT`	External clock source (I/O pin)
`T1_SOURCE_INT`	Internal clock source (TOSC)

Prescaler:

`T1_PS_1_1`	1:1 prescale
`T1_PS_1_2`	1:2 prescale
`T1_PS_1_4`	1:4 prescale
`T1_PS_1_8`	1:8 prescale

Oscillator Use:

`T1_OSC1EN_ON`	Enable Timer1 oscillator
`T1_OSC1EN_OFF`	Disable Timer1 oscillator

Synchronize Clock Input:

`T1_SYNC_EXT_ON`	Sync external clock input
`T1_SYNC_EXT_OFF`	Don’t sync external clock input

Use With CCP:

For devices with 1 or 2 CCPs

`T3_SOURCE_CCP`	Timer3 source for both CCP’s
`T1_CCP1_T3_CCP2`	Timer1 source for CCP1 and Timer3 source for CCP2
`T1_SOURCE_CCP`	Timer1 source for both CCP’s

For devices with more than 2 CCPs

`T34_SOURCE_CCP`	Timer3 and Timer4 are sources for all CCP’s
`T12_CCP12_T34_CCP345`	Timer1 and Timer2 are sources for CCP1 and CCP2 and Timer3 and Timer4 are sources for CCP3 through CCP5
`T12_CCP1_T34_CCP2345`	Timer1 and Timer2 are sources for CCP1 and Timer3 and Timer4 are sources for CCP2 through CCP5
`T12_SOURCE_CCP`	Timer1 and Timer2 are sources for all CCP’s

Remarks: This function configures timer1 according to the options specified and then enables it.

File Name: `t1open.c`

Code Example:

```
OpenTimer1( TIMER_INT_ON    &
            T1_8BIT_RW      &
            T1_SOURCE_EXT   &
            T1_PS_1_1       &
            T1_OSC1EN_OFF   &
            T1_SYNC_EXT_OFF );
```

OpenTimer2

Function: Configure and enable timer2.

Include: `timers.h`

Prototype: `void OpenTimer2( unsigned char config );`

Arguments: ***config***

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `timers.h`.

Enable Timer2 Interrupt:

`TIMER_INT_ON`	Interrupt enabled
`TIMER_INT_OFF`	Interrupt disabled

Prescale Value:

`T2_PS_1_1`	1:1 prescale
`T2_PS_1_4`	1:4 prescale
`T2_PS_1_16`	1:16 prescale

Postscale Value:

`T2_POST_1_1`	1:1 postscale
`T2_POST_1_2`	1:2 postscale
:	:
`T2_POST_1_15`	1:15 postscale
`T2_POST_1_16`	1:16 postscale

Use With CCP:

For devices with 1 or 2 CCPs

`T3_SOURCE_CCP`	Timer3 source for both CCP’s
`T1_CCP1_T3_CCP2`	Timer1 source for CCP1 and Timer3 source for CCP2
`T1_SOURCE_CCP`	Timer1 source for both CCP’s

For devices with more than 2 CCPs

`T34_SOURCE_CCP`	Timer3 and Timer4 are sources for all CCP’s
`T12_CCP12_T34_CCP345`	Timer1 and Timer2 are sources for CCP1 and CCP2 and Timer3 and Timer4 are sources for CCP3 through CCP5
`T12_CCP1_T34_CCP2345`	Timer1 and Timer2 are sources for CCP1 and Timer3 and Timer4 are sources for CCP2 through CCP5
`T12_SOURCE_CCP`	Timer1 and Timer2 are sources for all CCP’s

Remarks: This function configures timer2 according to the options specified and then enables it.

File Name: `t2open.c`

Code Example:

```
OpenTimer2( TIMER_INT_OFF &
            T2_PS_1_1     &
            T2_POST_1_8   );
```

OpenTimer3

Function: Configure and enable timer3.

Include: `timers.h`

Prototype: `void OpenTimer3( unsigned char` ***`config`*** `);`

Arguments: ***`config`***

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `timers.h`.

Enable Timer3 Interrupt:

`TIMER_INT_ON`	Interrupt enabled
`TIMER_INT_OFF`	Interrupt disabled

Timer Width:

`T3_8BIT_RW`	8-bit mode
`T3_16BIT_RW`	16-bit mode

Clock Source:

`T3_SOURCE_EXT`	External clock source (I/O pin)
`T3_SOURCE_INT`	Internal clock source (TOSC)

Prescale Value:

`T3_PS_1_1`	1:1 prescale
`T3_PS_1_2`	1:2 prescale
`T3_PS_1_4`	1:4 prescale
`T3_PS_1_8`	1:8 prescale

Synchronize Clock Input:

`T3_SYNC_EXT_ON`	Sync external clock input
`T3_SYNC_EXT_OFF`	Don’t sync external clock input

Use With CCP:

<u>For devices with 1 or 2 CCPs</u>

`T3_SOURCE_CCP`	Timer3 source for both CCP’s
`T1_CCP1_T3_CCP2`	Timer1 source for CCP1 and Timer3 source for CCP2
`T1_SOURCE_CCP`	Timer1 source for both CCP’s

<u>For devices with more than 2 CCPs</u>

`T34_SOURCE_CCP`	Timer3 and Timer4 are sources for all CCP’s
`T12_CCP12_T34_CCP345`	Timer1 and Timer2 are sources for CCP1 and CCP2 and Timer3 and Timer4 are sources for CCP3 through CCP5
`T12_CCP1_T34_CCP2345`	Timer1 and Timer2 are sources for CCP1 and Timer3 and Timer4 are sources for CCP2 through CCP5
`T12_SOURCE_CCP`	Timer1 and Timer2 are sources for all CCP’s

Remarks: This function configures timer3 according to the options specified and then enables it.

File Name: `t3open.c`

Code Example:

```
OpenTimer3( TIMER_INT_ON    &
            T3_8BIT_RW      &
            T3_SOURCE_EXT   &
            T3_PS_1_1       &
            T3_OSC1EN_OFF   &
            T3_SYNC_EXT_OFF );
```

OpenTimer4

Function: Configure and enable timer4.

Include: `timers.h`

Prototype: `void OpenTimer4( unsigned char` ***`config`*** `);`

Arguments: ***`config`***

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `timers.h`.

Enable Timer4 Interrupt:

`TIMER_INT_ON`	Interrupt enabled
`TIMER_INT_OFF`	Interrupt disabled

Prescale Value:

`T4_PS_1_1`	1:1 prescale
`T4_PS_1_4`	1:4 prescale
`T4_PS_1_16`	1:16 prescale

Postscale Value:

`T4_POST_1_1`	1:1 postscale
`T4_POST_1_2`	1:2 postscale
:	:
`T4_POST_1_15`	1:15 postscale
`T4_POST_1_16`	1:16 postscale

Remarks: This function configures timer4 according to the options specified and then enables it.

File Name: `t4open.c`

Code Example:

```
OpenTimer4( TIMER_INT_OFF &
            T4_PS_1_1     &
            T4_POST_1_8   );
```

ReadTimer0
ReadTimer1
ReadTimer2
ReadTimer3
ReadTimer4

Function: Read the value of the specified timer.

Include: `timers.h`

Prototype:

```
unsigned int  ReadTimer0( void );
unsigned int  ReadTimer1( void );
unsigned char ReadTimer2( void );
unsigned int  ReadTimer3( void );
unsigned char ReadTimer4( void );
```

Remarks: These functions read the value of the respective timer register(s).

Timer0:	`TMR0L,TMR0H`
Timer1:	`TMR1L,TMR1H`
Timer2:	`TMR2`
Timer3:	`TMR3L,TMR3H`
Timer4:	`TMR4`

Note: When using a timer in 8-bit mode that may be configured in 16-bit mode (e.g., timer0), the upper byte is not ensured to be zero. The user may wish to cast the result to a char for correct results. For example:

```
  // Example of reading a 16-bit result
  // from a 16-bit timer operating in
  // 8-bit mode:
  unsigned int result;
  result = (unsigned char) ReadTimer0();
```

Return Value: The current value of the timer.

File Name:

```
t0read.c
t1read.c
t2read.c
t3read.c
t4read.c
```

WriteTimer0
WriteTimer1
WriteTimer2
WriteTimer3
WriteTimer4

Function: Write a value into the specified timer.

Include: `timers.h`

Prototype:

```
void WriteTimer0( unsigned int  timer );
void WriteTimer1( unsigned int  timer );
void WriteTimer2( unsigned char timer );
void WriteTimer3( unsigned int  timer );
void WriteTimer4( unsigned char timer );
```

Arguments: ***timer***

The value that will be loaded into the specified timer.

Remarks: These functions write a value to the respective timer register(s):

Timer0:	`TMR0L,TMR0H`
Timer1:	`TMR1L,TMR1H`
Timer2:	`TMR2`
Timer3:	`TMR3L,TMR3H`
Timer4:	`TMR4`

File Name:

```
t0write.c
t1write.c
t2write.c
t3write.c
t4write.c
```

Code Example:

```
WriteTimer0( 10000 );
```

2.9.2 Example of Use

```
#include <p18C452.h>
#include <timers.h>
#include <usart.h>
#include <stdlib.h>

void main( void )
{
  int result;
  char str[7];

  // configure timer0
  OpenTimer0( TIMER_INT_OFF &
              T0_SOURCE_INT  &
              T0_PS_1_32 );

  // configure USART
  OpenUSART( USART_TX_INT_OFF  &
             USART_RX_INT_OFF  &
             USART_ASYNCH_MODE &
             USART_EIGHT_BIT   &
             USART_CONT_RX,
             25                 );

  while( 1 )
  {
    while( ! PORTBbits.RB3 ); // wait for RB3 high
    result = ReadTimer0();    // read timer

    if( result > 0xc000 )     // exit loop if value
      break;                  //   is out of range

    WriteTimer0( 0 );         // restart timer

    ultoa( result, str );     // convert timer to string
    putsUSART( str );         // print string
  }

  CloseTimer0();              // close modules
  CloseUSART();
}
```

2.10 USART FUNCTIONS

The following routines are provided for devices with a single USART peripheral:

TABLE 2-13: SINGLE USART PERIPHERAL FUNCTIONS

Function	Description
`BusyUSART`	Is the USART transmitting?
`CloseUSART`	Disable the USART.
`DataRdyUSART`	Is data available in the USART read buffer?
`getcUSART`	Read a byte from the USART.
`getsUSART`	Read a string from the USART.
`OpenUSART`	Configure the USART.
`putcUSART`	Write a byte to the USART.
`putsUSART`	Write a string from data memory to the USART.
`putrsUSART`	Write a string from program memory to the USART.
`ReadUSART`	Read a byte from the USART.
`WriteUSART`	Write a byte to the USART.
`baudUSART`	Set the baud rate configuration bits for enhanced USART.

The following routines are provided for devices with multiple USART peripherals:

TABLE 2-14: MULTIPLE USART PERIPHERAL FUNCTIONS

Function	Description
Busy***x***USART	Is USART ***x*** transmitting?
Close***x***USART	Disable USART ***x***.
DataRdy***x***USART	Is data available in the read buffer of USART ***x***?
getc***x***USART	Read a byte from USART ***x***.
gets***x***USART	Read a string from USART ***x***.
Open***x***USART	Configure USART ***x***.
putc***x***USART	Write a byte to USART ***x***.
puts***x***USART	Write a string from data memory to USART ***x***.
putrs***x***USART	Write a string from program memory to USART ***x***.
Read***x***USART	Read a byte from USART ***x***.
Write***x***USART	Write a byte to USART ***x***.
baud***x***USART	Set the baud rate configuration bits for enhanced USART ***x***.

2.10.1 Function Descriptions

BusyUSART
Busy1USART
Busy2USART

Function:	Is the USART transmitting?
Include:	`usart.h`

Prototype:	`char BusyUSART(  void );`
	`char Busy1USART( void );`
	`char Busy2USART( void );`

Remarks:	Returns a value indicating if the USART transmitter is currently busy. This function should be used prior to commencing a new transmission. `BusyUSART` should be used on parts with a single USART peripheral. `Busy1USART` and `Busy2USART` should be used on parts with multiple USART peripherals.
Return Value:	0 if the USART transmitter is idle 1 if the USART transmitter is in use

File Name:	`ubusy.c`
	`u1busy.c`
	`u2busy.c`

Code Example:	`while (BusyUSART());`

CloseUSART
Close1USART
Close2USART

Function:	Disable the specified USART.
Include:	`usart.h`

Prototype:	`void CloseUSART(  void );`
	`void Close1USART( void );`
	`void Close2USART( void );`

Remarks:	This function disables the interrupts, transmitter and receiver for the specified USART. `CloseUSART` should be used on parts with a single USART peripheral. `Close1USART` and `Close2USART` should be used on parts with multiple USART peripherals.

File Name:	`uclose.c`
	`u1close.c`
	`u2close.c`

DataRdyUSART
DataRdy1USART
DataRdy2USART

Function: Is data available in the read buffer?

Include: `usart.h`

Prototype:

```
char DataRdyUSART(  void );
char DataRdy1USART( void );
char DataRdy2USART( void );
```

Remarks: This function returns the status of the `RCIF` flag bit in the `PIR` register. `DataRdyUSART` should be used on parts with a single USART peripheral. `DataRdy1USART` and `DataRdy2USART` should be used on parts with multiple USART peripherals.

Return Value: 1 if data is available
0 if data is not available

File Name:

```
udrdy.c
u1drdy.c
u2drdy.c
```

Code Example:

```
while (!DataRdyUSART());
```

getcUSART
getc1USART
getc2USART

getc*x*USART is defined as Read*x*USART. *See* **ReadUSART**

getsUSART
gets1USART
gets2USART

Function: Read a fixed-length string of characters from the specified USART.

Include: `usart.h`

Prototype:

```
void getsUSART ( char * buffer,
                 unsigned char len );
void gets1USART ( char * buffer,
                  unsigned char len );
void gets2USART ( char * buffer,
                  unsigned char len );
```

Arguments: ***buffer***
A pointer to the location where incoming characters are to be stored.
len
The number of characters to read from the USART.

Remarks: This function only works in 8-bit transmit/receive mode. This function waits for and reads *len* number of characters out of the specified USART. There is no time out when waiting for characters to arrive. `getsUSART` should be used on parts with a single USART peripheral. `gets1USART` and `gets2USART` should be used on parts with multiple USART peripherals.

File Name:

```
ugets.c
u1gets.c
u2gets.c
```

Code Example:

```
char inputstr[10];
getsUSART( inputstr, 5 );
```

OpenUSART
Open1USART
Open2USART

Function: Configure the specified USART module.

Include: `usart.h`

Prototype:

```
void OpenUSART( unsigned char config,
                unsigned int spbrg);
void Open1USART( unsigned char config,
                 unsigned int spbrg);
void Open2USART( unsigned char config,
                 unsigned int spbrg);
```

Arguments:

`config`

A bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `usart.h`.

Interrupt on Transmission:

`USART_TX_INT_ON`	Transmit interrupt ON
`USART_TX_INT_OFF`	Transmit interrupt OFF

Interrupt on Receipt:

`USART_RX_INT_ON`	Receive interrupt ON
`USART_RX_INT_OFF`	Receive interrupt OFF

USART Mode:

`USART_ASYNCH_MODE`	Asynchronous Mode
`USART_SYNCH_MODE`	Synchronous Mode

Transmission Width:

`USART_EIGHT_BIT`	8-bit transmit/receive
`USART_NINE_BIT`	9-bit transmit/receive

Slave/Master Select*:

`USART_SYNC_SLAVE`	Synchronous Slave mode
`USART_SYNC_MASTER`	Synchronous Master mode

Reception mode:

`USART_SINGLE_RX`	Single reception
`USART_CONT_RX`	Continuous reception

Baud rate:

`USART_BRGH_HIGH`	High baud rate
`USART_BRGH_LOW`	Low baud rate

* Applies to Synchronous mode only

`spbrg`

This is the value that is written to the baud rate generator register which determines the baud rate at which the USART operates. The formulas for baud rate are:

Asynchronous mode, high speed:

FOSC / (16 * (***spbrg*** + 1))

Asynchronous mode, low speed:

FOSC / (64 * (***spbrg*** + 1))

Synchronous mode:

FOSC / (4 * (***spbrg*** + 1))

Where FOSC is the oscillator frequency.

Remarks: This function configures the USART module according to the specified configuration options.

`OpenUSART` should be used on parts with a single USART peripheral. `Open1USART` and `Open2USART` should be used on parts with multiple USART peripherals.

File Name:

```
uopen.c
u1open.c
u2open.c
```

OpenUSART
Open1USART
Open2USART (Continued)

Code Example:

```
OpenUSART1( USART_TX_INT_OFF  &
            USART_RX_INT_OFF  &
            USART_ASYNCH_MODE &
            USART_EIGHT_BIT   &
            USART_CONT_RX     &
            USART_BRGH_HIGH,
            25                );
```

putcUSART
putc1USART
putc2USART

putc*x*USART is defined as Write*x*USART. *See* **WriteUSART**

putsUSART
puts1USART
puts2USART
putrsUSART
putrs1USART
putrs2USART

Function: Writes a string of characters to the USART including the null character.

Include: `usart.h`

Prototype:

```
void putsUSART(  char *data );
void puts1USART( char *data );
void puts2USART( char *data );
void putrsUSART(  const rom char *data );
void putrs1USART( const rom char *data );
void putrs2USART( const rom char *data );
```

Arguments: ***data***

Pointer to a null-terminated string of data.

Remarks: This function only works in 8-bit transmit/receive mode. This function writes a string of data to the USART including the null character.

Strings located in data memory should be used with the “puts” versions of these functions.

Strings located in program memory, including string literals, should be used with the “putrs” versions of these functions.

`putsUSART` and `putrsUSART` should be used on parts with a single USART peripheral. The other functions should be used on parts with multiple USART peripherals.

File Name:

```
uputs.c
u1puts.c
u2puts.c
uputrs.c
u1putrs.c
u2putrs.c
```

Code Example:

```
putrsUSART( “Hello World!” );
```

ReadUSART
Read1USART
Read2USART
getcUSART
getc1USART
getc2USART

Function: Read a byte (one character) out of the USART receive buffer, including the 9th bit if enabled.

Include: usart.h

Prototype:

```
char ReadUSART(  void );
char Read1USART( void );
char Read2USART( void );
char getcUSART(  void );
char getc1USART( void );
char getc2USART( void );
```

Remarks: This function reads a byte out of the USART receive buffer. The Status bits and the 9th data bits are saved in a union with the following declaration:

```
  union USART
  {
    unsigned char val;
    struct
    {
      unsigned RX_NINE:1;
      unsigned TX_NINE:1;
      unsigned FRAME_ERROR:1;
      unsigned OVERRUN_ERROR:1;
      unsigned fill:4;
    };
  };
```

The 9th bit is read-only if 9-bit mode is enabled. The Status bits are always read.

On a part with a single USART peripheral, the getcUSART and ReadUSART functions should be used and the status information is read into a variable named USART_Status which is of the type USART described above.

On a part with multiple USART peripherals, the getc*x*USART and Read*x*USART functions should be used and the status information is read into a variable named USART*x*_Status which is of the type USART described above.

Return Value: This function returns the next character in the USART receive buffer.

File Name:

```
uread.c
u1read.c
u2read.c
#define in usart.h
#define in usart.h
#define in usart.h
```

Code Example:

```
int result;
result = ReadUSART();
result |= (unsigned int)
          USART_Status.RX_NINE << 8;
```

WriteUSART
Write1USART
Write2USART
putcUSART
putc1USART
putc2USART

Function: Write a byte (one character) to the USART transmit buffer, including the 9th bit if enabled.

Include: `usart.h`

Prototype:

```
void WriteUSART(  char data );
void Write1USART( char data );
void Write2USART( char data );
void putcUSART(  char data );
void putc1USART( char data );
void putc2USART( char data );
```

Arguments: ***data***

The value to be written to the USART.

Remarks: This function writes a byte to the USART transmit buffer. If 9-bit mode is enabled, the 9th bit is written from the field `TX_NINE`, found in a variable of type `USART`:

```
union USART
{
  unsigned char val;
  struct
  {
    unsigned RX_NINE:1;
    unsigned TX_NINE:1;
    unsigned FRAME_ERROR:1;
    unsigned OVERRUN_ERROR:1;
    unsigned fill:4;
  };
};
```

On a part with a single USART peripheral, the `putcUSART` and `WriteUSART` functions should be used and the Status register is named `USART_Status` which is of the type `USART` described above. On a part with multiple USART peripherals, the `putc`*`x`*`USART` and `Write`*`x`*`USART` functions should be used and the status register is named `USART`*`x`*`_Status` which is of the type `USART` described above.

File Name:

```
uwrite.c
u1write.c
u2write.c
#define in usart.h
#define in usart.h
#define in usart.h
```

Code Example:

```
unsigned int outval;
USART1_Status.TX_NINE = (outval & 0x0100)
                        >> 8;
Write1USART( (char) outval );
```

baudUSART baud1USART baud2USART

Function: Set the baud rate configuration bits for enhanced USART operation.

Include: `usart.h`

Prototype:

```
void baudUSART(  unsigned char baudconfig );
void baud1USART( unsigned char baudconfig  );
void baud2USART( unsigned char baudconfig  );
```

Arguments: ***`baudconfig`***

A bitmask that is created by performing a bitwise AND (‘&’) operation with a value from each of the categories listed below. These values are defined in the file `usart.h`:

Clock Idle State:

`BAUD_IDLE_CLK_HIGH`	Clock idle state is a high level
`BAUD_IDLE_CLK_LOW`	Clock idle state is a low level

Baud Rate Generation:

`BAUD_16_BIT_RATE`	16-bit baud generation rate
`BAUD_8_BIT_RATE`	8-bit baud generation rate

RX Pin Monitoring:

`BAUD_WAKEUP_ON`	RX pin monitored
`BAUD_WAKEUP_OFF`	RX pin not monitored

Baud Rate Measurement:

`BAUD_AUTO_ON`	Auto baud rate measurement enabled
`BAUD_AUTO_OFF`	Auto baud rate measurement disabled

Remarks: These functions are only available for processors with enhanced USART capability.

File Name:

```
ubaud.c
u1baud.c
u2baud.c
```

Code Example:

```
baudUSART (BAUD_IDLE_CLK_HIGH &
           BAUD_16_BIT_RATE &
           BAUD_WAKEUP_ON &
           BAUD_AUTO_ON);
```

2.10.2 Example of Use

```
#include <p18C452.h>
#include <usart.h>

void main(void)
{
  // configure USART
  OpenUSART( USART_TX_INT_OFF  &
             USART_RX_INT_OFF  &
             USART_ASYNCH_MODE &
             USART_EIGHT_BIT   &
             USART_CONT_RX     &
             USART_BRGH_HIGH,
             25 );

  while(1)
  {
    while( ! PORTAbits.RA0 );  //wait for RA0 high

    WriteUSART( PORTD );       //write value of PORTD

    if(PORTD == 0x80)          // check for termination
      break;                   //   value
  }

  CloseUSART();
}
```

Chapter 3. Software Peripheral Library

3.1 INTRODUCTION

This chapter documents software peripheral library functions. The source code for all of these functions is included with MPLAB C18 in the `src\traditional\pmc` and `src\extended\pmc` subdirectories of the compiler installation.

See the *MPASM™ Assembler, MPLINK™ Object Linker, MPLIB*™ Object Librarian User's Guide (DS33014) for more information about building libraries.

The following peripherals are supported by MPLAB C18 library routines

- External LCD Functions (**Section 3.2 "External LCD Functions"**)
- External CAN2510 Functions (**Section 3.3 "External CAN2510 Functions"**)
- Software I^{2}C™ Functions (**Section 3.4 "Software I^{2}C Functions"**)
- Software SPI™ Functions (**Section 3.5 "Software SPI™ Functions"**)
- Software UART Functions (**Section 3.6 "Software UART Functions"**)

3.2 EXTERNAL LCD FUNCTIONS

These functions are designed to allow the control of a Hitachi HD44780 LCD controller using I/O pins from a PIC18 microcontroller. The following functions are provided:

TABLE 3-1: EXTERNAL LCD FUNCTIONS

Function	Description
`BusyXLCD`	Is the LCD controller busy?
`OpenXLCD`	Configure the I/O lines used for controlling the LCD and initialize the LCD.
`putcXLCD`	Write a byte to the LCD controller.
`putsXLCD`	Write a string from data memory to the LCD.
`putrsXLCD`	Write a string from program memory to the LCD.
`ReadAddrXLCD`	Read the address byte from the LCD controller.
`ReadDataXLCD`	Read a byte from the LCD controller.
`SetCGRamAddr`	Set the character generator address.
`SetDDRamAddr`	Set the display data address.
`WriteCmdXLCD`	Write a command to the LCD controller.
`WriteDataXLCD`	Write a byte to the LCD controller.

The precompiled versions of these functions use default pin assignments that can be changed by redefining the following macro assignments in the file `xlcd.h`, found in the `h` subdirectory of the compiler installation:

TABLE 3-2: MACROS FOR SELECTING LCD PIN ASSIGNMENTS

LCD Controller Line	Macros	Default Value	Use
E Pin	`E_PIN`	`PORTBbits.RB4`	Pin used for the E line.
	`TRIS_E`	`DDRBbits.RB4`	Bit that controls the direction of the pin associated with the E line.
RS Pin	`RS_PIN`	`PORTBbits.RB5`	Pin used for the RS line.
	`TRIS_RS`	`DDRBbits.RB5`	Bit that controls the direction of the pin associated with the RS line.
RW Pin	`RW_PIN`	`PORTBbits.RB6`	Pin used for the RW line.
	`TRIS_RW`	`DDRBbits.RB6`	Bit that controls the direction of the pin associated with the RW line.
Data Lines	`DATA_PORT`	`PORTB`	Pins used for DATA lines. These routines assume all pins are on a single port.
	`TRIS_DATA_PORT`	`DDRB`	Data Direction register associated with the DATA lines.

The libraries that are provided can operate in either a 4-bit mode or 8-bit mode. When operating in 8-bit mode, all the lines of a single port are used. When operating in 4-bit mode, either the upper 4 bits or lower 4 bits of a single port are used. The table below lists the macros used for selecting between 4- or 8-bit mode and for selecting which bits of a port are used when operating in 4-bit mode.

TABLE 3-3: MACROS FOR SELECTING 4- OR 8-BIT MODE

Macro	Default Value	Use
`BIT8`	not defined	If this value is defined when the library functions are built, they will operate in 8-bit Transfer mode. Otherwise, they will operate in 4-bit Transfer mode.
`UPPER`	not defined	When `BIT8` is not defined, this value determines which nibble of the `DATA_PORT` is used for data transfer. If `UPPER` is defined, the upper 4 bits (4:7) of `DATA_PORT` are used. If `UPPER` is not defined, the lower 4 bits (0:3) of `DATA_PORT` are used.

After these definitions have been made, the user must recompile the XLCD routines and then include the updated files in the project. This can be accomplished by adding the XLCD source files into the project or by recompiling the library files using the provided batch files.

The XLCD libraries also require that the following functions be defined by the user to provide the appropriate delays:

TABLE 3-4: XLCD DELAY FUNCTIONS

Function	Behavior
`DelayFor18TCY`	Delay for 18 cycles.
`DelayPORXLCD`	Delay for 15 ms.
`DelayXLCD`	Delay for 5 ms.

3.2.1 Function Descriptions

BusyXLCD

Function:	Is the LCD controller busy?
Include:	`xlcd.h`
Prototype:	`unsigned char BusyXLCD( void );`
Remarks:	This function returns the status of the busy flag of the Hitachi HD44780 LCD controller.
Return Value:	1 if the controller is busy 0 otherwise.
File Name:	`busyxlcd.c`
Code Example:	`while( BusyXLCD() );`

OpenXLCD

Function: Configure the PIC® I/O pins and initialize the LCD controller.

Include: `xlcd.h`

Prototype: `void OpenXLCD( unsigned char lcdtype );`

Arguments: ***lcdtype***

A bitmask that is created by performing a bitwise AND operation (‘&’) with a value from each of the categories listed below. These values are defined in the file `xlcd.h`.

Data Interface:

`FOUR_BIT`	4-bit Data Interface mode
`EIGHT_BIT`	8-bit Data Interface mode

LCD Configuration:

`LINE_5X7`	5x7 characters, single line display
`LINE_5X10`	5x10 characters display
`LINES_5X7`	5x7 characters, multiple line display

Remarks: This function configures the PIC18 I/O pins used to control the Hitachi HD44780 LCD controller. It also initializes this controller.

File Name: `openxlcd.c`

Code Example:

```
OpenXLCD( EIGHT_BIT & LINES_5X7 );
```

putcXLCD

See **WriteDataXLCD.**

putsXLCD
putrsXLCD

Function: Write a string to the Hitachi HD44780 LCD controller.

Include: `xlcd.h`

Prototype:

```
void putsXLCD( char *buffer );
void putrsXLCD( const rom char *buffer );
```

Arguments: ***buffer***

Pointer to characters to be written to the LCD controller.

Remarks: This function writes a string of characters located in *`buffer`* to the Hitachi HD44780 LCD controller. It stops transmission when a null character is encountered. The null character is not transmitted.

Strings located in data memory should be used with the “puts” versions of these functions.

Strings located in program memory, including string literals, should be used with the “putrs” versions of these functions.

File Name:

```
putsxlcd.c
putrxlcd.c
```

Code Example:

```
char mybuff [20];
putrsXLCD( “Hello World” );
putsXLCD( mybuff );
```

ReadAddrXLCD

Function: Read the address byte from the Hitachi HD44780 LCD controller.

Include: `xlcd.h`

Prototype:

```
unsigned char ReadAddrXLCD( void );
```

Remarks: This function reads the address byte from the Hitachi HD44780 LCD controller. The LCD controller should not be busy when this operation is performed – this can be verified using the `BusyXLCD` function.

The address read from the controller is for the character generator RAM or the display data RAM depending on the previous `Set`??`RamAddr` function that was called.

Return Value: This function returns an 8-bit quantity. The address is contained in the lower order 7 bits and the BUSY status flag in the Most Significant bit.

File Name: `readaddr.c`

Code Example:

```
char addr;
while ( BusyXLCD() );
addr = ReadAddrXLCD();
```

ReadDataXLCD

Function: Read a data byte from the Hitachi HD44780 LCD controller.

Include: `xlcd.h`

Prototype: `char ReadDataXLCD( void );`

Remarks: This function reads a data byte from the Hitachi HD44780 LCD controller. The LCD controller should not be busy when this operation is performed – this can be verified using the `BusyXLCD` function.
The data read from the controller is for the character generator RAM or the display data RAM depending on the previous `Set`??`RamAddr` function that was called.

Return Value: This function returns the 8-bit data value.

File Name: `readdata.c`

Code Example:

```
char data;
while ( BusyXLCD() );
data = ReadAddrXLCD();
```

SetCGRamAddr

Function: Set the character generator address.

Include: `xlcd.h`

Prototype: `void SetCGRamAddr( unsigned char` ***`addr`*** `);`

Arguments: ***`addr`***
Character generator address.

Remarks: This function sets the character generator address of the Hitachi HD44780 LCD controller. The LCD controller should not be busy when this operation is performed – this can be verified using the `BusyXLCD` function.

File Name: `setcgram.c`

Code Example:

```
char cgaddr = 0x1F;
while( BusyXLCD() );
SetCGRamAddr( cgaddr );
```

SetDDRamAddr

Function: Set the display data address.

Include: `xlcd.h`

Prototype: `void SetDDRamAddr( unsigned char` ***`addr`*** `);`

Arguments: ***`addr`***
Display data address.

Remarks: This function sets the display data address of the Hitachi HD44780 LCD controller. The LCD controller should not be busy when this operation is performed – this can be verified using the `BusyXLCD` function.

File Name: `setddram.c`

Code Example:

```
char ddaddr = 0x10;
while( BusyXLCD() );
SetDDRamAddr( ddaddr );
```

WriteCmdXLCD

Function: Write a command to the Hitachi HD44780 LCD controller.

Include: `xlcd.h`

Prototype: `void WriteCmdXLCD( unsigned char cmd );`

Arguments: ***cmd***

Specifies the command to be performed. The command may be one of the following values defined in `xlcd.h`:

`DOFF`	Turn display off
`CURSOR_OFF`	Enable display with no cursor
`BLINK_ON`	Enable display with blinking cursor
`BLINK_OFF`	Enable display with unblinking cursor
`SHIFT_CUR_LEFT`	Cursor shifts to the left
`SHIFT_CUR_RIGHT`	Cursor shifts to the right
`SHIFT_DISP_LEFT`	Display shifts to the left
`SHIFT_DISP_RIGHT`	Display shifts to the right

Alternatively, the command may be a bitmask that is created by performing a bitwise AND operation (‘`&`’) with a value from each of the categories listed below. These values are defined in the file `xlcd.h`.

Data Transfer Mode:

`FOUR_BIT`	4-bit Data Interface mode
`EIGHT_BIT`	8-bit Data Interface mode

Display Type:

`LINE_5X7`	5x7 characters, single line
`LINE_5X10`	5x10 characters display
`LINES_5X7`	5x7 characters, multiple lines

Remarks: This function writes the command byte to the Hitachi HD44780 LCD controller. The LCD controller should not be busy when this operation is performed – this can be verified using the `BusyXLCD` function.

File Name: `wcmdxlcd.c`

Code Example:

```
while( BusyXLCD() );
WriteCmdXLCD( EIGHT_BIT & LINES_5X7 );
WriteCmdXLCD( BLINK_ON );
WriteCmdXLCD( SHIFT_DISP_LEFT );
```

putcXLCD
WriteDataXLCD

Function: Writes a byte to the Hitachi HD44780 LCD controller.

Include: `xlcd.h`

Prototype: `void WriteDataXLCD( char data );`

Arguments: ***data***

The value of *data* can be any 8-bit value, but should correspond to the character RAM table of the HD44780 LCD controller.

Remarks: This function writes a data byte to the Hitachi HD44780 LCD controller. The LCD controller should not be busy when this operation is performed – this can be verified using the `BusyXLCD` function.
The data read from the controller is for the character generator RAM or the display data RAM depending on the previous `Set`??`RamAddr` function that was called.

File Name: `writdata.c`

3.2.2 Example of Use

```
#include <p18C452.h>
#include <xlcd.h>
#include <delays.h>
#include <usart.h>

void DelayFor18TCY( void )
{
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
  Nop();
}

void DelayPORXLCD (void)
{
  Delay1KTCYx(60); // Delay of 15ms
                   // Cycles = (TimeDelay * Fosc) / 4
                   // Cycles = (15ms * 16MHz) / 4
                   // Cycles = 60,000
  return;
}

void DelayXLCD (void)
{
  Delay1KTCYx(20); // Delay of 5ms
                   // Cycles = (TimeDelay * Fosc) / 4
                   // Cycles = (5ms * 16MHz) / 4
                   // Cycles = 20,000
  return;
}
void main( void )
{
  char data;

  // configure external LCD
  OpenXLCD( EIGHT_BIT & LINES_5X7 );

  // configure USART
  OpenUSART( USART_TX_INT_OFF  & USART_RX_INT_OFF &
             USART_ASYNCH_MODE & USART_EIGHT_BIT  &
             USART_CONT_RX,
             25);

  while(1)
  {
    while(!DataRdyUSART());  //wait for data
    data = ReadUSART();      //read data
    WriteDataXLCD(data);     //write to LCD
    if(data=='Q')
      break;
  }

  CloseUSART();
}
```

3.3 EXTERNAL CAN2510 FUNCTIONS

This section documents the MCP2510 external peripheral library functions. The following functions are provided:

TABLE 3-5: EXTERNAL CAN2510 FUNCTIONS

Function	Description
`CAN2510BitModify`	Modifies the specified bits in a register to the new values.
`CAN2510ByteRead`	Reads the MCP2510 register specified by the address.
`CAN2510ByteWrite`	Writes a value to the MCP2510 register specified by the address.
`CAN2510DataRead`	Reads a message from the specified receive buffer.
`CAN2510DataReady`	Determines if data is waiting in the specified receive buffer.
`CAN2510Disable`	Drives the selected PIC18CXXX I/O pin high to disable the Chip Select of the MCP2510.**(1)**
`CAN2510Enable`	Drives the selected PIC18CXXX I/O pin low to Chip Select the MCP2510.**(1)**
`CAN2510ErrorState`	Reads the current Error State of the CAN bus.
`CAN2510Init`	Initialize the PIC18CXXX SPI port for communications to the MCP2510 and then configures the MCP2510 registers to interface with the CAN bus.
`CAN2510InterruptEnable`	Modifies the CAN2510 interrupt enable bits (CANINTE register) to the new values.
`CAN2510InterruptStatus`	Indicates the source of the CAN2510 interrupt.
`CAN2510LoadBufferStd`	Loads a Standard data frame into the specified transfer buffer.
`CAN2510LoadBufferXtd`	Loads an Extended data frame into the specified transfer buffer.
`CAN2510LoadRTRStd`	Loads a Standard remote frame into the specified transfer buffer.
`CAN2510LoadRTRXtd`	Loads an Extended remote frame into the specified transfer buffer.
`CAN2510ReadMode`	Reads the MCP2510 current mode of operation.
`CAN2510ReadStatus`	Reads the status of the MCP2510 Transmit and Receive Buffers.
`CAN2510Reset`	Resets the MCP2510.
`CAN2510SendBuffer`	Requests message transmission for the specified transmit buffer(s).
`CAN2510SequentialRead`	Reads the number of specified bytes in the MCP2510, starting at the specified address. These values will be stored in DataArray.
`CAN2510SequentialWrite`	Writes the number of specified bytes in the MCP2510, starting at the specified address. These values will be written from DataArray.
`CAN2510SetBufferPriority`	Loads the specified priority for the specified transmit buffer.
`CAN2510SetMode`	Configures the MCP2510 mode of operation.
`CAN2510SetMsgFilterStd`	Configures ALL of the filter and mask values of the specific receive buffer for a standard message.

TABLE 3-5: EXTERNAL CAN2510 FUNCTIONS (CONTINUED)

Function	Description
`CAN2510SetMsgFilterXtd`	Configures ALL of the filter and mask values of the specific receive buffer for a extended message.
`CAN2510SetSingleFilterStd`	Configures the specified Receive filter with a filter value for a Standard (Std) message.
`CAN2510SetSingleFilterXtd`	Configures the specified Receive filter with a filter value for a Extended (Xtd) message.
`CAN2510SetSingleMaskStd`	Configures the specified Receive buffer mask with a mask value for a Standard (Std) format message.
`CAN2510SetSingleMaskXtd`	Configures the specified Receive buffer mask with a mask value for an Extended (Xtd) message.
`CAN2510WriteBuffer`	Initiates CAN message transmission of selected buffer.
`CAN2510WriteStd`	Writes a Standard format message out to the CAN bus using the first available transmit buffer.
`CAN2510WriteXtd`	Writes an Extended format message out to the CAN bus using the first available transmit buffer.

Note 1: The functions `CAN2510Enable` and `CAN2510Disable` will need to be recompiled if:

- the PICmicro® MCU assignment of the $\overline{\text{CS}}$ pin is modified from RC2
- the device header file needs to be changed

3.3.1 Function Descriptions

CAN2510BitModify

Function: Modifies the specified bits in a register to the new values.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510BitModify(
    unsigned char addr
    unsigned char mask
    unsigned char data );
```

Arguments:

addr
The value of ***addr*** specifies the address of the MCP2510 register to modify.

mask
The value of ***mask*** specifies the bits that will be modified.

data
The value of ***data*** specifies the new state of the bits.

Remarks: This function modifies the contents of the register specified by address, the mask specifies which bits are to be modified and the data specifies the new value to load into those bits. Only specific registers can be modified with the Bit Modify command.

File Name: `canbmod.c`

CAN2510ByteRead

Function: Reads the MCP2510 register specified by the address.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510ByteRead(
   unsigned char address );
```

Arguments: ***address***
The address of the MCP2510 that is to be read.

Remarks: This function reads a single byte from the MCP2510 at the specified address.

Return Value: The contents of the specified address.

File Name: `readbyte.c`

CAN2510ByteWrite

Function: Writes a value to the MCP2510 register specified by the address.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510ByteWrite(
   unsigned char address,
   unsigned char value );
```

Arguments: ***address***
The address of the MCP2510 that is to be written.

value
The value that is to be written.

Remarks: This function writes a single byte from the MCP2510 at the specified address.

File Name: `wrtbyte.c`

CAN2510DataRead

Function: Reads a message from the specified receive buffer.

Required CAN Mode(s): All (except Configuration mode)

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510DataRead(
   unsigned char bufferNum,
   unsigned long *msgId,
   unsigned char *numBytes,
   unsigned char *data );
```

Arguments: ***bufferNum***
Receive buffer from which to read the message. One of the following values:

`CAN2510_RXB0`	Read receive buffer 0
`CAN2510_RXB1`	Read receive buffer 1

msgId
Points to a location that will be modified by the function to contain the CAN standard message identifier.

CAN2510DataRead (Continued)

	numBytes Points to a location that will be modified by the function to contain the number of bytes in this message.
	data Points to an array that will be modified by the function to contain the message data. This array should be at least 8 bytes long, since that is the maximum message data length.
Remarks:	This function determines if the message is a standard or extended message, decodes the ID and message length, and fills in the user-supplied locations with the appropriate information. The `CAN2510DataReady` function should be used to determine if a specified buffer has data to read.
Return Value:	Function returns one of the following values: `CAN2510_XTDMSG` Extended format message `CAN2510_STDMSG` Standard format message `CAN2510_XTDRTR` Remote transmit request (XTD message) `CAN2510_STDRTR` Remote transmit request (STD message)
File Name:	`canread.c`

CAN2510DataReady

Function:	Determines if data is waiting in the specified receive buffer.
Required CAN Mode(s):	All (except Configuration mode)
Include:	`can2510.h`

Prototype:	`unsigned char CAN2510DataReady(`
	`unsigned char` ***`bufferNum`*** `);`

Arguments:	***bufferNum*** Receive buffer to check for waiting message. One of the following values: `CAN2510_RXB0` Check Receive Buffer 0 `CAN2510_RXB1` Check Receive Buffer 1 `CAN2510_RXBX` Check Receive Buffer 0 and Receive Buffer 1
Remarks:	This function tests the appropriate `RXnIF` bit in the CANINTF register.
Return Value:	Returns zero if no message detected or a non-zero value if a message was detected. 1 = buffer0 2 = buffer1 3 = both
File Name:	`canready.c`

CAN2510Disable

Function: Drives the selected PIC18CXXX I/O pin high to disable the Chip Select of the MCP2510.

Required CAN Mode(s): All

Include: `canenabl.h`

Note: This include file will need to be modified if the Chip Select signal is not associated with the RC2 pin of the PICmicro MCU.

Prototype: `void CAN2510Disable( void );`

Arguments: None

Remarks: This function requires that the user modifies the file to specify the PIC18CXXX I/O pin (and Port) that will be used to connect to the MCP2510 $\overline{\text{CS}}$ pin. The default pin is RC2.

Note: The source file that contains this function (and the `CAN2510Enable` function) must have the definitions modified to correctly specify the Port (A, B, C, ...) and Pin number (1, 2, 3, ...) that is used to control the MCP2510 $\overline{\text{CS}}$ pin. After the modification, the processor-specific library must be rebuilt. See **Section 1.5.3 “Rebuilding”** for information on rebuilding.

File Name: `canenabl.c`

CAN2510Enable

Function: Drives the selected PIC18CXXX I/O pin low to Chip Select the MCP2510.

Required CAN Mode(s): All

Include: `canenabl.h`

Note: This include file will need to be modified if the Chip Select signal is not associated with the RC2 pin of the PICmicro MCU.

Prototype: `void CAN2510Enable( void );`

Remarks: This function requires that the user modifies the file to specify the PIC18CXXX I/O pin (and Port) that will be used to connect to the MCP2510 $\overline{\text{CS}}$ pin. The default pin is RC2.

Note: The source file that contains this function (and the `CAN2510Disable` function) must have the definitions modified to correctly specify the Port (A, B, C, ...) and Pin number (1, 2, 3, ...) that is used to control the MCP2510 $\overline{\text{CS}}$ pin. After the modification, the processor-specific library must be rebuilt. See **Section 1.5.3 “Rebuilding”** for information on rebuilding.

File Name: `canenabl.c`

CAN2510ErrorState

Function: Reads the current Error State of the CAN bus.

Required CAN Mode(s): Normal mode, Loopback mode, Listen Only mode
(Error counters are reset in Configuration mode)

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510ErrorState( void );
```

Remarks: This function returns the Error State of the CAN bus. The Error State is dependent on the values in the TEC and REC registers.

Return Value: Function returns one of the following values:

`CAN2510_BUS_OFF`	TEC > 255
`CAN2510_ERROR_PASSIVE_TX`	TEC > 127
`CAN2510_ERROR_PASSIVE_RX`	REC > 127
`CAN2510_ERROR_ACTIVE_WITH_TXWARN`	TEC > 95
`CAN2510_ERROR_ACTIVE_WITH_RXWARN`	REC > 95
`CAN2510_ERROR_ACTIVE`	TEC ≤ 95 and REC ≤ 95

File Name: `canerrst.c`

CAN2510Init

Function: Initialize the PIC18CXXX SPI port for communications to the MCP2510 and then configures the MCP2510 registers to interface with the CAN bus.

Required CAN Mode(s): Configuration mode

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510Init(
   unsigned short long BufferConfig,
   unsigned short long BitTimeConfig,
   unsigned char interruptEnables,
   unsigned char SPI_syncMode,
   unsigned char SPI_busMode,
   unsigned char SPI_smpPhase );
```

Arguments: The values of the following parameters are defined in the include file `can2510.h`.

BufferConfig

The value of BufferConfig is constructed through the bitwise AND (‘&’) operation of the following options. Only one option per group function may be selected. The option in the **bold font** is the default value.

Reset MCP2510 Device

Specifies if the MCP2510 Reset command is to be sent. This does not correspond to a bit in the MCP2510 registers.

`CAN2510_NORESET`	**Don’t reset the MCP2510**
`CAN2510_RESET`	Reset the MCP2510

Buffer 0 Filtering

Controlled by the `RXB0M1:RXB0M0` bits (RXB0CTRL register)

`CAN2510_RXB0_USEFILT`	**Receive all messages, Use filters**
`CAN2510_RXB0_STDMSG`	Receive only Standard messages
`CAN2510_RXB0_XTDMSG`	Receive only Extended messages
`CAN2510_RXB0_NOFILT`	Receive all messages, NO filters

Buffer 1 Filtering

Controlled by the `RXB1M1:RXB1M0` bits (RXB1CTRL register)

`CAN2510_RXB1_USEFILT`	**Receive all messages, Use filters**
`CAN2510_RXB1_STDMSG`	Receive only Standard messages
`CAN2510_RXB1_XTDMSG`	Receive only Extended messages
`CAN2510_RXB1_NOFILT`	Receive all messages, NO filters

CAN2510Init (Continued)

Receive Buffer 0 to Receive Buffer 1 Rollover
Controlled by the `BUKT` bit (RXB0CTRL register)

`CAN2510_RXB0_ROLL`	**If receive buffer 0 is full, message goes to receive buffer 1**
`CAN2510_RXB0_NOROLL`	Rollover Disabled

RX1BF Pin Setting
Controlled by the `B1BFS:B1BFE:B1BFM` bits (BFPCTRL register)

`CAN2510_RX1BF_OFF`	**RX1BF pin is high-impedance**
`CAN2510_RX1BF_INT`	RX1BF pin is an output which indicates Receive Buffer 1 was loaded. Can be used as an interrupt signal.
`CAN2510_RX1BF_GPOUTH`	RX1BF pin is a general purpose digital output, Output High
`CAN2510_RX1BF_GPOUTL`	RX1BF pin is a general purpose digital output, Output Low

RX0BF Pin Setting
Controlled by the `B0BFS:B0BFE:B0BFM` bits (BFPCTRL register)

`CAN2510_RX0BF_OFF`	**RX0BF pin is high-impedance**
`CAN2510_RX0BF_INT`	RX0BF pin is an output which indicates Receive Buffer 0 was loaded. Can be used as an interrupt signal.
`CAN2510_RX0BF_GPOUTH`	RX0BF pin is a general purpose digital output, Output High
`CAN2510_RX0BF_GPOUTL`	RX0BF pin is a general purpose digital output, Output Low

TX2 Pin Setting
Controlled by the `B2RTSM` bit (TXRTSCTRL register)

`CAN2510_TX2_GPIN`	**TX2RTS pin is a digital input**
`CAN2510_TX2_RTS`	TX2RTS pin is an input used to initiate a Request To Send frame from TXBUF2

TX1 Pin Setting
Controlled by the `B1RTSM` bit (TXRTSCTRL register)

`CAN2510_TX1_GPIN`	**TX1RTS pin is a digital input**
`CAN2510_TX1_RTS`	TX1RTS pin is an input used to initiate a Request To Send frame from TXBUF1

TX0 Pin Setting
Controlled by the `B0RTSM` bit (TXRTSCTRL register)

`CAN2510_TX0_GPIN`	**TX0RTS pin is a digital input**
`CAN2510_TX0_RTS`	TX0RTS pin is an input used to initiate a Request To Send frame from TXBUF0

Request Mode of Operation
Controlled by the `REQOP2:REQOP0` bits (CANCTRL register)

`CAN2510_REQ_CONFIG`	**Configuration mode**
`CAN2510_REQ_NORMAL`	Normal Operation mode
`CAN2510_REQ_SLEEP`	Sleep mode
`CAN2510_REQ_LOOPBACK`	Loop Back mode
`CAN2510_REQ_LISTEN`	Listen Only mode

CLKOUT Pin Setting
Controlled by the `CLKEN:CLKPRE1:CLKPRE0` bits (CANCTRL register)

`CAN2510_CLKOUT_8`	**CLKOUT = Fosc / 8**
`CAN2510_CLKOUT_4`	CLKOUT = Fosc / 4
`CAN2510_CLKOUT_2`	CLKOUT = Fosc / 2
`CAN2510_CLKOUT_1`	CLKOUT = Fosc
`CAN2510_CLKOUT_OFF`	CLKOUT is Disabled

CAN2510Init (Continued)

BitTimeConfig

The value of BitTimeConfig is constructed through the bitwise AND (‘&’) operation of the following options. Only one option per group function may be selected. The option in the **bold font** is the default value.

Baud Rate Prescaler (BRP)

Controlled by the `BRP5:BRP0` bits (CNF1 register)

`CAN2510_BRG_1X`	**TQ = 1 x (2TOSC)**
:	**:**
`CAN2510_BRG_64X`	TQ = 64 x (2TOSC)

Synchronization Jump Width

Controlled by the `SJW1:SJW0` bits (CNF1 register)

`CAN2510_SJW_1TQ`	**SJW length = 1 TQ**
`CAN2510_SJW_2TQ`	SJW length = 2 TQ
`CAN2510_SJW_3TQ`	SJW length = 3 TQ
`CAN2510_SJW_4TQ`	SJW length = 4 TQ

Phase 2 Segment Width

Controlled by the `PH2SEG2:PH2SEG0` bits (CNF3 register)

`CAN2510_PH2SEG_2TQ`	**Length = 2 TQ**
`CAN2510_PH2SEG_3TQ`	Length = 3 TQ
`CAN2510_PH2SEG_4TQ`	Length = 4 TQ
`CAN2510_PH2SEG_5TQ`	Length = 5 TQ
`CAN2510_PH2SEG_6TQ`	Length = 6 TQ
`CAN2510_PH2SEG_7TQ`	Length = 7 TQ
`CAN2510_PH2SEG_8TQ`	Length = 8 TQ

Phase 1 Segment Width

Controlled by the `PH1SEG2:PH1SEG0` bits (CNF2 register)

`CAN2510_PH1SEG_1TQ`	**Length = 1 TQ**
`CAN2510_PH1SEG_2TQ`	Length = 2 TQ
`CAN2510_PH1SEG_3TQ`	Length = 3 TQ
`CAN2510_PH1SEG_4TQ`	Length = 4 TQ
`CAN2510_PH1SEG_5TQ`	Length = 5 TQ
`CAN2510_PH1SEG_6TQ`	Length = 6 TQ
`CAN2510_PH1SEG_7TQ`	Length = 7 TQ
`CAN2510_PH1SEG_8TQ`	Length = 8 TQ

Propagation Segment Width

Controlled by the `PRSEG2:PRSEG0` bits (CNF2 register)

`CAN2510_PROPSEG_1TQ`	**Length = 1 TQ**
`CAN2510_PROPSEG_2TQ`	Length = 2 TQ
`CAN2510_PROPSEG_3TQ`	Length = 3 TQ
`CAN2510_PROPSEG_4TQ`	Length = 4 TQ
`CAN2510_PROPSEG_5TQ`	Length = 5 TQ
`CAN2510_PROPSEG_6TQ`	Length = 6 TQ
`CAN2510_PROPSEG_7TQ`	Length = 7 TQ
`CAN2510_PROPSEG_8TQ`	Length = 8 TQ

Phase 2 Source

Controlled by the `BTLMODE bit` (CNF2 register). This determines if the Phase 2 length is determined by the `PH2SEG2:PH2SEG0` bits or the greater length of `PH1SEG2:PH1SEG0` bits and (2TQ).

`CAN2510_PH2SOURCE_PH2`	**Length = `PH2SEG2:PH2SEG0`**
`CAN2510_PH2SOURCE_PH1`	Length = greater of `PH1SEG2:PH1SEG0` and 2TQ

Bit Sample Point Frequency

Controlled by the `SAM` bit (CNF2 register). This determines if the bit is sampled 1 or 3 times at the sample point.

`CAN2510_SAMPLE_1x`	**Bit is sampled once**
`CAN2510_SAMPLE_3x`	Bit is sampled three times

CAN2510Init (Continued)

RX pin Noise Filter in Sleep Mode

Controlled by the `WAKFIL` bit (CNF3 register). This determines if the RX pin will use a filter to reject noise when the device is in Sleep mode.

`CAN2510_RX_FILTER`	**Filtering on RX pin when in Sleep mode**
`CAN2510_RX_NOFILTER`	No filtering on RX pin when in Sleep mode

`interruptEnables`

The value of `interruptEnables` can be a combination of the following values, combined using a bitwise AND (‘&’) operation. The option in the **bold font** is the default value. Controlled by all bits in the CANINTE register.

`CAN2510_NONE_EN`	**No interrupts enabled**
`CAN2510_MSGERR_EN`	Interrupt on error during message reception or transmission
`CAN2510_WAKEUP_EN`	Interrupt on CAN bus activity
`CAN2510_ERROR_EN`	Interrupt on EFLG error condition change
`CAN2510_TXB2_EN`	Interrupt on transmission buffer 2 becoming empty
`CAN2510_TXB1_EN`	Interrupt on transmission buffer 1 becoming empty
`CAN2510_TXB0_EN`	Interrupt on transmission buffer 0 becoming empty
`CAN2510_RXB1_EN`	Interrupt when message received in receive buffer 1
`CAN2510_RXB0_EN`	Interrupt when message received in receive buffer 0

`SPI_syncMode`

Specifies the PIC18CXXX SPI synchronization frequency:

`CAN2510_SPI_FOSC4`	**Communicates at FOSC/4**
`CAN2510_SPI_FOSC16`	Communicates at FOSC/16
`CAN2510_SPI_FOSC64`	Communicates at FOSC/64
`CAN2510_SPI_FOSCTMR2`	Communicates at TMR2/2

`SPI_busMode`

Specifies the PIC18CXXX SPI bus mode:

`CAN2510_SPI_MODE00`	**Communicate using SPI mode 00**
`CAN2510_SPI_MODE01`	Communicate using SPI mode 01

`SPI_smpPhase`

Specifies the PIC18CXXX SPI sample point:

`CAN2510_SPI_SMPMID`	**Samples in middle of SPI bit**
`CAN2510_SPI_SMPEND`	Samples at end of SPI bit

Remarks: This function initializes the PIC18CXXX SPI module, resets the MCP2510 device (if requested) and then configures the MCP2510 registers.

Note: When this function is completed, the MCP2510 is left in the Configuration mode.

Return Value: Indicates if the MCP2510 could be initialized.
0 if initialization completed
-1 if initialization did not complete

File Name: `caninit.c`

CAN2510InterruptEnable

Function: Modifies the CAN2510 interrupt enable bits (CANINTE register) to the new values.

Required CAN Mode(s): All

Include: `can2510.h`, `spi_can.h`

Prototype:

```
void CAN2510InterruptEnable(
   unsigned char interruptEnables );
```

Arguments: ***interruptEnables***

The value of ***interruptEnables*** can be a combination of the following values, combined using a bitwise AND ('&') operation. The option in the **bold font** is the default value. Controlled by all bits in the CANINTE register.

CAN2510_NONE_EN	**No interrupts enabled (00000000)**
CAN2510_MSGERR_EN	Interrupt on error during message reception or transmission (10000000)
CAN2510_WAKEUP_EN	Interrupt on CAN bus activity (01000000)
CAN2510_ERROR_EN	Interrupt on EFLG error condition change (00100000)
CAN2510_TXB2_EN	Interrupt on transmission buffer 2 becoming empty (00010000)
CAN2510_TXB1_EN	Interrupt on transmission buffer 1 becoming empty (00001000)
CAN2510_TXB0_EN	Interrupt on transmission buffer 0 becoming empty (00000100)
CAN2510_RXB1_EN	Interrupt when message received in receive buffer 1 (00000010)
CAN2510_RXB0_EN	Interrupt when message received in receive buffer 0 (00000001)

Remarks: This function updates the CANINTE register with the value that is determined by ANDing the desired interrupt sources.

File Name: `caninte.c`

CAN2510InterruptStatus

Function: Indicates the source of the CAN2510 interrupt.

Required CAN Mode(s): All

Include: `can2510.h`, `spi_can.h`

Prototype:

```
unsigned char CAN2510InterruptStatus(
   void );
```

Remarks: This function reads the CANSTAT register and specifies a code depending on the state of the `ICODE2:ICODE0` bits.

Return Value: Function returns one of the following values:

`CAN2510_NO_INTS`	No interrupts occurred
`CAN2510_WAKEUP_INT`	Interrupt on CAN bus activity
`CAN2510_ERROR_INT`	Interrupt on EFLG error condition change
`CAN2510_TXB2_INT`	Interrupt on transmission buffer 2 becoming empty
`CAN2510_TXB1_INT`	Interrupt on transmission buffer 1 becoming empty
`CAN2510_TXB0_INT`	Interrupt on transmission buffer 0 becoming empty
`CAN2510_RXB1_INT`	Interrupt when message received in receive buffer 1
`CAN2510_RXB0_INT`	Interrupt when message received in receive buffer 0

File Name: `canints.c`

CAN2510LoadBufferStd

Function: Loads a Standard data frame into the specified transfer buffer.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510LoadBufferStd(
   unsigned char bufferNum,
   unsigned int  msgId,
   unsigned char numBytes,
   unsigned char *data );
```

Arguments:

bufferNum

Specifies the buffer to load the message into. One of the following values:

`CAN2510_TXB0`	Transmit buffer 0
`CAN2510_TXB1`	Transmit buffer 1
`CAN2510_TXB2`	Transmit buffer 2

msgId

CAN message identifier, up to 11 bits for a standard message.

numBytes

Number of bytes of data to transmit, from 0 to 8. If value is greater than 8, only the first 8 bytes of data will be stored.

data

Array of data values to be loaded. The array must be at least as large as the value specified in ***numBytes***.

CAN2510LoadBufferStd (Continued)

Remarks: This function loads the message information, but does not transmit the message. Use the `CAN2510WriteBuffer()` function to write the message onto the CAN bus.
This function does not set the priority of the buffer. Use the `CAN2510SetBufferPriority()` function to set buffer priority.

File Name: `canloads.c`

CAN2510LoadBufferXtd

Function: Loads an Extended data frame into the specified transfer buffer.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510LoadBufferXtd(
    unsigned char bufferNum,
    unsigned long msgId,
    unsigned char numBytes,
    unsigned char *data );
```

Arguments:

bufferNum
Specifies the buffer to load the message into. One of the following values:

CAN2510_TXB0	Transmit buffer 0
CAN2510_TXB1	Transmit buffer 1
CAN2510_TXB2	Transmit buffer 2

msgId
CAN message identifier, up to 29 bits for a extended message.

numBytes
Number of bytes of data to transmit, from 0 to 8. If value is greater than 8, only the first 8 bytes of data will be stored.

data
Array of data values to be loaded. The array must be at least as large as the value specified in ***numBytes***.

Remarks: This function loads the message information, but does not transmit the message. Use the `CAN2510WriteBuffer()` function to write the message onto the CAN bus.
This function does not set the priority of the buffer. Use the `CAN2510SetBufferPriority()` function to set buffer priority.

File Name: `canloadx.c`

CAN2510LoadRTRStd

Function: Loads a Standard remote frame into the specified transfer buffer.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510LoadBufferStd(
   unsigned char bufferNum,
   unsigned int  msgId,
   unsigned char numBytes);
```

Arguments: ***bufferNum***

Specifies the buffer to load the message into. One of the following values:

`CAN2510_TXB0`	Transmit buffer 0
`CAN2510_TXB1`	Transmit buffer 1
`CAN2510_TXB2`	Transmit buffer 2

msgId

CAN message identifier, up to 11 bits for a standard message.

numBytes

Number of bytes of data to transmit, from 0 to 8. If value is greater than 8, only the first 8 bytes of data will be stored.

Remarks: This function loads the message information, but does not transmit the message. Use the `CAN2510WriteBuffer()` function to write the message onto the CAN bus.

This function does not set the priority of the buffer. Use the `CAN2510SetBufferPriority()` function to set buffer priority.

File Name: `canlrtrs.c`

CAN2510LoadRTRXtd

Function: Loads an Extended remote frame into the specified transfer buffer.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510LoadBufferXtd(
   unsigned char bufferNum,
   unsigned long msgId,
   unsigned char numBytes);
```

Arguments: ***bufferNum***

Specifies the buffer to load the message into. One of the following values:

`CAN2510_TXB0`	Transmit buffer 0
`CAN2510_TXB1`	Transmit buffer 1
`CAN2510_TXB2`	Transmit buffer 2

msgId

CAN message identifier, up to 29 bits for a extended message.

numBytes

Number of bytes of data to transmit, from 0 to 8. If value is greater than 8, only the first 8 bytes of data will be stored.

Remarks: This function loads the message information, but does not transmit the message. Use the `CAN2510WriteBuffer()` function to write the message onto the CAN bus.

This function does not set the priority of the buffer. Use the `CAN2510SetBufferPriority()` function to set buffer priority.

File Name: `canlrtrx.c`

CAN2510ReadMode

Function: Reads the MCP2510 current mode of operation.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype: `unsigned char CAN2510ReadMode( void );`

Remarks: This function reads the current Operating mode. The mode may have a pending request for a new mode.

Return Value: ***`mode`***

The value of ***`mode`*** can be one of the following values (defined in `can2510.h`). Specified by the `OPMODE2:OPMODE0` bits (CANSTAT register). One of the following values:

`CAN2510_MODE_CONFIG`	Configuration registers can be modified
`CAN2510_MODE_NORMAL`	Normal (send and receive messages)
`CAN2510_MODE_SLEEP`	Wait for interrupt
`CAN2510_MODE_LISTEN`	Listen only, don't send
`CAN2510_MODE_LOOPBACK`	Used for testing, messages stay internal

File Name: `canmoder.c`

CAN2510ReadStatus

Function: Reads the status of the MCP2510 Transmit and Receive Buffers.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype: `unsigned char CAN2510ReadStatus( void );`

Remarks: This function reads the current status of the transmit and receive buffers.

Return Value: ***`status`***

The value of ***`status`*** (an unsigned byte) has the following format:

bit 7	TXB2IF
bit 6	TXB2REQ
bit 5	TXB1IF
bit 4	TXB1REQ
bit 3	TXB0IF
bit 2	TXB0REQ
bit 1	RXB1IF
bit 0	RXB0IF

File Name: `canstats.c`

CAN2510Reset

Function:	Resets the MCP2510.
Required CAN Mode(s):	All

Include:	`can2510.h`
	`spi_can.h`
	`spi.h`

Prototype:	`void CAN2510Reset( void );`
Remarks:	This function resets the MCP2510.
File Name:	`canreset.c`

CAN2510SendBuffer

Function: Requests message transmission for the specified transmit buffer(s).

Required CAN Mode(s): Normal mode

Include: `can2510.h`

Prototype:

```
void CAN2510WriteBuffer
    ( unsigned char bufferNum );
```

Arguments: ***bufferNum***

Specifies the buffer to request transmission of. One of the following values:

`CAN2510_TXB0`	Transmit buffer 0
`CAN2510_TXB1`	Transmit buffer 1
`CAN2510_TXB2`	Transmit buffer 2
`CAN2510_TXB0_B1`	Transmit buffer 0 and buffer 1
`CAN2510_TXB0_B2`	Transmit buffer 0 and buffer 2
`CAN2510_TXB1_B2`	Transmit buffer 1 and buffer 2
`CAN2510_TXB0_B1_B2`	Transmit buffer 0, buffer 1 and buffer 2

Remarks: This function requests transmission of a previously loaded message stored in the specified buffer(s). To load a message, use the `CAN2510LoadBufferStd()` or `CAN2510LoadBufferXtd()` routines.

File Name: `cansend.c`

CAN2510SequentialRead

Function: Reads the number of specified bytes in the MCP2510, starting at the specified address. These values will be stored in ***DataArray***.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510SequentialRead(
   unsigned char *DataArray
   unsigned char CAN2510addr
   unsigned char numbytes );
```

Arguments:

DataArray
The start address of the data array that stores the sequential read data.

CAN2510addr
The address of the MCP2510 where the sequential reads start from.

numbytes
The number of bytes to sequentially read.

CAN2510SequentialRead (Continued)

Remarks: This function reads sequential bytes from the MCP2510 starting at the specified address. These values are loaded starting at the first address of the array that is specified.

File Name: `readseq.c`

CAN2510SequentialWrite

Function: Writes the number of specified bytes in the MCP2510, starting at the specified address. These values will be written from ***DataArray***.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510SequentialWrite(
   unsigned char *DataArray
   unsigned char CAN2510addr
   unsigned char numbytes );
```

Arguments:

DataArray
The start address of the data array that contains the sequential write data.

CAN2510addr
The address of the MCP2510 where the sequential writes start from.

numbytes
The number of bytes to sequentially write.

Remarks: This function writes sequential bytes to the MCP2510 starting at the specified address. These values are contained starting at the first address of the array that is specified.

File Name: `wrtseq.c`

CAN2510SetBufferPriority

Function: Loads the specified priority for the specified transmit buffer.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510SetBufferPriority(
   unsigned char bufferNum,
   unsigned char bufferPriority );
```

Arguments:

bufferNum
Specifies the buffer to configure the priority of. One of the following values:

`CAN2510_TXB0`	Transmit buffer 0
`CAN2510_TXB1`	Transmit buffer 1
`CAN2510_TXB2`	Transmit buffer 2

bufferPriority
Priority of buffer. One of the following values:

`CAN2510_PRI_HIGHEST`	Highest message priority
`CAN2510_PRI_HIGH`	High message priority
`CAN2510_PRI_LOW`	Low message priority
`CAN2510_PRI_LOWEST`	Lowest message priority

Remarks: This function loads the specified priority of an individual buffer.

File Name: `cansetpr.c`

CAN2510SetMode

Function: Configures the MCP2510 mode of operation.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
void CAN2510SetMode( unsigned char mode );
```

Arguments: ***mode***

The value of ***mode*** can be one of the following values (defined in `can2510.h`). Controlled by the REQOP2:REQOP0 bits (CANCTRL register). One of the following values:

CAN2510_MODE_CONFIG	Configuration registers can be modified
CAN2510_MODE_NORMAL	Normal (send and receive messages)
CAN2510_MODE_SLEEP	Wait for interrupt
CAN2510_MODE_LISTEN	Listen only, don’t send
CAN2510_MODE_LOOPBACK	Used for testing, messages stay internal

Remarks: This function configures the specified mode. The mode will not change until all pending message transmissions are complete.

File Name: `canmodes.c`

CAN2510SetMsgFilterStd

Function: Configures ALL of the filter and mask values of the specific receive buffer for a standard message.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510SetMsgFilterStd(
    unsigned char bufferNum,
    unsigned int  mask,
    unsigned int  *filters );
```

Arguments: ***bufferNum***

Specifies the receive buffer to configure the mask and filters for. One of the following values:

CAN2510_RXB0	Configure RXM0, RXF0 and RXF1
CAN2510_RXB1	Configure RXM1, RXF2, RXF3, RXF4 and RXF5

mask

Value to store in the corresponding mask

filters

Array of filter values.

- For Buffer 0
  - Standard-length messages: Array of 2 unsigned integers
- For Buffer 1
  - Standard-length messages: Array of 4 unsigned integers

Remarks: This function configures the MCP2510 into Configuration mode, then writes the mask and filter values out to the appropriate registers. Before returning, it configures the MCP2510 to the original mode.

Return Value: Indicates if the MCP2510 modes could be modified properly.
0 if initialization and restoration of Operating mode completed
-1 if initialization and restoration of Operating mode did not complete

File Name: `canfms.c`

CAN2510SetMsgFilterXtd

Function: Configures ALL of the filter and mask values of the specific receive buffer for a extended message.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510SetMsgFilterXtd(
    unsigned char bufferNum,
    unsigned long mask,
    unsigned long *filters );
```

Arguments:

bufferNum
Specifies the receive buffer to configure the mask and filters for one of the following values:

`CAN2510_RXB0`	Configure RXM0, RXF0 and RXF1
`CAN2510_RXB1`	Configure RXM1, RXF2, RXF3, RXF4 and RXF5

mask
Value to store in the corresponding mask

filters
Array of filter values.
For Buffer 0
Extended-length messages: Array of 2 unsigned long integers
For Buffer 1
Extended-length messages: Array of 4 unsigned long integers

Remarks: This function configures the MCP2510 into Configuration mode, then writes the mask and filter values out to the appropriate registers. Before returning, it configures the MCP2510 to the original mode.

Return Value: Indicates if the MCP2510 modes could be modified properly:
0 if Initialization and restoration of Operating mode completed
-1 if initialization and restoration of Operating mode did not complete

File Name: `canfmx.c`

CAN2510SetSingleFilterStd

Function:	Configures the specified Receive filter with a filter value for a Standard (Std) message.
Required CAN Mode(s):	Configuration mode
Include:	`can2510.h`

Prototype:	`void CAN2510SetSingleFilterStd(`
	`unsigned char` ***`filterNum`***`,`
	`unsigned int` ***`filter`*** `);`

Arguments:	***`filterNum`*** Specifies the acceptance filter to configure. One of the following values: `CAN2510_RXF0` Configure RXF0 (for RXB0) `CAN2510_RXF1` Configure RXF1 (for RXB0) `CAN2510_RXF2` Configure RXF2 (for RXB1) `CAN2510_RXF3` Configure RXF3 (for RXB1) `CAN2510_RXF4` Configure RXF4 (for RXB1) `CAN2510_RXF5` Configure RXF5 (for RXB1) ***`filter`*** Value to store in the corresponding filter
Remarks:	This function writes the filter value to the appropriate registers. The MCP2510 must be in Configuration mode before executing this function.
File Name:	`canfilts.c`

CAN2510SetSingleFilterXtd

Function:	Configures the specified Receive filter with a filter value for a Extended (Xtd) message.
Required CAN Mode(s):	Configuration mode
Include:	`can2510.h`

Prototype:	`void CAN2510SetSingleFilterXtd(`
	`unsigned char` ***`filterNum`***`,`
	`unsigned long` ***`filter`*** `);`

Arguments:	***`filterNum`*** Specifies the acceptance filter to configure. One of the following values: `CAN2510_RXF0` Configure RXF0 (for RXB0) `CAN2510_RXF1` Configure RXF1 (for RXB0) `CAN2510_RXF2` Configure RXF2 (for RXB1) `CAN2510_RXF3` Configure RXF3 (for RXB1) `CAN2510_RXF4` Configure RXF4 (for RXB1) `CAN2510_RXF5` Configure RXF5 (for RXB1) ***`filter`*** Value to store in the corresponding filter
Remarks:	This function writes the filter value to the appropriate registers. The MCP2510 must be in Configuration mode before executing this function.
File Name:	`canfiltx.c`

CAN2510SetSingleMaskStd

Function: Configures the specified Receive buffer mask with a mask value for a Standard (Std) format message.

Required CAN Mode(s): Configuration mode

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510SetSingleMaskStd(
   unsigned char maskNum,
   unsigned int  mask );
```

Arguments:

maskNum

Specifies the acceptance mask to configure. One of the following values:

`CAN2510_RXM0`	Configure RXM0	(for RXB0)
`CAN2510_RXM1`	Configure RXM1	(for RXB1)

mask

Value to store in the corresponding mask

Remarks: This function writes the mask value to the appropriate registers. The MCP2510 must be in Configuration mode before executing this function.

File Name: `canmasks.c`

CAN2510SetSingleMaskXtd

Function: Configures the specified Receive buffer mask with a mask value for an Extended (Xtd) message.

Required CAN Mode(s): Configuration mode

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510SetSingleMaskXtd(
   unsigned char maskNum,
   unsigned long mask );
```

Arguments:

maskNum

Specifies the acceptance mask to configure. One of the following values:

`CAN2510_RXM0`	Configure RXM0	(for RXB0)
`CAN2510_RXM1`	Configure RXM1	(for RXB1)

mask

Value to store in the corresponding mask

Remarks: This function writes the mask value to the appropriate registers. The MCP2510 must be in Configuration mode before executing this function.

File Name: `canmaskx.c`

CAN2510WriteBuffer

Function: Initiates CAN message transmission of selected buffer.

Required CAN Mode(s): All

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510WriteBuffer(
   unsigned char bufferNum )
```

Arguments: ***bufferNum***

Specifies the buffer to load the message into. One of the following values:

`CAN2510_TXB0`	Transmit buffer 0
`CAN2510_TXB1`	Transmit buffer 1
`CAN2510_TXB2`	Transmit buffer 2

Remarks: This function initiates transmission of the selected transmit bufffer.

File Name: `canwrbuf.c`

CAN2510WriteStd

Function: Writes a Standard format message out to the CAN bus using the first available transmit buffer.

Required CAN Mode(s): Normal mode

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510WriteStd(
   unsigned int  msgId,
   unsigned char msgPriority,
   unsigned char numBytes,
   unsigned char *data );
```

Arguments:

msgId
CAN message identifier, 11 bits for a standard message. This 11-bit identifier is stored in the lower 11 bits of msgId (an unsigned integer).

msgPriority
Priority of buffer. One of the following values:

`CAN2510_PRI_HIGHEST`	Highest message priority
`CAN2510_PRI_HIGH`	High intermediate message priority
`CAN2510_PRI_LOW`	Low intermediate message priority
`CAN2510_PRI_LOWEST`	Lowest message priority

numBytes
Number of bytes of data to transmit, from 0 to 8. If value is greater than 8, only the first 8 bytes of data will be sent.

data
Array of data values to be written. Must be at least as large as the value specified in ***numBytes***.

Remarks: This function will query each transmit buffer for a pending message, and will post the specified message into the first available buffer.

Return Value: Value indicates which buffer was used to transmit the message (0, 1 or 2).
-1 indicates that no message was sent.

File Name: `canwrits.c`

CAN2510WriteXtd

Function: Writes an Extended format message out to the CAN bus using the first available transmit buffer.

Required CAN Mode(s): Normal mode

Include: `can2510.h`

Prototype:

```
unsigned char CAN2510WriteXtd(
   unsigned long msgId,
   unsigned char msgPriority,
   unsigned char numBytes,
   unsigned char *data );
```

Arguments:

msgId
CAN message identifier, 29 bits for an extended message. This 29-bit identifier is stored in the lower 29 bits of msgId (an unsigned long).

msgPriority
Priority of buffer. One of the following values:

`CAN2510_PRI_HIGHEST`	Highest message priority
`CAN2510_PRI_HIGH`	High intermediate message priority
`CAN2510_PRI_LOW`	Low intermediate message priority
`CAN2510_PRI_LOWEST`	Lowest message priority

numBytes
Number of bytes of data to transmit, from 0 to 8. If value is greater than 8, only the first 8 bytes of data will be sent.

data
Array of data values to be written. Must be at least as large as the value specified in ***numBytes***.

Remarks: This function will query each transmit buffer for a pending message, and will post the specified message into the first available buffer.

Return Value: Value indicates which buffer was used to transmit the message (0, 1 or 2).
-1 indicates that no message was sent.

File Name: `canwritx.c`

3.4 SOFTWARE I^{2}C FUNCTIONS

These functions are designed to allow the implementation of an I^{2}C bus using I/O pins from a PIC18 microcontroller. The following functions are provided:

TABLE 3-6: I^{2}C™ SOFTWARE FUNCTIONS

Function	Description
`Clock_test`	Generate a delay for slave clock stretching.
`SWAckI2C`	Generate an I^{2}C™ bus *Acknowledge* condition.
`SWGetcI2C`	Read a byte from the I^{2}C bus.
`SWGetsI2C`	Read a data string.
`SWNotAckI2C`	Generate an I^{2}C bus *Not Acknowledge* condition.
`SWPutcI2C`	Write a single byte to the I^{2}C bus.
`SWPutsI2C`	Write a string to the I^{2}C bus.
`SWReadI2C`	Read a byte from the I^{2}C bus.
`SWRestartI2C`	Generate an I^{2}C bus *Restart* condition.
`SWStartI2C`	Generate an I^{2}C bus *Start* condition.
`SWStopI2C`	Generate an I^{2}C bus *Stop* condition.
`SWWriteI2C`	Write a single byte to the I^{2}C bus.

The precompiled versions of these functions use default pin assignments that can be changed by redefining the macro assignments in the file `sw_i2c.h`, found in the `h` subdirectory of the compiler installation:

TABLE 3-7: MACROS FOR SELECTING I^{2}C™ PIN ASSIGNMENTS

I^{2}C Line	Macros	Default Value	Use
DATA Pin	`DATA_PIN`	`PORTBbits.RB4`	Pin used for the DATA line.
	`DATA_LAT`	`LATBbits.RB4`	Latch associated with DATA pin.
	`DATA_LOW`	`TRISBbits.TRISB4 = 0;`	Statement to configure the DATA pin as an output.
	`DATA_HI`	`TRISBbits.TRISB4 = 1;`	Statement to configure the DATA pin as an input.
CLOCK Pin	`SCLK_PIN`	`PORTBbits.RB3`	Pin used for the CLOCK line.
	`SCLK_LAT`	`LATBbits.LATB3`	Latch associated with the CLOCK pin.
	`CLOCK_LOW`	`TRISBbits.TRISB3 = 0;`	Satement to configure the CLOCK pin as an output.
	`CLOCK_HI`	`TRISBbits.TRISB3 = 1;`	Statement to configure the CLOCK pin as an input.

After these definitions have been made, the user must recompile the I^{2}C routines and then use the updated files in the project. This can be accomplished by adding the library source files into the project or by recompiling the library files using the provided batch files.

3.4.1 Function Descriptions

Clock_test

Function: Generate a delay for slave clock stretching.

Include: `sw_i2c.h`

Prototype:
```
char Clock_test( void );
```

Remarks: This function is called to allow for slave clock stretching. The delay time may need to be adjusted per application requirements. If at the end of the delay period the clock line is low, a value is returned indicating clock error.

Return Value: 0 is returned if no clock error occurred
-2 is returned if a clock error occurred

File Name: `swckti2c.c`

SWAckI2C
SWNotAckI2C

Function: Generate an I^2C bus *Acknowledge/Not Acknowledge* condition.

Include: `sw_i2c.h`

Prototype:
```
char SWAckI2C( void );
char SWNotAckI2C( void );
```

Remarks: This function is called to generate an I^2C bus Acknowledge sequence.

Return Value: 0 if the slave Acknowledges
-1 if the slave does not Acknowledge

File Name: `swacki2c.c`

SWGetcI2C

See **SWReadI2C**.

SWGetsI2C

Function: Read a string from the I^2C bus.

Include: `sw_i2c.h`

Prototype:
```
char SWGetsI2C(
      unsigned char *rdptr,
      unsigned char length );
```

Arguments: ***rdptr***
Location to store the data read from the I^2C bus.
length
Number of bytes to read.

Remarks: This function reads in a string of predetermined length.

Return Value: -1 if the master generated a *NOT ACK* bus condition before all bytes have been received
0 otherwise

File Name: `swgtsi2c.c`

Code Example:
```
char x[10];
SWGetsI2C( x,5 );
```

SWNotAckI2C

See **SWAckI2C**.

SWPutcI2C

See **SWWriteI2C**.

SWPutsI2C

Function: Write a string to the I^{2}C bus.

Include: `sw_i2c.h`

Prototype:

```
char SWPutsI2C(
      unsigned char *wrdptr );
```

Arguments: ***wrdptr***

Pointer to data to be written to the I^{2}C bus.

Remarks: This function writes out a data string up to (but not including) a null character.

Return Value: -1 if there was an error writing to the I^{2}C bus

0 otherwise

File Name: `swptsi2c.c`

Code Example:

```
char mybuff [] = “Hello”;
SWPutsI2C(mybuff);
```

SWReadI2C
SWGetcI2C

Function: Read a byte from the I^{2}C bus.

Include: `sw_i2c.h`

Prototype: `char SWReadI2C( void );`

Remarks: This function reads in a single data byte by generating the appropriate signals on the predefined I^{2}C clock line.

Return Value: This function returns the acquired I^{2}C data byte.

-1 if there was an error in this function.

File Name: `swgtci2c.c`

SWRestartI2C

Function: Generate an I^{2}C *Restart* bus condition.

Include: `sw_i2c.h`

Prototype: `void SWRestartI2C( void );`

Remarks: This function is called to generate an I^{2}C bus restart condition.

File Name: `swrsti2c.c`

SWStartI2C

Function:	Generate an I^{2}C bus *Start* condition.
Include:	`sw_i2c.h`
Prototype:	`void SWStartI2C( void );`
Remarks:	This function is called to generate an I^{2}C bus Start condition.
File Name:	`swstri2c.c`

SWStopI2C

Function:	Generate an I^{2}C bus *Stop* condition.
Include:	`sw_i2c.h`
Prototype:	`void SWStopI2C( void );`
Remarks:	This function is called to generate an I^{2}C bus Stop condition.
File Name:	`swstpi2c.c`

SWWriteI2C
SWPutcI2C

Function: Write a byte to the I^{2}C bus.

Include: `sw_i2c.h`

Prototype:

```
char SWWriteI2C(
      unsigned char data_out );
```

Arguments: ***data_out***
Single data byte to be written to the I^{2}C bus.

Remarks: This function writes out a single data byte to the predefined data pin.

Return Value: 0 if write is successful
-1 if there was an error condition

File Name: `swptci2c.c`

Code Example

```
if(SWWriteI2C(0x80))
  {
    errorHandler();
  }
```

3.4.2 Example of Use

The following is a simple code example illustrating a software I^{2}C implementation communicating with a Microchip 24LC01B I^{2}C EE memory device.

```
#include <p18cxxx.h>
#include <sw_i2c.h>
#include <delays.h>

// FUNCTION Prototype
void main(void);
void byte_write(void);
void page_write(void);
void current_address(void);
void random_read(void);
void sequential_read(void);
void ack_poll(void);
unsigned char warr[] = {8,7,6,5,4,3,2,1,0};
unsigned char rarr[15];
unsigned char far *rdptr = rarr;
unsigned char far *wrptr = warr;
unsigned char var;

#define W_CS  PORTA.2

//*************************************************
void main( void )
{
  byte_write();
  ack_poll();
  page_write();
  ack_poll();
  Nop();
  sequential_read();
  Nop();
  while (1);  // Loop indefinitely
}

void byte_write( void )
{
  SWStartI2C();
  var = SWPutcI2C(0xA0); // control byte
  SWAckI2C();
  var = SWPutcI2C(0x10); // word address
  SWAckI2C();
  var = SWPutcI2C(0x66); // data
  SWAckI2C();
  SWStopI2C();
}

void page_write( void )
{
  SWStartI2C();
  var = SWPutcI2C(0xA0); // control byte
  SWAckI2C();
  var = SWPutcI2C(0x20); // word address
  SWAckI2C();
  var = SWPutsI2C(wrptr); // data
  SWStopI2C();
}
```

```
void sequential_read( void )
{
  SWStartI2C();
  var = SWPutcI2C( 0xA0 ); // control byte
  SWAckI2C();
  var = SWPutcI2C( 0x00 ); // address to read from
  SWAckI2C();
  SWRestartI2C();
  var = SWPutcI2C( 0xA1 );
  SWAckI2C();
  var = SWGetsI2C( rdptr, 9 );
  SWStopI2C();
}

void current_address( void )
{
  SWStartI2C();
  SWPutcI2C( 0xA1 ); // control byte
  SWAckI2C();
  SWGetcI2C();     // word address
  SWNotAckI2C();
  SWStopI2C();
}

void ack_poll( void )
{
  SWStartI2C();
  var = SWPutcI2C( 0xA0 );  // control byte
  while( SWAckI2C() )
  {
    SWRestartI2C();
    var = SWPutcI2C(0xA0); // data
  }
  SWStopI2C();
}
```

3.5 SOFTWARE SPI™ FUNCTIONS

These functions are designed to allow the implementation of an SPI using I/O pins from a PIC18 microcontroller. The following functions are provided:

TABLE 3-8: SOFTWARE SPI™ FUNCTIONS

Function	Description
`ClearCSSWSPI`	Clear the Chip Select ($\overline{\text{CS}}$) pin.
`OpenSWSPI`	Configure the I/O pins for use as an SPI™.
`putcSWSPI`	Write a byte of data to the software SPI.
`SetCSSWSPI`	Set the Chip Select ($\overline{\text{CS}}$) pin.
`WriteSWSPI`	Write a byte of data to the software SPI bus.

The precompiled versions of these functions use default pin assignments that can be changed by redefining the macro assignments in the file `sw_spi.h`, found in the `h` subdirectory of the compiler installation:

TABLE 3-9: MACROS FOR SELECTING SPI™ PIN ASSIGNMENTS

LCD Controller Line	Macros	Default Value	Use
$\overline{\text{CS}}$ Pin	`SW_CS_PIN` `TRIS_SW_CS_PIN`	`PORTBbits.RB2` `TRISBbits.TRISB2`	Pin used for the Chip Select ($\overline{\text{CS}}$) line. Bit that controls the direction of the pin associated with the $\overline{\text{CS}}$ line.
DIN Pin	`SW_DIN_PIN` `TRIS_SW_DIN_PIN`	`PORTBbits.RB3` `TRISBbits.TRISB3`	Pin used for the DIN line. Bit that controls the direction of the pin associated with the DIN line.
DOUT Pin	`SW_DOUT_PIN` `TRIS_SW_DOUT_PIN`	`PORTBbits.RB7` `TRISBbits.TRISB7`	Pin used for the DOUT line. Bit that controls the direction of the pin associated with the DOUT line.
SCK Pin	`SW_SCK_PIN` `TRIS_SW_SCK_PIN`	`PORTBbits.RB6` `TRISBbits.TRISB6`	Pin used for the SCK line. Bit that controls the direction of the pin associated with the SCK line.

The libraries that are provided can operate in one of four modes. The table below lists the macros used for selecting between these modes. Exactly one of these must be defined when rebuilding the software SPI libraries.

TABLE 3-10: MACROS FOR SELECTING MODES

Macro	Default Value	Meaning

`MODE0`	defined	CKP = 0
		CKE = 0

`MODE1`	not defined	CKP = 1
		CKE = 0

`MODE2`	not defined	CKP = 0
		CKE = 1

`MODE3`	not defined	CKP = 1
		CKE = 1

After these definitions have been made, the user must recompile the software SPI routines and then include the updated files in the project. This can be accomplished by adding the software SPI source files into the project or by recompiling the library files using the provided batch files.

3.5.1 Function Descriptions

ClearCSSWSPI

Function: Clear the Chip Select ($\overline{CS}$) pin that is specified in the `sw_spi.h` header file.

Include: `sw_spi.h`

Prototype: `void ClearCSSWSPI( void );`

Remarks: This function clears the I/O pin that is specified in `sw_spi.h` to be the Chip Select ($\overline{CS}$) pin for the software SPI.

File Name: `clrcsspi.c`

OpenSWSPI

Function: Configure the I/O pins for the software SPI.

Include: `sw_spi.h`

Prototype: `void OpenSWSPI( void );`

Remarks: This function configures the I/O pins used for the software SPI to the correct input or ouput state and logic level.

File Name: `opensspi.c`

putcSWSPI

See **WriteSWSPI**.

SetCSSWSPI

Function: Set the Chip Select ($\overline{\text{CS}}$) pin that is specified in the `sw_spi.h` header file.

Include: `sw_spi.h`

Prototype: `void SetCSSWSPI( void );`

Remarks: This function sets the I/O pin that is specified in `sw_spi.h` to be the Chip Select ($\overline{\text{CS}}$) pin for the software SPI.

File Name: `setcsspi.c`

WriteSWSPI
putcSWSPI

Function: Write a byte to the software SPI.

Include: `sw_spi.h`

Prototype: `char WriteSWSPI( char` ***`data`*** `);`

Arguments: ***`data`***
Data to be written to the software SPI.

Remarks: This function writes the specified byte of data out the software SPI and returns the byte of data that was read. This function does not provide any control of the Chip Select pin ($\overline{\text{CS}}$).

Return Value: This function returns the byte of data that was read from the data in (DIN) pin of the software SPI.

File Name: `wrtsspi.c`

Code Example:

```
char addr = 0x10;
char result;
result = WriteSWSPI( addr );
```

3.5.2 Example of Use

```
#include <p18C452.h>
#include <sw_spi.h>
#include <delays.h>

void main( void )
{
  char address;

  // configure software SPI
  OpenSWSPI();

  for( address=0; address<0x10; address++ )
  {
    ClearCSSWSPI();         //clear CS pin
    WriteSWSPI( 0x02 );     //send write cmd
    WriteSWSPI( address ); //send address hi
    WriteSWSPI( address ); //send address low
    SetCSSWSPI();           //set CS pin
    Delay10KTCYx( 50 );     //wait 5000,000TCY
  }
}
```

3.6 SOFTWARE UART FUNCTIONS

These functions are designed to allow the implementation of a UART using I/O pins from a PIC18 microcontroller. The following functions are provided:

TABLE 3-11: SOFTWARE UART FUNCTIONS

Function	Description
`getcUART`	Read a byte from the software UART.
`getsUART`	Read a string from the software UART.
`OpenUART`	Configure I/O pins for use as a UART.
`putcUART`	Write a byte to the software UART.
`putsUART`	Write a string to the software UART.
`ReadUART`	Read a byte from the software UART.
`WriteUART`	Write a byte to the software UART.

The precompiled versions of these functions use default pin assignments that can be changed by redefining the equate (equ) statements in the files `writuart.asm`, `readuart.asm` and `openuart.asm`, found in the `src/traditional/pmc/sw_uart or scr/extended/pmc/sw_uart` subdirectory of the compiler installation:

TABLE 3-12: MACROS FOR SELECTING UART PIN ASSIGNMENTS

LCD Controller Line	Definition	Default Value	Use
TX Pin	`SWTXD`	`PORTB`	Port used for the transmit line.
	`SWTXDpin`	`4`	Bit in the `SWTXD` port used for the TX line.
	`TRIS_SWTXD`	`TRISB`	Data Direction register associated with the port used for the TX line.
RX Pin	`SWRXD`	`PORTB`	Port used for the receive line.
	`SWRXDpin`	`5`	Bit in the `SWRXD` port used for the RX line.
	`TRIS_SWRXD`	`TRISB`	Data Direction register associated with the port used for the RX line.

If changes to these definitions are made, the user must recompile the software UART routines and then include the updated files in the project. This can be accomplished by adding the software UART source files into the project or by recompiling the library files using the batch files provided with the MPLAB C18 compiler installation.

The UART libraries also require that the following functions be defined by the user to provide the appropriate delays:

TABLE 3-13: SOFTWARE UART DELAY FUNCTIONS

Function	Behavior
`DelayTXBitUART`	Delay for: ((((2*Fosc) / (4*baud)) + 1) / 2) - 12 cycles
`DelayRXHalfBitUART`	Delay for: ((((2*Fosc) / (8*baud)) + 1) / 2) - 9 cycles
`DelayRXBitUART`	Delay for: ((((2*Fosc) / (4*baud)) + 1) / 2) - 14 cycles

3.6.1 Function Descriptions

getcUART

See **ReadUART**.

getsUART

Function: Read a string from the software UART.

Include: `sw_uart.h`

Prototype:

```
void getsUART( char * buffer,
               unsigned char len);
```

Arguments: ***`buffer`***
Pointer to the string of characters read from the software UART.
`len`
Number of characters to be read from the software UART.

Remarks: This function reads ***`len`*** characters from the software UART and places them in ***`buffer`***.

File Name: `getsuart.c`

Code Example:

```
char x[10];
getsUART( x, 5 );
```

OpenUART

Function: Configure the I/O pins for the software UART.

Include: `sw_uart.h`

Prototype: `void OpenUART( void );`

Remarks: This function configures the I/O pins used for the software UART to the correct input or ouput state and logic level.

File Name: `openuart.asm`

Code Example: `OpenUART();`

putcUART

See **WriteUART**.

putsUART

Function: Write a string to the software UART.

Include: `sw_uart.h`

Prototype: `void putsUART( char * buffer );`

Arguments: ***`buffer`***
String to be written to the software UART.

Remarks: This function writes a string of characters to the software UART. The entire string including the null is sent to the UART.

File Name: `putsuart.c`

Code Example:

```
char mybuff [] = “Hello”;
putsUART( mybuff );
```

ReadUART
getcUART

Function:	Read a byte from the software UART.
Include:	`sw_uart.h`
Prototype:	`char ReadUART( void );`
Remarks:	This function reads a byte of data out the software UART.
Return Value:	Returns the byte of data that was read from the receive data (RXD) pin of the software UART.
File Name:	`readuart.asm`

Code Example:	`char x;`
	`x = ReadUART();`

WriteUART
putcUART

Function:	Write a byte to the software UART.
Include:	`sw_uart.h`
Prototype:	`void WriteUART( char` ***`data`*** `);`
Arguments:	***data*** Byte of data to be written to software UART.
Remarks:	This function writes the specified byte of data out the software UART.
File Name:	`writuart.asm`

Code Example:	`char x = ‘H’;`
	`WriteUART( x );`

3.6.2 Example of Use

```
#include <p18C452.h>
#include <sw_uart.h>

void main( void )
{
  char data;

  // configure software UART
  OpenUART();

  while( 1 )
  {
    data = ReadUART();   //read a byte
    WriteUART( data );   //bounce it back
  }
}
```

Chapter 4. General Software Library

4.1 INTRODUCTION

This chapter documents general software library functions found in the precompiled standard C library file. The source code for all of these functions is included with MPLAB C18 in the following subdirectories of the compiler installation:

- `src\traditional\stdlib`
- `src\extended\stdlib`
- `src\traditional\delays`
- `src\extended\delays`

The following categories of routines are supported by the MPLAB C18 library:

- Character Classification Functions
- Data Conversion Functions
- Memory and String Manipulation Functions
- Delay Functions
- Reset Functions
- Character Output Functions

4.2 CHARACTER CLASSIFICATION FUNCTIONS

These functions are consistent with the ANSI 1989 standard C library functions of the same name. The following functions are provided:

TABLE 4-1: CHARACTER CLASSIFICATION FUNCTIONS

Function	Description
`isalnum`	Determine if a character is alphanumeric.
`isalpha`	Determine if a character is alphabetic.
`iscntrl`	Determine if a character is a control character.
`isdigit`	Determine if a character is a decimal digit.
`isgraph`	Determine if a character is a graphical character.
`islower`	Determine if a character is a lowercase alphabetic character.
`isprint`	Determine if a character is a printable character.
`ispunct`	Determine if a character is a punctuation character.
`isspace`	Determine if a character is a white space character.
`isupper`	Determine if a character is an uppercase alphabetic character.
`isxdigit`	Determine if a character is a hexadecimal digit.

4.2.1 Function Descriptions

isalnum

Function:	Determine if a character is alphanumeric.
Include:	`ctype.h`
Prototype:	`unsigned char isalnum( unsigned char` ***`ch`*** `);`
Arguments:	***ch*** Character to be checked.
Remarks:	A character is considered to be alphanumeric if it is in the range of ‘A’ to ‘Z’, ‘a’ to ‘z’ or ‘0’ to ‘9’.
Return Value:	Non-zero if the character is alphanumeric Zero otherwise
File Name:	`isalnum.c`

isalpha

Function:	Determine if a character is alphabetic.
Include:	`ctype.h`
Prototype:	`unsigned char isalpha( unsigned char` ***`ch`*** `);`
Arguments:	***`ch`*** Character to be checked.
Remarks:	A character is considered to be alphabetic if it is in the range of ‘A’ to ‘Z’ or ‘a’ to ‘z’.
Return Value:	Non-zero if the character is alphabetic Zero otherwise
File Name:	`isalpha.c`

iscntrl

Function:	Determine if a character is a control character.
Include:	`ctype.h`
Prototype:	`unsigned char iscntrl( unsigned char` ***`ch`*** `);`
Arguments:	***`ch`*** Character to be checked.
Remarks:	A character is considered to be a control character if it is not a printable character as defined by `isprint()`.
Return Value:	Non-zero if the character is a control character Zero otherwise
File Name:	`iscntrl.c`

isdigit

Function: Determine if a character is a decimal digit.

Include: `ctype.h`

Prototype: `unsigned char isdigit( unsigned char ch );`

Arguments: ***ch***
Character to be checked.

Remarks: A character is considered to be a digit character if it is in the range of ‘0’ to ‘9’.

Return Value: Non-zero if the character is a digit character
Zero otherwise

File Name: `isdigit.c`

isgraph

Function: Determine if a character is a graphical character.

Include: `ctype.h`

Prototype: `unsigned char isgraph( unsigned char ch );`

Arguments: ***ch***
Character to be checked.

Remarks: A character is considered to be a graphical case alphabetic character if it is any printable character except space.

Return Value: Non-zero if the character is a graphical character
Zero otherwise

File Name: `isgraph.c`

islower

Function: Determine if a character is a lowercase alphabetic character.

Include: `ctype.h`

Prototype: `unsigned char islower( unsigned char ch );`

Arguments: ***ch***
Character to be checked.

Remarks: A character is considered to be a lowercase alphabetic character if it is in the range of ‘a’ to ‘z’.

Return Value: Non-zero if the character is a lowercase alphabetic character
Zero otherwise

File Name: `islower.c`

isprint

Function: Determine if a character is a printable character.

Include: `ctype.h`

Prototype: `unsigned char isprint( unsigned char ch );`

Arguments: ***ch***
Character to be checked.

Remarks: A character is considered to be a printable character if it is in the range 0x20 to 0x7e, inclusive.

Return Value: Non-zero if the character is a printable character
Zero otherwise

File Name: `isprint.c`

ispunct

Function: Determine if a character is a punctuation character.

Include: `ctype.h`

Prototype: `unsigned char ispunct( unsigned char ch );`

Arguments: ***ch***
Character to be checked.

Remarks: A character is considered to be a punctuation character if it is a printable character which is neither a space nor an alphanumeric character.

Return Value: Non-zero if the character is a punctuation character
Zero otherwise

File Name: `ispunct.c`

isspace

Function: Determine if a character is a white space character.

Include: `ctype.h`

Prototype: `unsigned char isspace (unsigned char ch);`

Arguments: ***ch***
Character to be checked.

Remarks: A character is considered to be a white space character if it is one of the following: space (‘ ’), tab(‘\t’), carriage return (‘\r’), new line (‘\n’), form feed (‘\f’) or vertical tab (‘\v’).

Return Value: Non-zero if the character is a white space character
Zero otherwise

File Name: `isspace.c`

isupper

Function:	Determine if a character is an uppercase alphabetic character.
Include:	`ctype.h`
Prototype:	`unsigned char isupper (unsigned char` ***`ch`***`);`
Arguments:	***`ch`*** Character to be checked.
Remarks:	A character is considered to be an uppercase alphabetic character if it is in the range of ‘A’ to ‘Z’.
Return Value:	Non-zero if the character is an uppercase alphabetic character Zero otherwise
File Name:	`isupper.c`

isxdigit

Function:	Determine if a character is a hexadecimal digit.
Include:	`ctype.h`
Prototype:	`unsigned char isxdigit( unsigned char` ***`ch`*** `);`
Arguments:	***`ch`*** Character to be checked.
Remarks:	A character is considered to be a hexidecimal digit character if it is in the range of ‘0’ to ‘9’, ‘a’ to ‘f’ or ‘A’ to ‘F’.
Return Value:	Non-zero if the character is a hexidecimal digit character Zero otherwise
File Name:	`isxdig.c`

4.3 DATA CONVERSION FUNCTIONS

Except as noted in the function descriptions, these functions are consistent with the ANSI 1989 standard C library functions of the same name. The functions provided are:

TABLE 4-2: DATA CONVERSION FUNCTIONS

Function	Description
`atob`	Convert a string to an 8-bit signed byte.
`atof`	Convert a string into a floating point value.
`atoi`	Convert a string to a 16-bit signed integer.
`atol`	Convert a string into a long integer representation.
`btoa`	Convert an 8-bit signed byte to a string.
`itoa`	Convert a 16-bit signed integer to a string.
`ltoa`	Convert a signed long integer to a string.
`rand`	Generate a pseudo-random integer.
`srand`	Set the starting seed for the pseudo-random number generator.
`tolower`	Convert a character to a lowercase alphabetical ASCII character.
`toupper`	Convert a character to an uppercase alphabetical ASCII character.
`ultoa`	Convert an unsigned long integer to a string.

4.3.1 Function Descriptions

atob

Function: Convert a string to an 8-bit signed byte.

Include: `stdlib.h`

Prototype: `signed char atob( const char * s );`

Arguments: ***s***
Pointer to ASCII string to be converted.

Remarks: This function converts the ASCII string `s` into an 8-bit signed byte (-128 to 127). The input string must be in base 10 (decimal radix) and can begin with a character indicating sign (‘+’ or ‘-’). Overflow results are undefined. This function is an MPLAB C18 extension to the ANSI standard libraries.

Return Value: 8-bit signed byte for all strings in the range (-128 to 127).

File Name: `atob.asm`

atof

Function: Convert a string into a floating point value.

Include: `stdlib.h`

Prototype: `double atof ( const char * s );`

Arguments: ***s***
Pointer to ASCII string to be converted.

Remarks: This function converts the ASCII string ***s*** into a floating point value. Examples of floating point strings that are recognized are:

```
-3.1415
1.0E2
1.0E+2
1.0E-2
```

Return Value: The function returns the converted value.

File Name: `atof.c`

atoi

Function:	Convert a string to a 16-bit signed integer.
Include:	`stdlib.h`
Prototype:	`int atoi( const char * s );`
Arguments:	***s*** Pointer to ASCII string to be converted.
Remarks:	This function converts the ASCII string ***s*** into an 16-bit signed integer (-32768 to 32767). The input string must be in base 10 (decimal radix) and can begin with a character indicating sign ('+' or '-'). Overflow results are undefined. This function is an MPLAB C18 extension to the ANSI standard libraries.
Return Value:	16-bit signed integer for all strings in the range (-32768 to 32767).
File Name:	`atoi.asm`

atol

Function:	Convert a string into a long integer representation.
Include:	`stdlib.h`
Prototype:	`long atol( const char * s );`
Arguments:	***s*** Pointer to ASCII string to be converted.
Remarks:	This function converts the ASCII string ***s*** into a long value. The input string must be in base 10 (decimal radix) and can begin with a character indicating sign ('+' or '-'). Overflow results are undefined. This function is an MPLAB C18 extension to the ANSI standard libraries.
Return Value:	The function returns the converted value.
File Name:	`atol.asm`

btoa

Function:	Convert an 8-bit signed byte to a string.
Include:	`stdlib.h`

Prototype:	`char * btoa( signed char value,`
	`             char * string );`

Arguments:	***value*** An 8-bit signed byte. ***string*** Pointer to ASCII string that will hold the result. ***string*** must be long enough to hold the ASCII representation, including the sign character for negative values and a trailing null character.
Remarks:	This function converts the 8-bit signed byte in the argument ***value*** to a ASCII string representation. This function is an MPLAB C18 extension of the ANSI required libraries.
Return Value:	Pointer to the result ***string***.
File Name:	`btoa.asm`

itoa

Function: Convert a 16-bit signed integer to a string.

Include: `stdlib.h`

Prototype:

```
char * itoa( int value,
             char * string );
```

Arguments:

value
A 16-bit signed integer.

string
Pointer to ASCII string that will hold the result. ***string*** must be long enough to hold the ASCII representation, including the sign character for negative values and a trailing null character.

Remarks: This function converts the 16-bit signed integer in the argument ***value*** to a ASCII string representation.

This function is an MPLAB C18 extension of the ANSI required libraries.

Return Value: Pointer to the result ***string***.

File Name: `itoa.asm`

ltoa

Function: Convert a signed long integer to a string.

Include: `stdlib.h`

Prototype:

```
char * ltoa( long value,
             char * string );
```

Arguments:

value
A signed long integer to be converted.

string
Pointer to ASCII string that will hold the result.

Remarks: This function converts the signed long integer in the argument ***value*** to a ASCII string representation. ***string*** must be long enough to hold the ASCII representation, including the sign character for negative values and a trailing null character. This function is an MPLAB C18 extension to the ANSI required libraries.

Return Value: Pointer to the result ***string***.

File Name: `ltoa.asm`

rand

Function: Generate a pseudo-random integer.

Include: `stdlib.h`

Prototype: `int rand( void );`

Remarks: Calls to this function return pseudo-random integer values in the range [0,32767]. To use this function effectively, you must seed the random number generator using the `srand()` function. This function will always return the same sequence of integers when identical seed values are used.

Return Value: A psuedo-random integer value.

File Name: `rand.asm`

srand

Function: Set the starting seed for the pseudo-random number sequence.

Include: `stdlib.h`

Prototype: `void srand( unsigned int seed );`

Arguments: ***seed***
The starting value for the pseudo-random number sequence.

Remarks: This function sets the starting seed for the pseudo-random number sequence generated by the `rand()` function. The `rand()` function will always return the same sequence of integers when identical seed values are used. If `rand()` is called without `srand()` having first been called, the sequence of numbers generated will be the same as if `srand()` had been called with a seed value of 1.

File Name: `rand.asm`

tolower

Function: Convert a character to a lowercase alphabetical ASCII character.

Include: `ctype.h`

Prototype: `char tolower( char ch );`

Arguments: ***ch***
Character to be converted.

Remarks: This function converts ***ch*** to a lowercase alphabetical ASCII character provided that the argument is a valid uppercase alphabetical character.

Return Value: This function returns a lowercase character if the argument was uppercase to begin with; otherwise the original character is returned.

File Name: `tolower.c`

toupper

Function: Convert a character to an uppercase alphabetical ASCII character.

Include: `ctype.h`

Prototype: `char toupper( char ch );`

Arguments: ***ch***
Character to be converted.

Remarks: This function converts ***ch*** to a uppercase alphabetical ASCII character provided that the argument is a valid lowercase alphabetical character.

Return Value: This function returns an uppercase character if the argument was lowercase to begin with; otherwise the original character is returned.

File Name: `toupper.c`

ultoa

Function:	Convert an unsigned long integer to a string.
Include:	`stdlib.h`

Prototype:	`char * ultoa( unsigned long` ***`value`***`,`
	`char *` ***`string`***`);`

Arguments:	***`value`***
	An unsigned long integer to be converted.
	`string`
	Pointer to ASCII string that will hold the result.

Remarks:	This function converts the unsigned long integer in the argument ***`value`*** to a ASCII string representation. ***`string`*** must be long enough to hold the ASCII representation, including a trailing null character. This function is an MPLAB C18 extension to the ANSI required libraries.
Return Value:	Pointer to the result ***`string`***.
File Name:	`ultoa.asm`

4.4 MEMORY AND STRING MANIPULATION FUNCTIONS

Except as noted in the function descriptions, these functions are consistent with the ANSI (1989) standard C library functions of the same name. The following functions are provided:

TABLE 4-3: MEMORY AND STRING MANIPULATION FUNCTIONS

Function	Description
`memchr` `memchrpgm`	Search for a value in a specified memory region.

`memcmp`
`memcmppgm`
`memcmppgm2ram`
`memcmpram2pgm`
	Compare the contents of two arrays.

`memcpy`
`memcpypgm`
`memcpypgm2ram`
`memcpyram2pgm`
	Copy a buffer.

`memmove`
`memmovepgm`
`memmovepgm2ram`
`memmoveram2pgm`
	Copy a buffer, where the source and destination may overlap.

`memset` `memsetpgm`	Initialize an array with a single repeated value.

`strcat`
`strcatpgm`
`strcatpgm2ram`
`strcatram2pgm`
	Append a copy of the source string to the end of the destination string.

`strchr` `strchrpgm`	Locate the first occurrence of a value in a string.

`strcmp`
`strcmppgm`
`strcmppgm2ram`
`strcmpram2pgm`
	Compare two strings.

`strcpy`
`strcpypgm`
`strcpypgm2ram`
`strcpyram2pgm`
	Copy a string from data or program memory into data memory.

TABLE 4-3: MEMORY AND STRING MANIPULATION FUNCTIONS (CONTINUED)

strcspn strcspnpgm strcspnpgmram strcspnrampgm	Calculate the number of consecutive characters at the beginning of a string that are not contained in a set of characters.
strlen strlenpgm	Determine the length of a string.
strlwr strlwrpgm	Convert all uppercase characters in a string to lowercase.
strncat strncatpgm strncatpgm2ram strncatram2pgm	Append a specified number of characters from the source string to the end of the destination string.
strncmp strncmppgm strncmppgm2ram strncmpram2pgm	Compare two strings, up to a specified number of characters.
strncpy strncpypgm strncpypgm2ram strncpyram2pgm	Copy characters from the source string into the destination string, up to the specified number of characters.
strpbrk strpbrkpgm strpbrkpgmram strpbrkrampgm	Search a string for the first occurrence of a character from a set of characters.
strrchr strrchrpgm	Locate the last occurrence of a specified character in a string.
strspn strspnpgm strspnpgmram strspnrampgm	Calculate the number of consecutive characters at the beginning of a string that are contained in a set of characters.
strstr strstrpgm strstrpgmram strstrrampgm	Locate the first occurrence of a string inside another string.
strtok strtokpgm strtokpgmram strtokrampgm	Break a string into substrings or tokens, by inserting null characters in place of specified delimiters.
strupr struprpgm	Convert all lowercase characters in a string to uppercase.

4.4.1 Function Descriptions

memchr
memchrpgm

Function: Locate the first occurrence of a byte value in a specified memory region.

Include: `string.h`

Prototype:

```
void * memchr( const void *mem,
               unsigned char c,
               size_t n );
rom char * memchrpgm( const rom char *mem,
                      const unsigned char c,
                      sizerom_t n );
```

Arguments:

mem
Pointer to a memory region.

c
Byte value to find.

n
Maximum number of bytes to search.

Remarks: This function searches up to ***n*** bytes of the region ***mem*** to find the first occurrence of ***c***.
This function differs from the ANSI specified function in that ***c*** is defined as an `unsigned char` parameter rather than an `int parameter`.

Return Value: If ***c*** appears in the first ***n*** bytes of ***mem***, this function returns a pointer to the character in ***mem***. Otherwise, it returns a null pointer.

File Names:
`memchr.asm`
`mchrpgm.asm`

memcmp
memcmppgm
memcmppgm2ram
memcmpram2pgm

Function: Compare the contents of two arrays of bytes.

Include: `string.h`

Prototype:

```
signed char memcmp(
       const void * buf1,
       const void * buf2,
       size_t memsize );
signed char memcmppgm(
       const rom void * buf1,
       const rom void * buf2,
       sizerom_t memsize );
signed char memcmppgm2ram(
       const void * buf1,
       const rom void * buf2,
       sizeram_t memsize );
signed char memcmpram2pgm(
       const rom void * buf1,
       const void * buf2,
       sizeram_t memsize );
```

memcmp
memcmppgm
memcmppgm2ram
memcmpram2pgm (Continued)

Arguments:

buf1
Pointer to first array.
buf2
Pointer to second array.
memsize
Number of elements to be compared in arrays.

Remarks: This function compares the first ***memsize*** number of bytes in ***buf1*** to the first ***memsize*** number of bytes in ***buf2*** and returns a value indicating whether the buffers are less than, equal to or greater than each other.

Return Value: Returns a value that is:

<0 if ***buf1*** is less than ***buf2***
==0 if ***buf1*** is the same as ***buf2***
>0 if ***buf1*** is greater than ***buf2***

File Names:

```
memcmp.asm
memcmpp2p.asm
memcmpp2r.asm
memcmpr2p.asm
```

memcpy
memcpypgm
memcpypgm2ram
memcpyram2pgm

Function: Copy the contents of the source buffer into the destination buffer.

Include: `string.h`

Prototype:

```
void * memcpy(
             void * dest,
             const void * src,
             size_t memsize );
rom void * memcpypgm(
             rom void * dest,
             const rom void * src,
             sizerom_t memsize );
void * memcpypgm2ram(
             void * dest,
             const rom void * src,
             sizeram_t memsize );
rom void * memcpyram2pgm(
             rom void * dest,
             const void * src,
             sizeram_t memsize );
```

Arguments:

dest
Pointer to destination array.
src
Pointer to source array.
memsize
Number of bytes of ***src*** array to copy into ***dest***.

Remarks: This function copies the first ***memsize*** number of bytes in ***src*** to the array ***dest***. If ***src*** and ***dest*** overlap, the behavior is undefined.

memcpy
memcpypgm
memcpypgm2ram
memcpyram2pgm (Continued)

Return Value: This function returns the value of ***dest***.

File Names:

```
memcpy.asm
memcpyp2p.asm
memcpyp2r.asm
memcpyr2p.asm
```

memmove
memmovepgm
memmovepgm2ram
memmoveram2pgm

Function: Copy the contents of the source buffer into the destination buffer, even if the regions overlap.

Include: `string.h`

Prototype:

```
void * memmove( void * dest,
                const void * src,
                size_t memsize );
rom void * memmovepgm(
                rom void * dest,
                const rom void * src,
                sizerom_t memsize );
void * memmovepgm2ram(
                void * dest,
                const rom void * src,
                sizeram_t memsize );
rom void * memmoveram2pgm(
                rom void * dest,
                const void * src,
                sizeram_t memsize );
```

Arguments:

dest
Pointer to destination array.

src
Pointer to source array.

memsize
Number of bytes of ***src*** array to copy into ***dest***.

Remarks: This function copies the first ***memsize*** number of bytes in ***src*** to the array ***dest***. This function performs correctly even if ***src*** and ***dest*** overlap.

Return Value: This function returns the value of ***dest***.

File Names:

```
memmove.asm
memmovp2p.asm
memmovp2r.asm
memmovr2p.asm
```

memset
memsetpgm

Function: Copy the specified character into the destination array.

Include: `string.h`

Prototype:

```
void * memset( void * dest,
               unsigned char value,
               size_t memsize );
rom void * memsetpgm(
               rom void * dest,
               unsigned char value,
               sizerom_t memsize );
```

Arguments:

dest
Pointer to destination array.

value
Character value to be copied.

memsize
Number of bytes of ***dest*** into which ***value*** is copied.

Remarks: This function copies the character ***value*** into the first ***memsize*** bytes of the array ***dest***. This functions differs from the ANSI specified function in that ***value*** is defined as an `unsigned char` rather than as an `int` parameter.

Return Value: This function returns the value of ***dest***.

File Name:

```
memset.asm
memsetpgm.asm
```

strcat
strcatpgm
strcatpgm2ram
strcatram2pgm

Function: Append a copy of the source string to the end of the destination string.

Include: `string.h`

Prototype:

```
char * strcat( char * dest,
               const char * src );
rom char * strcatpgm(
               rom char * dest,
               const rom char * src );
char * strcatpgm2ram(
               char * dest,
               const rom char * src );
rom char * strcatram2pgm(
               rom char * dest,
               const char * src );
```

Arguments:

dest
Pointer to destination array.

src
Pointer to source array.

Remarks: This function copies the string in ***src*** to the end of the string in ***dest***. The ***src*** string starts at the null in ***dest***. A null character is added to the end of the resulting string in ***dest***. If ***src*** and ***dest*** overlap, the behavior is undefined.

Return Value: This function returns the value of ***dest***.

strcat
strcatpgm
strcatpgm2ram
strcatram2pgm (Continued)

File Names:

```
strcat.asm
scatp2p.asm
scatp2r.asm
scatp2p.asm
```

strchr
strchrpgm

Function: Locate the first occurrence of a specified character in a string.

Include: `string.h`

Prototype:

```
char * strchr( const char * str,
               unsigned char c );
rom char * strchrpgm(
               const rom char * str,
               unsigned char c );
```

Arguments:

str
Pointer to a string to be searched.
c
Character to find.

Remarks: This function searches the string ***str*** to find the first occurrence of character ***c***.
This function differs from the ANSI specified function in that ***c*** is defined as an `unsigned char` parameter rather than an `int` parameter.

Return Value: If ***c*** appears in ***str***, this function returns a pointer to the character in ***str***. Otherwise, it returns a null pointer.

File Names:

```
strchr.asm
schrpgm.asm
```

strcmp
strcmppgm
strcmppgm2ram
strcmpram2pgm

Function: Compare two strings.

Include: `string.h`

Prototype:

```
signed char strcmp(
      const char * str1,
      const char * str2 );
signed char strcmppgm(
      const rom char * str1,
      const rom char * str2 );
signed char strcmppgm2ram(
      const char * str1,
      const rom char * str2 );
signed char strcmpram2pgm(
      const rom char * str1,
      const char * str2 );
```

strcmp
strcmppgm
strcmppgm2ram
strcmpram2pgm

Arguments: ***str1***
Pointer to first string.
str2
Pointer to second string.

Remarks: This function compares the string in ***str1*** to the string in ***str2*** and returns a value indicating if ***str1*** is less than, equal to or greater than ***str2***.

Return Value: Returns a value that is:
<0 if ***str1*** is less than ***str2***
==0 if ***str1*** is the same as ***str2***
>0 if ***str1*** is greater than ***str2***

File Name:
```
strcmp.asm
scmpp2p.asm
scmpp2r.asm
scmpr2p.asm
```

strcpy
strcpypgm
strcpypgm2ram
strcpyram2pgm

Function: Copy the source string into the destination string.

Include: `string.h`

Prototype:
```
char * strcpy( char * dest,
               const char * src );
rom char * strcpypgm(
               rom char * dest,
               const rom char * src );char *
char * strcpypgm2ram(
               char * dest,
               const rom char *src );
rom char * strcpyram2pgm(
               rom char * dest,
               const char * src );
```

Arguments: ***dest***
Pointer to destination string.
src
Pointer to source string.

Remarks: This function copies the string in ***src*** to ***dest***. Characters in ***src*** are copied up to, and including, the terminating null character in ***src***. If ***src*** and ***dest*** overlap, the behavior is undefined.

Return Value: This function returns the value of ***dest***.

File Name:
```
strcpy.asm
scpyp2p.asm
scpyp2r.asm
scpyr2p.asm
```

strcspn
strcspnpgm
strcspnpgmram
strcspnrampgm

Function: Calculate the number of consecutive characters at the beginning of a string that are not contained in a set of characters.

Include: `string.h`

Prototype:

```
size_t strcspn( const char * str1,
                const char * str2 );
sizerom_t strcspnpgm(
                  const rom char * str1,
                  const rom char * str2 );
sizerom_t strcspnpgmram(
                  const rom char * str1,
                  const char * str2 );
sizeram_t strcspnrampgm(
                  const char * str1,
                  const rom char * str2 );
```

Arguments: ***str1***

Pointer to a string to be searched.

str2

Pointer to a string that is treated as a set of characters.

Remarks: This function will determine the number of consecutive characters from the beginning of ***str1*** that are not contained in ***str2***. For example:

str1	***str2***	**result**
“hello”	“aeiou”	1
“antelope”	“aeiou”	0
“antelope”	“xyz”	8

Return Value: This function returns the number of consecutive characters from the beginning of ***str1*** that are not contained in ***str2***, as shown in the examples above.

File Names:

```
strcspn.asm
scspnpp.asm
scspnpr.asm
scspnrp.asm
```

strlen
strlenpgm

Function: Return the length of the string.

Include: `string.h`

Prototype:

```
size_t strlen( const char * str );
sizerom_t strlenpgm( const rom char * str );
```

Arguments: ***str***

Pointer to string.

Remarks: This function determines the length of the string, not including the terminating null character.

Return Value: This function returns the length of the string.

File Name:

```
strlen.asm
slenpgm.asm
```

strlwr
strlwrpgm

Function: Convert all uppercase characters in a string to lowercase.

Include: `string.h`

Prototype:

```
char * strlwr( char * str );
rom char * strlwrpgm( rom char * str );
```

Arguments: ***str***
Pointer to string.

Remarks: This function converts all uppercase characters in ***str*** to lowercase characters. All characters that are not uppercase (A to Z) are not affected.

Return Value: This function returns the value of ***str***.

File Name:
`strlwr.asm`
`slwrpgm.asm`

strncat
strncatpgm
strncatpgm2ram
strncatram2pgm

Function: Append a specified number of characters from the source string to the destination string.

Include: `string.h`

Prototype:

```
char * strncat( char * dest,
                const char * src,
                size_t n );
rom char * strncatpgm(
                rom char * dest,
                const rom char * src,
                sizerom_t n );
char * strncatpgm2ram(
                char * dest,
                const rom char * src,
                sizeram_t n );
rom char * strncatram2pgm(
                rom char * dest,
                const char * src,
                sizeram_t n );
```

Arguments: ***dest***
Pointer to destination array.
src
Pointer to source array.
n
Number of characters to append.

Remarks: This function appends exactly ***n*** characters from the string in ***src*** to the end of the string in ***dest***. If a null character is copied before ***n*** characters have been copied, null characters will be appended to ***dest*** until exactly ***n*** characters have been appended.
If ***src*** and ***dest*** overlap, the behavior is undefined.
If a null character is not encountered, then a null character is not appended.

Return Value: This function returns the value of ***dest***.

strncat
strncatpgm
strncatpgm2ram
strncatram2pgm (Continued)

File Names:

```
strncat.asm
sncatp2p.asm
sncatp2r.asm
sncatr2p.asm
```

strncmp
strncmppgm
strncmppgm2ram
strncmpram2pgm

Function: Compare two strings, up to a specified number of characters.

Include: `string.h`

Prototype:

```
signed char strncmp( const char * str1,
                     const char * str2,
                     size_t n );
signed char strncmppgm(
                     const rom char * str1,
                     const rom char * str2,
                     sizerom_t n );
signed char strncmppgm2ram(
                     const char * str1,
                     const rom char * str2,
                     sizeram_t n );
signed char strncmpram2pgm(
                     const rom char * str1,
                     const char * str2,
                     sizeram_t n );
```

Arguments:

str1
Pointer to first string.

str2
Pointer to second string.

n
Maximum number of characters to compare.

Remarks: This function compares the string in ***str1*** to the string in ***str2*** and returns a value indicating if ***str1*** is less than, equal to or greater than ***str2***. If ***n*** characters are compared and no differences are found, this function will return a value indicating that the strings are equivalent.

Return Value: Returns a value based on the first character that differs between ***str1*** and ***str2***. It returns:

<0	if ***str1*** is less than ***str2***
==0	if ***str1*** is the same as ***str2***
>0	if ***str1*** is greater than ***str2***

File Name:

```
strncmp.asm
sncmpp2p.asm
sncmpp2r.asm
sncmpr2p.asm
```

strncpy
strncpypgm
strncpypgm2ram
strncpyram2pgm

Function: Copy characters from the source string into the destination string, up to the specified number of characters.

Include: `string.h`

Prototype:

```
char * strncpy( char * dest,
                const char * src,
                size_t n );
rom char * strncpypgm(
                rom char * dest,
                const rom char * src,
                sizerom_t n );
char *strncpypgm2ram(
                char * dest,
                const rom char * src,
                sizeram_t n );
rom char * strncpyram2pgm(
                rom char * dest,
                const char * src,
                sizeram_t n );
```

Arguments:

dest
Pointer to destination string.
src
Pointer to source string.
n
Maximum number of characters to copy.

Remarks: This function copies the string in ***src*** to ***dest***. Characters in ***src*** are copied into ***dest*** until the terminating null character or ***n*** characters have been copied. If ***n*** characters were copied and no null character was found then ***dest*** will not be null-terminated.
If copying takes place between objects that overlap, the behavior is undefined.

Return Value: This function returns the value of ***dest***.

File Name:

```
strncpy.asm
sncpyp2p.asm
sncpyp2r.asm
sncpyr2p.asm
```

strpbrk
strpbrkpgm
strpbrkpgmram
strpbrkrampgm

Function: Search a string for the first occurrence of a character from a specified set of characters.

Include: `string.h`

Prototype:

```
char * strpbrk( const char * str1,
                const char * str2 );
rom char * strpbrkpgm(
                const rom char * str1,
                const rom char * str2 );
rom char * strpbrkpgmram(
                const rom char * str1,
                const char * str2 );
char * strpbrkrampgm(
                const char * str1,
                const rom char * str2 );
```

Arguments: ***str1***
Pointer to a string to be searched.
str2
Pointer to a string that is treated as a set of characters.

Remarks: This function will search ***str1*** for the first occurrence of a character contained in ***str2***.

Return Value: If a character in ***str2*** is found, a pointer to that character in ***str1*** is returned. If no character from ***str2*** is found in ***str1***, a null pointer is returned.

File Names:
`strpbrk.asm`
`spbrkpp.asm`
`spbrkpr.asm`
`spbrkrp.asm`

strrchr

Function: Locate the last occurrence of a specified character in a string.

Include: `string.h`

Prototype:

```
char * strrchr( const char * str,
                const char c );
```

Arguments: ***str***
Pointer to a string to be searched.
c
Character to find.

Remarks: This function searches the string ***str***, including the terminating null character, to find the last occurrence of character ***c***.
This function differs from the ANSI specified function in that ***c*** is defined as an `unsigned char` parameter rather than an `int` parameter.

Return Value: If *c* appears in ***str***, this function returns a pointer to the character in ***str***. Otherwise, it returns a null pointer.

File Names: `strrchr.asm`

strspn
strspnpgm
strspnpgmram
strspnrampgm

Function: Calculate the number of consecutive characters at the beginning of a string that are contained in a set of characters.

Include: `string.h`

Prototype:

```
size_t strspn( const char * str1,
               const char * str2 );
sizerom_t strspnpgm(
               const rom char * str1,
               const rom char * str2 );
sizerom_t strspnpgmram(
               const rom char * str1,
               const char * str2 );
sizeram_t strspnrampgm(
               const char * str1,
               const rom char * str2 );
```

Arguments:

str1
Pointer to a string to be searched.

str2
Pointer to a string that is treated as a set of characters.

Remarks: This function will determine the number of consecutive characters from the beginning of ***str1*** that are contained in ***str2***. For example:

str1	***str2***	**result**
“banana”	“ab”	2
“banana”	“abn”	6
“banana”	“an”	0

Return Value: This function returns the number of consecutive characters from the beginning of ***str1*** that are contained in ***str2***, as shown in the examples above.

File Names:

```
strspn.asm
sspnpp.asm
sspnpr.asm
sspnrp.asm
```

strstr
strstrpgm
strstrpgmram
strstrrampgm

Function: Locate the first occurrence of a string inside another string.

Include: `string.h`

Prototype:

```
char * strstr( const char * str,
               const char * substr );
rom char * strstrpgm(
               const rom char * str,
               const rom char * substr );
rom char * strstrpgmram(
               const rom char * str,
               const char * substr );
char * strstrrampgm(
               const char * str,
               const rom char * substr );
```

Arguments: ***str***
Pointer to a string to be searched.
substr
Pointer to a string pattern for which to search.

Remarks: This function will find the first occurrence of the string ***substr*** (excluding the null terminator) within string ***str***.

Return Value: If the string is located, a pointer to that string in ***str*** will be returned. Otherwise a null pointer is returned.

File Names:

```
strstr.asm
sstrpp.asm
sstrpr.asm
sstrrp.asm
```

strtok
strtokpgm
strtokpgmram
strtokrampgm

Function: Break a string into substrings or tokens, by inserting null characters in place of specified delimiters.

Include: `string.h`

Prototype:

```
char * strtok( char * str,
               const char * delim );
rom char * strtokpgm(
               rom char * str,
               const rom char * delim );
char * strtokpgmram(
               char * str,
               const rom char * delim );
rom char * strtokrampgm(
               rom char * str,
               const char * delim );
```

Arguments: ***str***
Pointer to a string to be searched.
delim
Pointer to a set of characters that indicate the end of a token.

strtok
strtokpgm
strtokpgmram
strtokrampgm (Continued)

Remarks:

This function can be used to split up a string into substrings by replacing specified characters with null characters. The first time this function is invoked on a particular string, that string should be passed in ***str***. After the first time, this function can continue parsing the string from the last delimiter by invoking it with a null value passed in ***str***.

When `strtok` is invoked with a non-null parameter for ***str***, it starts searching ***str*** from the beginning. It skips all leading characters that appear in the string ***delim***, then skips all characters not appearing in ***delim***, then sets the next character to null.

When `strtok` is invoked with a null parameter for ***str***, it searches the string that was most recently examined, beginning with the character after the one that was set to null during the previous call. It skips all characters not appearing in ***delim***, then sets the next character to null.

If `strtok` finds the end of the string before it finds a delimiter, it does not modify the string.

The set of characters that is passed in ***delim*** need not be the same for each call to `strtok`.

Return Value:

If a delimiter was found, this function returns a pointer into ***str*** to the first character that was searched that did not appear in the set of characters ***delim***. This character represents the first character of a token that was created by the call.

If no delimiter was found prior to the terminating null character, a null pointer is returned from the function.

File Names:

```
strtok.asm
stokpgm.asm
stokpr.asm
stokrp.asm
```

strupr
struprpgm

Function: Convert all lowercase characters in a string to uppercase.

Include: `string.h`

Prototype:

```
char * strupr( char * str );
rom char * struprpgm( rom char * str );
```

Arguments:

str

Pointer to string.

Remarks: This function converts all lowercase characters in ***str*** to uppercase characters. All characters that are not lowercase (a to z) are not affected.

Return Value: This function returns the value of ***str***.

File Name:

```
strupr.asm
suprpgm.asm
```

4.5 DELAY FUNCTIONS

The delay functions execute code for a specific number of processor instruction cycles. For time based delays, the processor operating frequency must be taken into account. The following routines are provided:

TABLE 4-4: DELAY FUNCTIONS

Function	Description
`Delay1TCY`	Delay one instruction cycle.
`Delay10TCYx`	Delay in multiples of 10 instruction cycles.
`Delay100TCYx`	Delay in multiples of 100 instruction cycles.
`Delay1KTCYx`	Delay in multiples of 1,000 instruction cycles.
`Delay10KTCYx`	Delay in multiples of 10,000 instruction cycles.

4.5.1 Function Descriptions

Delay1TCY

Function: Delay 1 instruction cycle (TCY).

Include: `delays.h`

Prototype: `void Delay1TCY( void );`

Remarks: This function is actually a `#define` for the `NOP` instruction. When encountered in the source code, the compiler simply inserts a `NOP`.

File Name: `#define in delays.h`

Delay10TCYx

Function: Delay in multiples of 10 instruction cycles (TCY).

Include: `delays.h`

Prototype: `void Delay10TCYx( unsigned char` ***`unit`*** `);`

Arguments: ***`unit`***
The value of ***`unit`*** can be any 8-bit value. A value in the range [1,255] will delay (***`unit`*** * 10) cycles. A value of 0 causes a delay of 2,560 cycles.

Remarks: This function creates a delay in multiples of 10 instruction cycles.

File Name: `d10tcyx.asm`

Delay100TCYx

Function: Delay in multiples of 100 instruction cycles (TCY).

Include: `delays.h`

Prototype: `void Delay100TCYx( unsigned char` ***`unit`*** `);`

Arguments: ***`unit`***
The value of ***`unit`*** can be any 8-bit value. A value in the range [1,255] will delay (***`unit`*** * 100) cycles. A value of 0 causes a delay of 25,600 cycles.

Delay100TCYx (Continued)

Remarks: This function creates a delay in multiples of 100 instruction cycles. This function uses the globally allocated variable, `DelayCounter1`. If this function is used in both interrupt and mainline code, the variable `DelayCounter1` should be saved and restored in the interrupt handler. Refer to the `save=` clause of the `#pragma interrupt` or `#pragma interruptlow` directives for more information. Note that other delay functions also use the globally allocated `DelayCounter1` variable.

File Name: `d100tcyx.asm`

Delay1KTCYx

Function: Delay in multiples of 1,000 instruction cycles (TCY).

Include: `delays.h`

Prototype: `void Delay1KTCYx( unsigned char` ***`unit`*** `);`

Arguments: ***`unit`***

The value of ***`unit`*** can be any 8-bit value. A value in the range [1,255] will delay (***`unit`*** * 1000) cycles. A value of 0 causes a delay of 256,000 cycles.

Remarks: This function creates a delay in multiples of 1,000 instruction cycles. This function uses the globally allocated variables, `DelayCounter1` and `DelayCounter2`. If this function is used in both interrupt and mainline code, these variables, `DelayCounter1` and `DelayCounter2,` should be saved and restored in the interrupt handler. Refer to the `save=` clause of the `#pragma interrupt` and `#pragma interruptlow` directives for more information. Note that other delay functions also use the globally allocated `DelayCounter1` variable.

File Name: `d1ktcyx.asm`

Delay10KTCYx

Function: Delay in multiples of 10,000 instruction cycles (TCY).

Include: `delays.h`

Prototype: `void Delay10KTCYx( unsigned char` ***`unit`*** `);`

Arguments: ***`unit`***

The value of ***`unit`*** can be any 8-bit value. A value in the range [1,255] will delay (***`unit`*** * 10000) cycles. A value of 0 causes a delay of 2,560,000 cycles.

Remarks: This function creates a delay in multiples of 10,000 instruction cycles. This function uses the globally allocated variable, `DelayCounter1`. If this function is used in both interrupt and mainline code, the variable `DelayCounter1` should be saved and restored in the interrupt handler. Refer to the `save=` clause of the `#pragma interrupt` or `#pragma interruptlow` directives for more information. Note that other delay functions also use the globally allocated `DelayCounter1` variable.

File Name: `d10ktcyx.asm`

4.6 RESET FUNCTIONS

The Reset functions may be used to help determine the source of a Reset or wake-up event and for reconfiguring the processor status following a Reset. The following routines are provided:

TABLE 4-5: RESET FUNCTIONS

Function	Description
`isBOR`	Determine if the cause of a Reset was the Brown-out Reset circuit.
`isLVD`	Determine if the cause of a Reset was a low voltage detect condition.
`isMCLR`	Determine if the cause of a Reset was the $\overline{\text{MCLR}}$ pin.
`isPOR`	Detect a Power-on Reset condition.
`isWDTTO`	Determine if the cause of a Reset was a Watchdog timer time-out.
`isWDTWU`	Determine if the cause of a wake-up was the Watchdog timer.
`isWU`	Detects if the microcontroller was just waken up from Sleep from the $\overline{\text{MCLR}}$ pin or an interrupt.
`StatusReset`	Set the $\overline{\text{POR}}$ and $\overline{\text{BOR}}$ bits.

Note: If you are using Brown-out Reset (BOR) or the Watchdog Timer (WDT), then you must define the enable macros (`#define BOR_ENABLED` and `#define WDT_ENABLED`, respectively) in the header file `reset.h` and recompile the source code.
If the device is configured to reset on stack overflow/underflow, then you must define the enable macro (`#define STVR_ENABLED`) in the header file `reset.h` and recompile the source code.

4.6.1 Function Descriptions

isBOR

Function: Determine if the cause of a Reset was the Brown-out Reset circuit.

Include: `reset.h`

Prototype: `char isBOR( void );`

Remarks: This function detects if the microcontroller was reset due to the Brown-out Reset circuit. This condition is indicated by the following Status bits:
`POR` = 1
`BOR` = 0

Return Value: 1 if the Reset was due to the Brown-out Reset circuit
0 otherwise

File Name: `isbor.c`

isLVD

Function: Determine if the cause of a Reset was a low voltage detect condition.

Include: `reset.h`

Prototype: `char isLVD( void );`

Remarks: This function detects if the voltage of the device has become lower than the value specified in the LVDCON register (LVDL3:LVDL0 bits.)

Return Value: 1 if a Reset was due to LVD during normal operation
0 otherwise

File Name: `islvd.c`

isMCLR

Function: Determine if the cause of a Reset was the $\overline{\text{MCLR}}$ pin.

Include: `reset.h`

Prototype: `char isMCLR( void );`

Remarks: This function detects if the microcontroller was reset via the $\overline{\text{MCLR}}$ pin while in normal operation. This situation is indicated by the following Status bits:
$\overline{\texttt{POR}}$ = 1
If Brown-out is enabled, $\overline{\texttt{BOR}}$ = 1
If WDT is enabled, $\overline{\texttt{TO}}$ = 1
$\overline{\texttt{PD}}$ = 1
If stack overflow/underflow reset is enabled, then the stack overflow and underflow flag bits will be cleared in the `STKPTR` register.

Return Value: 1 if the Reset was due to $\overline{\text{MCLR}}$ during normal operation
0 otherwise

File Name: `ismclr.c`

isPOR

Function: Detect a Power-on Reset condition.

Include: `reset.h`

Prototype: `char isPOR( void );`

Remarks: This function detects if the microcontroller just left a Power-on Reset. This condition is indicated by the following Status bits:
$\overline{\texttt{POR}}$ = 0
$\overline{\texttt{BOR}}$ = 0
$\overline{\texttt{TO}}$ = 1
$\overline{\texttt{PD}}$ = 1
This condition also can occur for $\overline{\text{MCLR}}$ during normal operation and when the `CLRWDT` instruction is executed.
After `isPOR` is called, `StatusReset` should be called to set the $\overline{\texttt{POR}}$ and $\overline{\texttt{BOR}}$ bits.

Return Value: 1 if the device just left a Power-on Reset
0 otherwise

File Name: `ispor.c`

isWDTTO

Function: Determine if the cause of a Reset was a Watchdog Timer (WDT) time out.

Include: `reset.h`

Prototype: `char isWDTTO( void );`

Remarks: This function detects if the microcontroller was reset due to the WDT during normal operation. This condition is indicated by the following Status bits:
$\overline{\texttt{POR}}$ = 1
$\overline{\texttt{BOR}}$ = 1
$\overline{\texttt{TO}}$ = 0
$\overline{\texttt{PD}}$ = 1

Return Value: 1 if the Reset was due to the WDT during normal operation
0 otherwise

File Name: `iswdtto.c`

isWDTWU

Function: Determine if the cause of a wake-up was the Watchdog Timer (WDT).

Include: `reset.h`

Prototype: `char isWDTWU( void );`

Remarks: This function detects if the microcontroller was brought out of Sleep by the WDT. This condition is indicated by the following Status bits:
$\overline{\text{POR}}$ = 1
$\overline{\text{BOR}}$ = 1
$\overline{\text{TO}}$ = 0
$\overline{\text{PD}}$ = 0

Return Value: 1 if device was brought out of Sleep by the WDT
0 otherwise

File Name: `iswdtwu.c`

isWU

Function: Detects if the microcontroller was just waken up from Sleep via the $\overline{\text{MCLR}}$ pin or interrupt.

Include: `reset.h`

Prototype: `char isWU( void );`

Remarks: This function detects if the microcontroller was brought out of Sleep by the $\overline{\text{MCLR}}$ pin or an interrupt. This condition is indicated by the following Status bits:
$\overline{\text{POR}}$ = 1
$\overline{\text{BOR}}$ = 1
$\overline{\text{TO}}$ = 1
$\overline{\text{PD}}$ = 0

Return Value: 1 if the device was brought out of Sleep by the $\overline{\text{MCLR}}$ pin or an interrupt
0 otherwise

File Name: `iswu.c`

StatusReset

Function: Set the $\overline{\text{POR}}$ and $\overline{\text{BOR}}$ bits in the `CPUSTA` register.

Include: `reset.h`

Prototype: `void StatusReset( void );`

Remarks: This function sets the `POR` and `BOR` bits in the `CPUSTA` register. These bits must be set in software after a Power-on Reset has occurred.

File Name: `statrst.c`

4.7 CHARACTER OUTPUT FUNCTIONS

The character output functions provide a central family of functions for processing output to peripherals, memory buffers and other consumers of character data.

When processing a call to `fprintf`, `printf`, `sprintf`, `vfprintf`, `vprintf` or `vsprintf`, MPLAB C18 will always process the variable length portion of the argument list with integer promotions enabled (see the “Integer Promotions” section of the *MPLAB® C18 C Compiler User’s Guide* (DS51288) for more information). This allows the standard library to interface with the compiler cleanly and with consistent behavior for the formatting of the output as would normally be expected from those functions.

4.7.1 Output Streams

Output is based on the use of a destination stream. A stream can be a peripheral, memory buffer, or any other consumer of data and is denoted by a pointer to an object of `FILE` type. MPLAB C18 defines two streams in the standard library:

`_H_USER` output via the user-defined output function `_user_putc`.

`_H_USART` output via the library output function `_usart_putc`.

The current version of the library supports only these two output streams. Both streams are always considered to be open and do not require use of functions such as `fopen`, `fclose`, etc.

The global variables `stdout` and `stderr` are defined by the library and have default value of `_H_USART`. To change the destination to be `_H_USER`, assign that value to the variable. For example, to change standard output to use the user defined output function:

```
stdout = _H_USER;
```

TABLE 4-6: CHARACTER OUTPUT FUNCTIONS

Function	Description
`fprintf`	Formatted string output to a stream.
`fputs`	String output to a stream.
`printf`	Formatted string output to `stdout`.
`putc`	Character output to a stream
`puts`	String output to `stdout`.
`sprintf`	Formatted string output to a data memory buffer.
`vfprintf`	Formatted string output to a stream with the arguments for processing the format string supplied via the `stdarg` facility.
`vprintf`	Formatted string output to `stdout` with the arguments for processing the format string supplied via the `stdarg` facility.
`vsprintf`	Formatted string output to a data memory buffer with the arguments for processing the format string supplied via the `stdarg` facility.
`_usart_putc`	Single character output to the USART (USART1 for devices which have more than one USART).
`_user_putc`	Single character output in an application defined manner.

4.7.2 Function Descriptions

fprintf

Function: Formatted string output to a stream.

Include: `stdio.h`

Prototype: `int fprintf (FILE *f, const rom char *fmt, ...);`

Remarks: The `fprintf` function formats output, passing the characters to the specified stream via the `putc` function. The format string is processed one character at a time and the characters are output as they appear in the format string, except for format specifiers. A format specifier is indicated in the format string by a percent sign, `%`; following that, a well-formed format specifier has the following components.[1] Except for the conversion operation, all format specifiers are optional:

1. Flag characters (order does not matter), where a flag character is one of `#`, `-`, `+`, `0` or `space`.
2. A *field width*, which is a decimal integer constant value an asterisk, `*`.
3. A *field precision*, which is a period (`.`), optionally followed by a decimal integer or an asterisk, `*`.
4. A *size specification*, which is one of the specifiers `h`, `H`, `hh`, `j`, `z`, `Z`, `t`, `T` or `l`.
5. A *conversion operation*, which is one of `c`, `b`, `B`, `d`, `i`, `n`, `o`, `p`, `P`, `s`, `S`, `u`, `x`, `X` or `%`.

[1] Not all components are valid for all conversion operations. Details are provided in the descriptions of the conversion operators.

fprintf (Continued)

Flag Characters

`#` The *alternate form* of the result will be presented. For the `o` conversion, the alternate form is as if the precision were increased such that the first digit of the result is forced to be a zero. For the `x` conversion, a non-zero result will have a `0x` prefix added to it. For the `X` conversion, a non-zero result will have a `0X` prefix added to it. For the `b` conversion, a non-zero result will have a `0b` prefix added to it. For the `B` conversion, a non-zero result will have a `0B` prefix added to it. For other conversions, the flag is ignored.

`-` The result will be left justified. If this flag is not specified, the result will be right justified.

`+` For a signed conversion, the result will always begin with a `+` or a `-` sign. By default, a sign character is only added to the result if the result is negative. For other conversions, the flag is ignored.

space For a signed conversion, if the result is non-negative or has no characters, a space will be prefixed to the result. If the space and `+` flags are both specified, the space flag will be ignored. For other conversions, the flag is ignored.

`0` For the integer conversions (`d`, `i`, `o`, `u`, `b`, `B`, `x`, `X`), leading zeroes are prefixed to the result (after any sign and/or base indicators) such that the result fills the field width. No space padding is performed. If the `-` flag is also specified, the `0` flag will be ignored. If a precision is specified, the `0` flag will be ignored. For other conversions, the flag is ignored.

Field Width

The field width specifies the minimum number of characters for the converted value. If the converted value is shorter than the field width, then the value is padded to have the number of characters be equal to the field width. By default, leading spaces are used for padding; the flag characters are used to alter the pad character and the justification of the value.

If the field width is an asterisk character, `*`, an `int` argument is read to specify the field width. If the value is negative, it is as if the `-` flag were specified, followed by a positive field width.

Field Precision

The field precision specifies the minimum number of digits which will be present in the converted value for a `d`, `i`, `o`, `u`, `b`, `B`, `x` or `X` conversion, or the maximum number of characters in the converted value for an `s` conversion.

If the field width is an asterisk character, `*`, an `int` argument is read to specify the field width. If the value is negative, it is as if the precision were unspecified.

For the `d`, `i`, `o`, `u`, `b`, `B`, `x` or `X` conversion operators, the default precision is `1`. For all other conversion operators the behavior when the precision is unspecified is described below.

fprintf (Continued)

Size Specifications

The size specification character applies to the integer conversion specifiers, d, i, o, u, b, B, x or X , and the pointer conversion specifiers, p and P. If present for any other conversion operator, it is ignored.

hh For integer conversion specifiers, the argument to be converted is a signed char or unsigned char argument.[2] For an n conversion specifier, the specifier denotes a pointer to a signed char argument.

h For integer conversion specifiers, the argument to be converted is a short int or unsigned short int. For an n conversion specifier, the specifier denotes a pointer to a short int argument. As a plain int is the same size as a short int for MPLAB C18, this option has no actual effect and is present for compatibility purposes only. For pointer conversion specifiers, the argument to be converted is a 16-bit pointer.

H For integer conversion specifiers, the argument to be converted is a short long int or unsigned short long int. For an n conversion specifier, the specifier denotes a pointer to a short long int argument. For pointer conversion specifiers, the argument to be converted is a 24-bit pointer.[3] For example, when outputting a far rom char *, the size specifier H should be used (%HS).

j For integer conversion specifiers, the argument to be converted is an intmax_t or uintmax_t argument. For an n conversion specifier, the specifier denotes a pointer to an intmax_t argument. For MPLAB C18, this is equivalent to the l size specifier.

l For integer conversion specifiers, the argument to be converted is a long int or unsigned long int. For an n conversion specifier, the specifier denotes a pointer to a long int argument. For pointer conversion specifiers, the size specifier is ignored.

t For integer conversion specifiers, the argument to be converted is an ptrdiff_t argument. For an n conversion specifier, the specifier denotes a pointer to a signed integer type corresponding to ptrdiff_t argument. For MPLAB C18, this is equivalent to the h size specifier.

T For integer conversion specifiers, the argument to be converted is an ptrdiffrom_t argument. For an n conversion specifier, the specifier denotes a pointer to a signed integer type corresponding to ptrdiffrom_t argument. For MPLAB C18, this is equivalent to the H size specifier.[4]

z For integer conversion specifiers, the argument to be converted is an size_t argument. For an n conversion specifier, the specifier denotes a pointer to a signed integer type corresponding to size_t argument. For MPLAB C18, this is equivalent to the h size specifier.

Z For integer conversion specifiers, the argument to be converted is an sizerom_t argument. For an n conversion specifier, the specifier denotes a pointer to a signed integer type corresponding to sizerom_t argument. For MPLAB C18, this is equivalent to the H size specifier.[5]

[2] Note that the integer promotions will still apply when the argument is passed. This specifier causes the argument to be cast back to 8 bits in size prior to the value being used.

[3] The H size specifier is an MPLAB C18 specific extension to ANSI C.

[4] The T size specifier is an MPLAB C18 specific extension to ANSI C.

[5] The Z size specifier is an MPLAB C18 specific extension to ANSI C.

fprintf (Continued)

Conversion Operators

`c` The `int` argument is converted to an `unsigned char` value and the character represented by that value is written.

`d`, `i`The `int` argument is formatted as signed decimal with the precision indicating the minimum number of digits to be written. If the converted value has fewer digits, it is prepended with zeros. If the converted value is zero and the precision is zero, no characters will be written.

`o` The `unsigned int` argument is converted to unsigned octal with the precision indicating the minimum number of digits to be written. If the converted value has fewer digits, it is prepended with leading zeros. If the converted value is zero and the precision is zero, no characters will be written.

`u` The `unsigned int` argument is formatted as unsigned decimal with the precision indicating the minimum number of digits to be written. If the converted value has fewer digits, it is prepended with zeros. If the converted value is zero and the precision is zero, no characters will be written.

`b` The `unsigned int` argument is formatted as unsigned binary with the precision indicating the minimum number of digits to be written. If the converted value has fewer digits, it is prepended with zeros. If the converted value is zero and the precision is zero, no characters will be written.[6]

`B` The `unsigned int` argument is formatted as unsigned binary with the precision indicating the minimum number of digits to be written. If the converted value has fewer digits, it is prepended with zeros. If the converted value is zero and the precision is zero, no characters will be written.[7]

`x` The `unsigned int` argument is formatted as unsigned hexadecimal with the precision indicating the minimum number of digits to be written. The characters `abcdef` are used for the representation if the decimal numbers 10 through 15. If the converted value has fewer digits, it is prepended with zeros. If the converted value is zero and the precision is zero, no characters will be written.

`X` The `unsigned int` argument is formatted as unsigned hexadecimal with the precision indicating the minimum number of digits to be written. The characters `ABCDEF` are used for the representation of the decimal numbers 10 through 15. If the converted value has fewer digits, it is prepended with zeros. If the converted value is zero and the precision is zero, no characters will be written.

`s` Characters from the data memory array of char argument are written until either a terminating `'\0'` character is seen (the `'\0'` character is not written) or the number of characters written is equal to the specified precision. If the precision is specified to be greater than the size of the array or is unspecified, the array must contain a terminating `'\0'` character.

`S` Characters from the program memory array of char argument are written until either a terminating `'\0'` character is seen (the `'\0'` character is not written) or the number of characters written is equal to the specified precision. If the precision is specified to be greater than the size of the array or is unspecified, the array must contain a terminating `'\0'` character.[8] When outputting a `far rom char *`, make sure to use the `H` size specifier (i.e., `%HS`).

[6] The `b` conversion operator is an MPLAB C18 specific extension to ANSI C.

[7] The `B` conversion operator is an MPLAB C18 specific extension to ANSI C.

[8] The `S` conversion operator is an MPLAB C18 specific extension to ANSI C.

fprintf (Continued)

`p` The pointer to void (data or program memory) argument is converted to an equivalent size unsigned integer type and that value is processed as if the `x` conversion operator had been specified. If the `H` size specifier is present, the pointer is a 24-bit pointer, else it is a 16-bit pointer.

`P` The pointer to void (data or program memory) argument is converted to an equivalent size unsigned integer type and that value is processed as if the `X` conversion operator had been specified. If the `H` size specifier is present, the pointer is a 24-bit pointer, else it is a 16-bit pointer.[9]

`n` The number of characters written so far shall be stored in the location referenced by the argument, which is a pointer to an integer type in data memory. The size of the integer type is determined by the size specifier present for the conversion, or a plain 16-bit integer if no size specifier is present.

`%` A literal `%` character is written. The conversion specification shall be `%%` only, no flags or other specifiers may be present.

If a conversion specifier is invalid (e.g., a flag character is present for the `%%` conversion specifier), the behavior is undefined.

Return Value: `fprintf` returns `EOF` if an error occurs, otherwise returns the number of characters output.

Filename: `fprintf.c`

Code Example:

```
#include <stdio.h>
void main (void)
{
  far rom char * S = ”Hello, World!”;
  int n = 0x1234;
  fprintf (_H_USART, "test output to USART\n");
  fprintf (_H_USER, "test output to application”
          “defined function\n" );
  fprintf (stdout, "hex output: %#x", n);
  fprintf (stderr, “%HS\n”, S);
}
```

[9] The `P` conversion operator is an MPLAB C18 specific extension to ANSI C.

fputs

Function: String output to a stream.

Include: `stdio.h`

Prototype: `int fputs (const rom char *s, FILE *f);`

Remarks: `fputs` outputs a null terminated string to the specified output stream, one character at a time via `putc`. A newline character is appended to the output. The terminating null is not output.

Return Value: `fputs` returns `EOF` if an error occurs, otherwise returns a non-negative value.

Filename: `fputs.c`

printf

Function: Formatted string output to `stdout`.

Include: `stdio.h`

Prototype: `int printf (const rom char *fmt, ...);`

Remarks: The `printf` function formats output, passing the characters to `stdout` via the `putc` function. The format string is processed as described for the `fprintf` function.

Return Value: `printf` returns `EOF` if an error occurs, otherwise returns the number of characters output.

Filename: `printf.c`

Code Example:

```
#include <stdio.h>
void main (void)
{
  /* will output via stdout (_H_USART by default) */
  printf ("Hello, World!\n");
}
```

putc

Function: Character output to a stream.

Include: `stdio.h`

Prototype: `int putc (char c, FILE *f);`

Remarks: `putc` outputs a single character to the specified output stream.

Return Value: `putc` returns `EOF` if an error occurs, otherwise returns the character which was output.

Filename: `putc.c`

puts

Function: String output to `stdout`.

Include: `stdio.h`

Prototype: `int puts (const rom char *s);`

Remarks: `puts` outputs a null terminated string to `stdout` one character at a time via `putc`. A newline character is appended to the output. The terminating null is not output.

Return Value: `puts` returns `EOF` if an error occurs, otherwise returns a non-negative value.

Filename: `puts.c`

Code Example:

```
#include <stdio.h>
void main (void)
{
  puts ("test message");
}
```

sprintf

Function: Formatted string output to a data memory buffer.

Include: `stdio.h`

Prototype: `int sprintf (char *buf, const rom char *fmt, ...);`

Remarks: The `sprintf` function formats output, storing the characters to the destination data memory buffer, `buf`. The format string, `fmt`, is processed as described for the `fprintf` function.

Return Value: `sprintf` returns `EOF` if an error occurs, otherwise the number of characters output is returned.

Filename: `sprintf.c`

Code Example:

```
#include <stdio.h>
void main (void)
{
  int i = 0xA12;
  char buf[20];
  sprintf (buf, "%#010x", i);
  /* buf will contain the string "0x00000a12"
}
```

vfprintf

Function: Formatted string output to a stream with the arguments for processing the format string supplied via the `stdarg` facility.

Include: `stdio.h`

Prototype:

```
int vfprintf (FILE *f, const rom char *fmt,
             va_list ap);
```

Remarks: The `vfprintf` function formats output, passing the characters to the specified output stream, `f`, via the `putc` function. The format string, `fmt`, is processed as described for the `fprintf` function except that the arguments consumed when processing the format string are retrieved via the `stdarg` variable length argument facility.

Return Value: `vfprintf` returns `EOF` if an error occurs, otherwise the number of characters output is returned.

Filename: `vfprintf.c`

vprintf

Function: Formatted string output to `stdout` with the arguments for processing the format string supplied via the `stdarg` facility.

Include: `stdio.h`

Prototype: `int vprintf (const rom char *fmt, va_list ap);`

Remarks: The `vprintf` function formats output, passing the characters to `stdout` via the putc function. The format string, `fmt`, is processed as described for the `fprintf` function except that the arguments consumed when processing the format string are retrieved via the `stdarg` variable length argument facility.

Return Value: `vprintf` returns `EOF` if an error occurs, otherwise the number of characters output is returned.

Filename: `vprintf.c`

vsprintf

Function:	Formatted string output to a data memory buffer with the arguments for processing the format string supplied via the `stdarg` facility.
Include:	`stdio.h`

Prototype:	`int vsprintf (char *buf, const rom char *fmt,`
	`               va_list ap);`

Remarks:	The `vsprintf` function formats output, storing the characters to the destination data memory buffer, `buf`. The format string, `fmt`, is processed as described for the `fprintf` function except that the arguments consumed when processing the format string are retrieved via the `stdarg` variable-length-argument facility.
Return Value:	`vsprintf` returns `EOF` if an error occurs, otherwise the number of characters output is returned.
Filename:	`vsprintf.c`

_usart_putc

Function:	Single character output to the USART (USART1 for devices which have more than one USART).
Include:	`stdio.h`
Prototype:	`int _usart_putc (char c);`
Remarks:	`_usart_putc` is the library output function invoked by `putc` when `_H_USART` is the destination stream. The character to be output is assigned to the transmit register (`TXREG`) when the USART is ready for output (`TRMT` is set). If the USART is not enabled when `_usart_putc` is called (`TXSTA` bit `TXEN` is clear), the USART will be enabled (`TXEN` and `SPEN` will be set) and set to maximum baud rate output (`SPBRG` will be assigned a value of zero). This configuration allows the character output library functions to be used with the MPLAB IDE support for USART debug output without explicit peripheral configuration.
Return Value:	`_usart_putc` returns the value of the character which was output.
Filename:	`_usart_putc.c`

_user_putc

Function:	Single character output in an application defined manner.
Include:	`stdio.h`
Prototype:	`int _user_putc (char c);`
Remarks:	`_user_putc` is an application defined function. It will be called by the character output functions for each character to be output when the destination stream is `_H_USER`.
Return Value:	`_user_putc` returns the value of the character which was output.

NOTES:

Chapter 5. Math Libraries

5.1 INTRODUCTION

This chapter documents math library functions. It includes two sections:

- 32-Bit Floating Point Math Library
- The C Standard Library Math Functions

5.2 32-BIT FLOATING POINT MATH LIBRARY

The basic floating point operations—add, subtract, multiply, divide and conversions between floats and integers—comply with the IEEE 754 standard for single precision floats with two exceptions. The exceptions will be discussed under Subnormals (**Section 5.2.1.2 "Subnormals"**) and Rounding (**Section 5.2.2 "Rounding"**). The extended mode and traditional mode use the same float representations and the results of float operations are the same.

The IEEE standard for binary floating-point arithmetic published in 1985 became known officially as ANSI/IEEE Std 754-1985 [IEEE85]. The standard has three important requirements:

- consistent representation of floating-point numbers by all machines adopting the standard;
- correctly rounded floating-point operations, using various rounding modes;
- consistent treatment of exceptional situations such as division by zero.

5.2.1 Floating-Point Representation

The C18 floating point number representation follows the single precision IEEE 754 standard. A floating-point number consists of four parts:

1. A sign
2. A significand
3. A base
4. An exponent

These components are of the form

$$x = \pm d_0.d_1.d_2.d_3 \cdots d_{23} \times 2^E$$

where ± is the sign, $d_0.d_1.d_2.d_3 \cdots d_{23}$ is the significand, and E is the exponent to which the base 2 is raised. Each d_i is a digit (0 or 1). The exponent E is an integer in the range $Emin$ to $Emax$ where $Emin$ = -126 and $Emax$ = 127.

Single-format numbers use a 32-bit word organized as a 1-bit sign, an 8-bit biased exponent e = E + 127, and a 23-bit fraction, which is the fractional part of the significand.

The most-significant bit of the significand (d_0) is not stored. This is possible because its value can be inferred from the exponent value: if the biased exponent value is 0, then d_0 = 0, otherwise d_0 = 1. Using this convention allows 24 bits of precision to be stored in 23 physical bits.

Sign	8-bit biased exponent *E*	23-bit unsigned fraction *f*
±	$e_7e_6e_5e_4e_3e_2e_1e_0$	$d_0d_1d_2d_3 \cdots d_{23}$

In the C18 implementation, the d_0 = 0 numbers are not used (see **Section 5.2.1.2 “Subnormals”**).

5.2.1.1 NORMALS

All the lines in Table 5-1 except the first and last refer to normalized numbers. The exponent bit string $e_7e_6e_5. . . e_0$ uses a biased representation; the bit string is stored as the binary representation of E+127, where E is the unbiased exponent. The number 127, which is added to the exponent E, is called the *exponent bias*. For example, the number 1=$(1.000. . . 0)_2$ 2^0 is stored as

0	01111111	00000000000000000000000

Here the exponent bit string is the binary representation for 0+127 and the fraction bit string is the binary representation for 0 (the fractional part of 1.0).

The range of exponent field bit strings for normalized numbers is 00000001 to 11111110 (the decimal numbers 1 through 254), representing actual exponents from E_{min} =-126 to E_{max} = 127.

TABLE 5-1: IEEE-754 SINGLE FORMAT

Biased Exponent	Number Represented
$(00000000)_2 = (00)_{16} = (0)_{10}$	$\pm (0.d_1d_2d_3. . . d_{23})_2 \times 2^{-126}$
$(00000001)_2 = (01)_{16} = (1)_{10}$	$\pm (1.d_1d_2d_3. . . d_{23})_2 \times 2^{-126}$
$(00000010)_2 = (02)_{16} = (2)_{10}$	$\pm (1.d_1d_2d_3. . . d_{23})_2 \times 2^{-125}$
$(00000011)_2 = (03)_{16} = (3)_{10}$	$\pm (1.d_1d_2d_3. . . d_{23})_2 \times 2^{-124}$
↓	↓
$(01111110)_2 = (7E)_{16} = (126)_{10}$	$\pm (1.d_1d_2d_3. . .d_{23})_2 \times 2^{-1}$
$(01111111)_2 = (7F)_{16} = (127)_{10}$	$\pm (1.d_1d_2d_3. . .d_{23})_2 \times 2^{0}$
$(10000000)_2 = (80)_{16} = (128)_{10}$	$\pm (1.d_1d_2d_3. . .d_{23})_2 \times 2^{1}$
↓	↓
$(11111100)_2 = (FC)_{16} = (252)_{10}$	$\pm (1.d_1d_2d_3. . .d_{23})_2 \times 2^{125}$
$(11111101)_2 = (FD)_{16} = (253)_{10}$	$\pm (1.d_1d_2d_3. . .d_{23})_2 \times 2^{126}$
$(11111110)_2 = (FE)_{16} = (254)_{10}$	$\pm (1.d_1d_2d_3. . .d_{23})_2 \times 2^{127}$
$(11111111)_2 = (FF)_{16} = (255)_{10}$	$\pm\infty$ if $d_1. . . d_{23} = 0$ NaN if $d_1. . .d_{23} \neq 0$

The smallest positive, non-zero normalized number that can be stored is represented by

0	00000001	00000000000000000000000

and this is denoted by

$$N_{min} =(1.000\ldots 0)_2 \times 2^{-126} = 2^{-126} \sim 1.2 \times 10^{38}$$

The constant N_{min} is accessible to C programmers using the manifest constant `FLT_MIN` defined in `<float.h>`.

The largest normalized number (equivalently, the largest finite number) is represented by

0	11111110	11111111111111111111111

and this is denoted by

$$N_{max} =(1.111. . . 1)_2 \times 2^{127}=(2 - 2^{-23}) \times 2^{127} \sim 2^{128} \sim 3.4 \times 10^{38}$$

The constant N_{max} is accessible to C programmers using the manifest constant `FLT_MAX` defined in `<float.h>`.

5.2.1.2 SUBNORMALS

The smallest normalized number that can be represented is 2^{-126}. The IEEE 754 standard uses the combination of a zero biased exponent *e* and a nonzero fraction *f* to represent smaller numbers called subnormal numbers. The structure of subnormal numbers is shown on line 1 of Table 5-1. In the C18 float implementation, subnormal numbers are always converted to signed zero.

IEEE 754 uses two different zero representations: + 0 and -0. The +0 is represented by all zero bits. The -0 is represented by all zero bits except for the sign bit.

If the result of a float operation is less than the smallest normalized number, the result is set to a signed zero before it is returned. Since, in the C18 implementation, no float operation can create a subnormal, a subnormal will appear only if it is constructed explicitly as a literal, or is generated in some way other than by standard float operations. If a subnormal value is used in a float operation, it is converted automatically to a signed zero before it is used in the operation.

5.2.1.3 NaNs

In addition to supporting signed infinities, signed zeroes and signed non-zero finite numbers, the IEEE floating-point format specifies an encoding for error patterns. These patterns are not numbers but a recording of the fact that an invalid operation has been attempted. Any such pattern is an error indicator, not a floating-point number and so is referred to as Not a Number, or NaN. Invalid operations are defined by the IEEE standard to include:

- Magnitude subtraction of infinities, such as (+∞) + (-∞)
- Multiplication of a zero by an infinity, such as (0) x (+∞)
- Division of a zero or infinity by zero or infinity, respectively, such as (+∞)/(-∞) or (+∞)/(+∞)

NaNs have a biased exponent of 255, which is also the exponent used to encode infinities. The interpretation when the biased exponent is 255 is: if the fraction is zero, the encoding represents an infinity; if the fraction is not zero, the encoding represents NaN (not a number). Ignoring the sign bit, which the standard does not interpret for NaNs, there are therefore $2^{23} – 1$ possible NaNs. The C18 implementation returns the NaN pattern $7FFF\ FFFF_{16}$ in response to an invalid operation. That is, the sign bit is 0, the exponent is 255, and the fraction bits are all 1s.

5.2.2 Rounding

The IEEE-754 standard requires that operations be correctly rounded. The standard defines the correctly rounded value of x, which is denoted by round(x), as follows: If x is a floating-point number, then round(x) = x. Otherwise, the correctly-rounded value depends on which of four rounding modes is in effect. The C18 float implementation uses the Round to Nearest mode with a slight modification to the IEEE 754 standard. The threshold for rounding up is about 0.502 instead of exactly 0.5. This gives a slight bias toward rounding toward zero. This modification results in a significant savings in code space and execution time with virtually no consequences for real-world calculations.

5.3 THE C STANDARD LIBRARY MATH FUNCTIONS

All the math functions of the standard C Library will return NaN if one or more of its arguments:

- is NaN.
- is outside the range of values for which the function has a defined real value, for example the square root of a negative number.

Table 5-2 lists the math functions.

TABLE 5-2: MATH LIBRARY FUNCTIONS

Function	Description
`acos`	Compute the inverse cosine (arccosine).
`asin`	Compute the inverse sine (arcsine).
`atan`	Compute the inverse tangent (arctangent).
`atan2`	Compute the inverse tangent (arctangent) of a ratio.
`ceil`	Compute the ceiling (least integer).
`cos`	Compute the cosine.
`cosh`	Compute the hyperbolic cosine.
`exp`	Compute the exponential e^x.
`fabs`	Compute the absolute value.
`floor`	Compute the floor (greatest integer).
`fmod`	Compute the remainder.
`frexp`	Split into fraction and exponent.
`ieeetomchp`	Convert an IEEE-754 format 32-bit floating point value into the Microchip 32-bit floating point format.
`ldexp`	Load exponent – compute $x * 2^n$.
`log`	Compute the natural logarithm.
`log10`	Compute the common (base 10) logarithm.
`mchptoieee`	Convert a Microchip format 32-bit floating point value into the IEEE-754 32-bit floating point format.
`modf`	Compute the modulus.
`pow`	Compute the exponential x^y.
`sin`	Compute the sine.
`sinh`	Compute the hyperbolic sine.
`sqrt`	Compute the square root.
`tan`	Compute the tangent.
`tanh`	Compute the hyperbolic tangent.

5.3.1 Function Descriptions

acos

Function: Compute the inverse cosine (arccosine)

Include: `math.h`

Prototype: `float acos( float x );`

Remarks: This function computes the inverse cosine (arccosine) of the argument `x`, which must be between –1 and +1. Arguments outside the permitted range produce domain errors and the result is NaN.

Return Value: The returned value is the arccosine in radians, and is between `0` and π.

File Name: `acos.c`

asin

Function: Compute the inverse sine (arcsine).

Include: `math.h`

Prototype: `float asin( float x );`

Remarks: This function computes the inverse sine (arcsine) of the argument `x`, which must be between –1 and +1. Arguments outside the permitted range produce domain errors and the result is NaN.

Return Value: The returned value is the arcsine in radians, and is between –π/2 and π/2.

File Name: `asin.c`

atan

Function: Compute the inverse tangent (arctangent).

Include: `math.h`

Prototype: `float atan( float x );`

Remarks: This function computes the inverse tangent (arctangent) of the argument `x`. If `x` is a NaN, a domain error occurs and the value returned is NaN.

Return Value: The returned value is in radians, and between `–`π/2 and π/2.

File Name: `atan.c`

atan2

Function Compute the inverse tangent (arctangent) of a ratio.

Include: `math.h`

Prototype: `float atan2( float y, float x );`

Remarks: This function computes the inverse tangent (arctangent) of `y/x`. If `x` or `y` is NaN, a domain occurs and the value returned is NaN. If `x` is a NaN, or if `x = y = 0`, or if `x = y =` ∞, a domain error occurs and the value returned is NaN.

Return Value: The returned value is in radians, and between – π and π.

File Name: `atan2.c`

ceil

Function: Compute the ceiling (least integer).

Include: `math.h`

Prototype: `float ceil ( float x );`

Remarks: None.

Return Value: The smallest integer greater than or equal to `x`.

File Name: `ceil.c`

cos

Function: Compute the cosine.

Include: `math.h`

Prototype: `float cos ( float x );`

Remarks: Computes the cosine of `x` (in radians). A domain error results from an argument that is infinite or NaN. Both cases return NaN.

Return Value: The cosine of argument `x`.

File Name: `cos.c`

cosh

Function: Compute the hyperbolic cosine.

Include: `math.h`

Prototype: `float cosh ( float x );`

Remarks: None.

Return Value: The hyperbolic cosine of argument `x`.

File Name: `cosh.c`

exp

Function: Compute the exponential e^x.

Include: `math.h`

Prototype: `float exp ( float x );`

Remarks: A range error occurs if the magnitude of `x` is too large. The range of this function is limited to values for the exponent of between approximately -103.2789 and 88.722283. The minimum value of the result is 2^{-149} and the maximum is 2^{127}.

Return Value: The value of the exponential e^x.

File Name: `exp.c`

fabs

Function: Compute the absolute value.

Include: `math.h`

Prototype: `float fabs( float x );`

Remarks: For floating point arguments that are zeroes and infinities, the return value is the argument with the sign bit cleared.

Return Value: The absolute value of `x`.

File Name: `fabs.c`

floor

Function: Compute the floor (greatest integer).

Include: `math.h`

Prototype: `float floor( float x );`

Remarks: None.

Return Value: The largest integer less than or equal to `x`.

File Name: `floor.c`

fmod

Function: Compute the remainder.

Include: `math.h`

Prototype: `float fmod( float x, float y );`

Remarks: None.

Return Value: The remainder for `x` modulo `y`.

File Name: `fmod.c`

frexp

Function: Split into fraction and exponent.

Include: `math.h`

Prototype: `float frexp( float x, int *pexp );`

Remarks: Separates the argument x into two parts that fit this formula:
`x = frexp(x, *pexp)` x 2^{*pexp}
The integer value, which is stored at location `pexp`, is chosen so that the fractional portion of the result is between ½ and 1.

Return Value: Fractional result that satisfies the conditions listed above.

File Name: `frexp.c`

ieeetomchp

Function: Convert an IEEE-754 format 32-bit floating point value into the Microchip 32-bit floating point format.

Include: `math.h`

Prototype: `unsigned long ieeetomchp( float v );`

Remarks: This function adjusts the sign bit of the floating point representation to be located as required by the Microchip format:

	eb	f0	f1	f2
IEEE-754 32-bit	seee eeee	exxx xxxx	xxxx xxxx	xxxx xxxx
Microchip 32-bit	eeee eeee	sxxx xxxx	xxxx xxxx	xxxx xxxx

s=sign bit *e=exponent* *x=significand*

Return Value: The converted 32-bit value.

File Name: `ieeetomchp.c`

ldexp

Function:	Load exponent – compute x * 2^n.
Include:	`math.h`
Prototype:	`float ldexp( float x, int n );`
Remarks:	None.
Return Value:	Returns the value of `x` * 2^n.
File Name:	`ldexp.c`

log

Function:	Compute the natural logarithm.
Include:	`math.h`
Prototype:	`float log( float x );`
Remarks:	A domain error occurs if the argument is not in the interval [0, +∞].
Return Value:	Natural logarithm of `x`.
File Name:	`log.c`

log10

Function:	Compute the common (base 10) logarithm.
Include:	`math.h`
Prototype:	`float log10( float x );`
Remarks:	A domain error occurs if the argument is not in the interval [0, +∞].
Return Value:	$\log_{10}x$.
File Name:	`log10.c`

mchptoieee

Function: Convert a Microchip format 32-bit floating point value into the IEEE-754 32-bit floating point format.

Include: `math.h`

Prototype: `float ieeetomchp( unsigned long v );`

Remarks: This function adjusts the sign bit of the floating point representation to be located as required by the IEEE format:

	eb	f0	f1	f2
IEEE-754 32-bit	seee eeee	exxx xxxx	xxxx xxxx	xxxx xxxx
Microchip 32-bit	eeee eeee	sxxx xxxx	xxxx xxxx	xxxx xxxx

s=sign bit *e=exponent* *x=significand*

Return Value: The converted floating point value.

File Name: `mchptoieee.c`

modf

Function:	Compute the modulus.
Include:	`math.h`
Prototype:	`float modf( float x, float *ipart );`
Remarks:	This function separates the argument x into integer and fractional parts. The fractional part is returned, and the integer part is stored at location `ipart`. If the argument is NaN, the results for both the fractional and integer part will be NaN as well.
Return Value:	Fractional portion of `x`.
File Name:	`modf.c`

pow

Function:	Compute the exponential x^y.
Include:	`math.h`
Prototype:	`float pow( float x, float y );`
Remarks:	Domain errors occur if `x` is finite and negative, and `y` is finite and not an integer; also if `x` is zero and `y` is less than or equal to zero. A range error occurs if x^y is too large or too small to be represented. In such a case, a correctly signed infinity or zero is returned and a range error is signaled.
Return Value:	`xy`.
File Name:	`pow.c`

sin

Function:	Compute the sine.
Include:	`math.h`
Prototype:	`float sin( float x );`
Remarks:	Computes the sine of `x` (in radians). A domain error results from an argument that is infinite or NaN. Both cases return NaN.
Return Value:	The sine of `x`.
File Name:	`sin.c`

sinh

Function:	Compute the hyperbolic sine.
Include:	`math.h`
Prototype:	`float sinh( float x );`
Remarks:	None.
Return Value:	The hyperbolic sine of argument `x`.
File Name:	`sinh.c`

sqrt

Function:	Compute the square root.
Include:	`math.h`
Prototype:	`float sqrt( float x );`
Remarks:	A domain error occurs if the argument `x` is strictly negative. The principal square root exists and is computable for every non-negative floating point number `x`.
Return Value:	The square root of `x`.
File Name:	`sqrt.c`

tan

Function:	Compute the tangent.
Include:	`math.h`
Prototype:	`float tan( float x );`
Remarks:	Computes the tangent of `x` (in radians). A domain error occurs if the argument is infinite or NaN. Both cases return NaN.
Return Value:	The tangent of `x`.
File Name:	`tan.c`

tanh

Function:	Compute the hyperbolic tangent.
Include:	`math.h`
Prototype:	`float tanh( float x );`
Remarks:	If the argument is NaN, the return value is NaN.
Return Value:	The hyperbolic tangent of `x`.
File Name:	`tanh.c`

Glossary

A

Absolute Section

A section with a fixed address that cannot be changed by the linker.

Access Memory

Special General Purpose Registers (GPR) on the PIC18 PICmicro microcontrollers that allow access regardless of the setting of the Bank Select Register (`BSR`).

Address

The code that identifies where a piece of information is stored in memory.

Anonymous Structure

An unnamed object.

ANSI

American National Standards Institute

Assembler

A language tool that translates assembly source code into machine code.

Assembly

A symbolic language that describes the binary machine code in a readable form.

Assigned Section

A section that has been assigned to a target memory block in the linker command file.

Asynchronously

Multiple events that do not occur at the same time. This is generally used to refer to interrupts that may occur at any time during processor execution.

B

Binary

The base two numbering system that uses the digits `0-1`. The right-most digit counts ones, the next counts multiples of 2, then $2^2 = 4$, etc.

C

Central Processing Unit

The part of a device that is responsible for fetching the correct instruction for execution, decoding that instruction, and then executing that instruction. When necessary, it works in conjunction with the arithmetic logic unit (ALU) to complete the execution of the instruction. It controls the program memory address bus, the data memory address bus, and accesses to the stack.

Compiler

A program that translates a source file written in a high-level language into machine code.

Conditional Compilation

The act of compiling a program fragment only if a certain constant expression, specified by a preprocessor directive, is true.

CPU

Central Processing Unit

E

Endianness

The ordering of bytes in a multi-byte object.

Error File

A file containing the diagnostics generated by the MPLAB C18 compiler.

Extended Mode

In Extended mode, the compiler will utilize the extended instructions (i.e., `ADDFSR`, `ADDULNK`, `CALLW`, `MOVSF`, `MOVSS`, `PUSHL`, `SUBFSR` and `SUBULNK`) and the indexed with literal offset addressing.

F

Fatal Error

An error that will halt compilation immediately. No further messages will be produced.

Frame Pointer

A pointer that references the location on the stack that separates the stack-based arguments from the stack-based local variables.

Free-standing

An implementation that accepts any strictly conforming program that does not use complex types and in which the use of the features specified in the library clause (ANSI ‘89 standard clause 7) is confined to the contents of the standard headers `<float.h>`, `<iso646.h>`, `<limits.h>`, `<stdarg.h>`, `<stdbool.h>`, `<stddef.h>` and `<stdint.h>`.

H

Hexadecimal

The base 16 numbering system that uses the digits 0-9 plus the letters A-F (or a-f). The digits A-F represent decimal values of 10 to 15. The right-most digit counts ones, the next counts multiples of 16, then 16^2 = 256, etc.

High-level Language

A language for writing programs that is further removed from the processor than assembly.

I

ICD

In-Circuit Debugger

ICE

In-Circuit Emulator

IDE

Integrated Development Environment

IEEE

Institute of Electrical and Electronics Engineers

Interrupt

A signal to the CPU that suspends the execution of a running application and transfers control to an ISR so that the event may be processed. Upon completion of the ISR, normal execution of the application resumes.

Interrupt Service Routine

A function that handles an interrupt.

ISO

International Organization for Standardization

ISR

Interrupt Service Routine

L

Latency

The time between when an event occurs and the response to it.

Librarian

A program that creates and manipulates libraries.

Library

A collection of relocatable object modules.

Linker

A program that combines object files and libraries to create executable code.

Little Endian

Within a given object, the Least Significant Byte is stored at lower addresses.

M

Memory Model

A description that specifies the size of pointers that point to program memory.

Microcontroller

A highly integrated chip that contains a CPU, RAM, some form of ROM, I/O ports and timers.

MPASM Assembler

Microchip Technology's relocatable macro assembler for PICmicro microcontroller families.

MPLIB Object Librarian

Microchip Technology's librarian for PICmicro microcontroller families.

MPLINK Object Linker

Microchip Technology's linker for PICmicro microcontroller families.

N

Non-extended Mode

In Non-extended mode, the compiler will not utilize the extended instructions nor the indexed with literal offset addressing.

O

Object File

A file containing object code. It may be immediately executable or it may require linking with other object code files (e.g., libraries) to produce a complete executable program.

Object Code

The machine code generated by an assembler or compiler.

Octal

The base 8 number system that only uses the digits 0-7. The right-most digit counts ones, the next digit counts multiples of 8, then 8^2 = 64, etc.

P

Pragma

A directive that has meaning to a specific compiler.

R

RAM

Random Access Memory

Random Access Memory

A memory device in which information can be accessed in any order.

Read Only Memory

Memory hardware that allows fast access to permanently stored data but prevents addition to or modification of the data.

ROM

Read Only Memory

Recursive

Self-referential (e.g., a function that calls itself).

Reentrant

A function that may have multiple, simultaneously active instances. This may happen due to either direct or indirect recursion or through execution during interrupt processing.

Relocatable

An object whose address has not been assigned to a fixed memory location.

Runtime Model

Set of assumptions under which the compiler operates.

S

Section

A portion of an application located at a specific address of memory.

Section Attribute

A characteristic ascribed to a section (e.g., an `access` section).

Special Function Register

Registers that control I/O processor functions, I/O status, timers or other modes or peripherals.

Storage Class

Determines the lifetime of the memory associated with the identified object.

Storage Qualifier

Indicates special properties of the objects being declared (e.g., `const`).

V

Vector

The memory locations that an application will jump to when either a Reset or interrupt occurs.

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