



16-Bit Language Tools Libraries

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Table of Contents

Preface	5
Chapter 1. Library Overview	
1.1 Introduction	11
1.2 OMF-Specific Libraries/Start-up Modules	12
1.3 Start-up Code	12
1.4 DSP Library	12
1.5 16-Bit Peripheral Libraries	12
1.6 Standard C Libraries with Math and Support Functions	13
1.7 Fixed Point Math Functions	13
1.8 Compiler Built-in Functions	13
Chapter 2. Standard C Libraries	
2.1 Introduction	15
2.2 Using the Standard C Libraries	16
2.3 <assert.h> diagnostics	17
2.4 <ctype.h> character handling	18
2.5 <errno.h> errors	27
2.6 <float.h> floating-point characteristics	28
2.7 <limits.h> implementation-defined limits	33
2.8 <locale.h> localization	35
2.9 <setjmp.h> non-local jumps	36
2.10 <signal.h> signal handling	37
2.11 <stdarg.h> variable argument lists	43
2.12 <stddef.h> common definitions	45
2.13 <stdio.h> input and output	47
2.14 <stdlib.h> utility functions	94
2.15 <string.h> string functions	118
2.16 <time.h> date and time functions	141
Chapter 3. Standard C Libraries - Math Functions	
3.1 Introduction	149
3.2 Using the Standard C Libraries	149
3.3 <math.h> mathematical functions	151

16-Bit Language Tools Libraries

Chapter 4. Standard C Libraries - Support Functions

4.1 Introduction	193
4.2 Using the Support Functions	194
4.3 Standard C Library Helper Functions	195
4.4 Standard C Library Functions That Require Modification	200
4.5 Functions/Constants to Support A Simulated UART	201
4.6 Functions for Erasing and Writing EEDATA Memory	204
4.7 Functions for Erasing and Writing Flash Memory	206
4.8 Functions for Specialized Copying and Initialization	209

Chapter 5. Fixed Point Math Functions

5.1 Introduction	213
5.2 Overview of Fixed Point Data Formats	214
5.3 Using the Fixed Point Libraries	217
5.4 <libq.h> mathematical functions	219

Appendix A. ASCII Character Set237

Index239

Worldwide Sales and Service252

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

This chapter contains general information that will be useful to know before using 16-bit libraries. Items discussed include:

- Document Layout
- Conventions Used in this Guide
- Recommended Reading
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support

DOCUMENT LAYOUT

This document describes how to use GNU language tools to write code for 16-bit applications. The document layout is as follows:

- **Chapter 1: Library Overview** – gives an overview of libraries. Some are described further in this document, while others are described in other documents or on-line Help files.
- **Chapter 2: Standard C Libraries** – lists the library functions and macros for standard C operation.
- **Chapter 3: Standard C Libraries - Math Functions** – lists the math functions for standard C operation.
- **Chapter 4: Standard C Libraries - Support Functions** – lists standard C library helper functions.
- **Chapter 5: Fixed Point Math Functions** – lists the fixed point library math functions.
- **Appendix A: ASCII Character Set**

16-Bit Language Tools Libraries

CONVENTIONS USED IN THIS GUIDE

The following conventions may appear in this documentation:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic	Referenced books	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic with right angle bracket	A menu path	<u><i>File>Save</i></u>
Bold	A dialog button	Click OK
	A tab	Click the Power tab
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain	Sample source code	#define START
	Filenames	autoexec.bat
	File paths	c:\mcc18\h
	Keywords	_asm, _endasm, static
	Command-line options	-Opa+, -Opa-
	Bit values	0, 1
	Constants	0xFF, 'A'
Italic	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mpasmwin [options] <i>file</i> [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

This documentation describes how to use 16-bit libraries. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Readme Files

For the latest information on Microchip tools, read the associated Readme files (HTML files) included with the software.

16-Bit Language Tools Getting Started (DS70094)

A guide to installing and working with the Microchip language tools for 16-bit devices. Examples using the 16-bit simulator SIM30 (a component of MPLAB SIM) are provided.

MPLAB[®] Assembler, Linker and Utilities for PIC24 MCUs and dsPIC[®] DSCs User's Guide (DS51317)

A guide to using the 16-bit assembler, object linker, and various utilities, including the 16-bit archiver/librarian.

MPLAB C Compiler for PIC24 MCUs and dsPIC[®] DSCs User's Guide (DS51284)

A guide to using the 16-bit C compiler. The 16-bit linker is used with this tool.

Device-Specific Documentation

The Microchip website contains many documents that describe 16-bit device functions and features. Among these are:

- Individual and family data sheets
- Family reference manuals
- Programmer's reference manuals

C Standards Information

American National Standard for Information Systems – *Programming Language – C*.
American National Standards Institute (ANSI), 11 West 42nd. Street, New York, New York, 10036.

This standard specifies the form and establishes the interpretation of programs expressed in the programming language C. Its purpose is to promote portability, reliability, maintainability and efficient execution of C language programs on a variety of computing systems.

C Reference Manuals

Harbison, Samuel P. and Steele, Guy L., *C A Reference Manual*, Fourth Edition, Prentice-Hall, Englewood Cliffs, N.J. 07632.

Kernighan, Brian W. and Ritchie, Dennis M., *The C Programming Language*, Second Edition. Prentice Hall, Englewood Cliffs, N.J. 07632.

Kochan, Steven G., *Programming In ANSI C*, Revised Edition. Hayden Books, Indianapolis, Indiana 46268.

Plauger, P.J., *The Standard C Library*, Prentice-Hall, Englewood Cliffs, N.J. 07632.

Van Sickle, Ted., *Programming Microcontrollers in C*, First Edition. LLH Technology Publishing, Eagle Rock, Virginia 24085.

16-Bit Language Tools Libraries

THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

DEVELOPMENT SYSTEMS CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

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The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers, assemblers, linkers and other language tools. These include all MPLAB C compilers; all MPLAB assemblers (including MPASM™ assembler); all MPLAB linkers (including MPLINK™ object linker); and all MPLAB librarians (including MPLIB™ object librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators. These include the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators
- **In-Circuit Debuggers** – The latest information on Microchip in-circuit debuggers. These include the MPLAB ICD 2 and 3 in-circuit debuggers and PICKit™ 2 and 3 debug express.
- **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 IDE Project Manager, MPLAB Editor and MPLAB SIM simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include the device (production) programmers MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger, MPLAB PM3, and PRO MATE II and development (nonproduction) programmers MPLAB ICD 2 in-circuit debugger, PICSTART® Plus and PICKit 1, 2 and 3.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

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>

16-Bit Language Tools Libraries

NOTES:

Chapter 1. Library Overview

1.1 INTRODUCTION

A library is a collection of functions grouped for reference and ease of linking. See the “MPLAB® Assembler, Linker and Utilities for PIC24 MCUs and dsPIC® DSCs User’s Guide” (DS51317) for more information about making and using libraries.

1.1.1 Assembly Code Applications

Free versions of the 16-bit language tool libraries are available from the Microchip web site. DSP and 16-bit peripheral libraries are provided with object files and source code. A math library containing functions from the standard C header file `<math.h>` is provided as an object file only. The complete standard C library is provided with the MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs (formerly MPLAB C30).

1.1.2 C Code Applications

The 16-bit language tool libraries are included in the `lib` subdirectory of the MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs install directory, which is by default:

```
C:\Program Files\Microchip\MPLAB C30\lib
```

These libraries can be linked directly into an application with 16-bit linker.

1.1.3 Chapter Organization

This chapter is organized as follows:

- OMF-Specific Libraries/Start-up Modules
- Start-up Code
- DSP Library
- 16-Bit Peripheral Libraries
- Standard C Libraries with Math and Support Functions
- Fixed Point Math Functions
- Compiler Built-in Functions

16-Bit Language Tools Libraries

1.2 OMF-SPECIFIC LIBRARIES/START-UP MODULES

Library files and start-up modules are specific to OMF (Object Module Format). An OMF can be one of the following:

- COFF – This is the default.
- ELF – The debugging format used for ELF object files is DWARF 2.0.

There are two ways to select the OMF:

1. Set an environment variable called `PIC30_OMF` for all tools.
2. Select the OMF on the command line when invoking the tool, i.e., `-omf=omf` or `-momf=omf`.

16-bit tools will first look for generic library files when building your application (no OMF specification). If these cannot be found, the tools will look at your OMF specifications and determine which library file to use.

As an example, if `libdsp.a` is not found and no environment variable or command-line option is set, the file, `libdsp-coff.a`, will be used by default.

1.3 START-UP CODE

In order to initialize variables in data memory, the linker creates a data initialization template. This template must be processed at start-up, before the application proper takes control. For C programs, this function is performed by the start-up modules in `libpic30-coff.a` (either `crt0.o` or `crt1.o`) or `libpic30-elf.a` (either `crt0.eo` or `crt1.eo`). Assembly language programs can utilize these modules directly by linking with the desired start-up module file. The source code for the start-up modules is provided in corresponding `.s` files.

The primary start-up module (`crt0`) initializes all variables (variables without initializers are set to zero as required by the ANSI standard) except for variables in the persistent data section. The alternate start-up module (`crt1`) performs no data initialization.

For more on start-up code, see the “*MPLAB[®] Assembler, Linker and Utilities for PIC24 MCUs and dsPIC[®] DSCs User's Guide*” (DS51317) and, for C applications, the “*MPLAB[®] C Compiler for PIC24 MCUs and dsPIC[®] DSCs User's Guide*” (DS51284).

1.4 DSP LIBRARY

The DSP library (`libdsp-omf.a`) provides a set of digital signal processing operations to a program targeted for execution on a dsPIC30F digital signal controller (DSC). In total, 49 functions are supported by the DSP Library.

Documentation for these libraries is provided in HTML Help files. Examples of use may also be provided. By default, the documentation is found in:

`C:\Program Files\Microchip\MPLAB C30\docs\dsp_lib`

1.5 16-BIT PERIPHERAL LIBRARIES

The 16-bit software and hardware peripheral libraries provide functions and macros for setting up and controlling 16-bit peripherals. These libraries are processor-specific and of the form, `libpDevice-omf.a`, where *Device* is the 16-bit device number (e.g., `libp30F6014-coff.a` for the dsPIC30F6014 device) and *omf* is either `coff` or `elf`.

Documentation for these libraries is provided in HTML Help files. Examples of use are also provided in each file. By default, the documentation is found in:

`C:\Program Files\Microchip\MPLAB C30\docs\periph_lib`

1.6 STANDARD C LIBRARIES WITH MATH AND SUPPORT FUNCTIONS

A complete set of ANSI-89 conforming libraries are provided. The standard C library files are `libc-omf.a` (written by Dinkumware, an industry leader) and `libm-omf.a` (math functions, written by Microchip).

Additionally, some 16-bit standard C library helper functions, and standard functions that must be modified for use with 16-bit devices, are in `libpic30-omf.a`.

A typical C application will require these libraries. Documentation for these library functions is contained in this manual.

1.7 FIXED POINT MATH FUNCTIONS

Fixed point math functions may be found in the library file, `libq-omf.a`. Documentation for these library functions is contained in this manual.

1.8 COMPILER BUILT-IN FUNCTIONS

The MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs contains built-in functions that, to the developer, work like library functions. These functions are listed in the “MPLAB[®] C Compiler for PIC24 MCUs and dsPIC[®] DSCs Users’ Guide” (DS51284).

16-Bit Language Tools Libraries

NOTES:

Chapter 2. Standard C Libraries

2.1 INTRODUCTION

Standard ANSI C library functions are contained in the file, `libc-omf.a`, where *omf* will be `coff` or `elf` depending upon the selected object module format.

2.1.1 Assembly Code Applications

A free version of the math functions library and header file is available from the Microchip web site. No source code is available with this free version.

2.1.2 C Code Applications

The MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs (formerly MPLAB C30) install directory (`c:\Program Files\Microchip\MPLAB C30`) contains the following subdirectories with library-related files:

- `lib` – standard C library files
- `src\libm` – source code for math library functions, batch file to rebuild the library
- `support\h` – header files for libraries

In addition, there is a file, `ResourceGraphs.pdf`, which contains diagrams of resources used by each function, located in `lib`.

2.1.3 Chapter Organization

This chapter is organized as follows:

- Using the Standard C Libraries
- `<assert.h>` diagnostics
- `<ctype.h>` character handling
- `<errno.h>` errors
- `<float.h>` floating-point characteristics
- `<limits.h>` implementation-defined limits
- `<locale.h>` localization
- `<setjmp.h>` non-local jumps
- `<signal.h>` signal handling
- `<stdarg.h>` variable argument lists
- `<stddef.h>` common definitions
- `<stdio.h>` input and output
- `<stdlib.h>` utility functions
- `<string.h>` string functions
- `<time.h>` date and time functions

2.2 USING THE STANDARD C LIBRARIES

Building an application which utilizes the standard C libraries requires two types of files: header files and library files.

2.2.1 Header Files

All standard C library entities are declared or defined in one or more standard headers (See list in **Section 2.1.3 “Chapter Organization”**.) To make use of a library entity in a program, write an include directive that names the relevant standard header.

The contents of a standard header is included by naming it in an include directive, as in:

```
#include <stdio.h> /* include I/O facilities */
```

The standard headers can be included in any order. Do not include a standard header within a declaration. Do not define macros that have the same names as keywords before including a standard header.

A standard header never includes another standard header.

2.2.2 Library Files

The archived library files contain all the individual object files for each library function.

When linking an application, the library file must be provided as an input to the linker (using the `--library` or `-l` linker option) such that the functions used by the application may be linked into the application.

A typical C application will require three library files: `libc-omf.a`, `libm-omf.a`, and `libpic30-omf.a`. (See **Section 1.2 “OMF-Specific Libraries/Start-up Modules”** for more on OMF-specific libraries.) These libraries will be included automatically if linking is performed using the compiler.

Note: Some standard library functions require a heap. These include the standard I/O functions that open files and the memory allocation functions. See the “*MPLAB[®] Assembler, Linker and Utilities for PIC24 MCUs and dsPIC[®] DSCs User’s Guide*” (DS51317) and “*MPLAB[®] C Compiler for PIC24 MCUs and dsPIC[®] DSCs User’s Guide*” (DS51284) for more information on the heap.

2.3 <ASSERT.H> DIAGNOSTICS

The header file, `assert.h`, consists of a single macro that is useful for debugging logic errors in programs. By using the `assert` statement in critical locations where certain conditions should be true, the logic of the program may be tested.

Assertion testing may be turned off without removing the code by defining `NDEBUG` before including `<assert.h>`. If the macro `NDEBUG` is defined, `assert()` is ignored and no code is generated.

assert

Description: If the expression is false, an assertion message is printed to `stderr` and the program is aborted.

Include: `<assert.h>`

Prototype: `void assert(int expression);`

Argument: `expression` The expression to test.

Remarks: The expression evaluates to zero or non-zero. If zero, the assertion fails, and a message is printed to `stderr`. The message includes the source file name (`__FILE__`), the source line number (`__LINE__`), the expression being evaluated and the message. The macro then calls the function `abort()`. If the macro `_VERBOSE_DEBUGGING` is defined, a message will be printed to `stderr` each time `assert()` is called.

Example: `#include <assert.h> /* for assert */`

```
int main(void)
{
    int a;

    a = 2 * 2;
    assert(a == 4); /* if true-nothing prints */
    assert(a == 6); /* if false-print message */
                    /* and abort */
}
```

Output:

```
sampassert.c:9 a == 6 -- assertion failed
ABRT
```

with `_VERBOSE_DEBUGGING` defined:

```
sampassert.c:8 a == 4 -- OK
sampassert.c:9 a == 6 -- assertion failed
ABRT
```

2.4 <CTYPE.H> CHARACTER HANDLING

The header file, `ctype.h`, consists of functions that are useful for classifying and mapping characters. Characters are interpreted according to the Standard C locale.

isalnum

Description:	Test for an alphanumeric character.
Include:	<code><ctype.h></code>
Prototype:	<code>int isalnum(int c);</code>
Argument:	<code>c</code> The character to test.
Return Value:	Returns a non-zero integer value if the character is alphanumeric; otherwise, returns a zero.
Remarks:	Alphanumeric characters are included within the ranges A-Z, a-z or 0-9.
Example:	<pre>#include <ctype.h> /* for isalnum */ #include <stdio.h> /* for printf */ int main(void) { int ch; ch = '3'; if (isalnum(ch)) printf("3 is an alphanumeric\n"); else printf("3 is NOT an alphanumeric\n"); ch = '#'; if (isalnum(ch)) printf("# is an alphanumeric\n"); else printf("# is NOT an alphanumeric\n"); }</pre>

Output:

```
3 is an alphanumeric
# is NOT an alphanumeric
```

isalpha

Description:	Test for an alphabetic character.
Include:	<code><ctype.h></code>
Prototype:	<code>int isalpha(int c);</code>
Argument:	<code>c</code> The character to test.
Return Value:	Returns a non-zero integer value if the character is alphabetic; otherwise, returns zero.
Remarks:	Alphabetic characters are included within the ranges A-Z or a-z.

isalpha (Continued)

Example:

```
#include <ctype.h> /* for isalpha */
#include <stdio.h> /* for printf */

int main(void)
{
    int ch;

    ch = 'B';
    if (isalpha(ch))
        printf("B is alphabetic\n");
    else
        printf("B is NOT alphabetic\n");

    ch = '#';
    if (isalpha(ch))
        printf("# is alphabetic\n");
    else
        printf("# is NOT alphabetic\n");
}
```

Output:
B is alphabetic
is NOT alphabetic

isctrl

Description: Test for a control character.

Include: <ctype.h>

Prototype: int isctrl(int c);

Argument: c character to test.

Return Value: Returns a non-zero integer value if the character is a control character; otherwise, returns zero.

Remarks: A character is considered to be a control character if its ASCII value is in the range, 0x00 to 0x1F inclusive, or 0x7F.

Example:

```
#include <ctype.h> /* for isctrl */
#include <stdio.h> /* for printf */

int main(void)
{
    char ch;

    ch = 'B';
    if (isctrl(ch))
        printf("B is a control character\n");
    else
        printf("B is NOT a control character\n");

    ch = '\t';
    if (isctrl(ch))
        printf("A tab is a control character\n");
    else
        printf("A tab is NOT a control character\n");
}
```

Output:
B is NOT a control character
A tab is a control character

isdigit

Description:	Test for a decimal digit.
Include:	<ctype.h>
Prototype:	int isdigit(int c);
Argument:	c character to test.
Return Value:	Returns a non-zero integer value if the character is a digit; otherwise, returns zero.
Remarks:	A character is considered to be a digit character if it is in the range of '0'-'9'.
Example:	<pre>#include <ctype.h> /* for isdigit */ #include <stdio.h> /* for printf */ int main(void) { int ch; ch = '3'; if (isdigit(ch)) printf("3 is a digit\n"); else printf("3 is NOT a digit\n"); ch = '#'; if (isdigit(ch)) printf("# is a digit\n"); else printf("# is NOT a digit\n"); }</pre> <p>Output: 3 is a digit # is NOT a digit</p>

isgraph

Description:	Test for a graphical character.
Include:	<ctype.h>
Prototype:	int isgraph (int c);
Argument:	c character to test
Return Value:	Returns a non-zero integer value if the character is a graphical character; otherwise, returns zero.
Remarks:	A character is considered to be a graphical character if it is any printable character except a space.
Example:	<pre>#include <ctype.h> /* for isgraph */ #include <stdio.h> /* for printf */ int main(void) { int ch;</pre>

isgraph (Continued)

```
ch = '3';
if (isgraph(ch))
    printf("3 is a graphical character\n");
else
    printf("3 is NOT a graphical character\n");

ch = '#';
if (isgraph(ch))
    printf("# is a graphical character\n");
else
    printf("# is NOT a graphical character\n");

ch = ' ';
if (isgraph(ch))
    printf("a space is a graphical character\n");
else
    printf("a space is NOT a graphical character\n");
}
```

Output:

```
3 is a graphical character
# is a graphical character
a space is NOT a graphical character
```

islower

Description:	Test for a lower case alphabetic character.
Include:	<ctype.h>
Prototype:	int islower (int c);
Argument:	c character to test
Return Value:	Returns a non-zero integer value if the character is a lower case alphabetic character; otherwise, returns zero.
Remarks:	A character is considered to be a lower case alphabetic character if it is in the range of 'a'-'z'.
Example:	<pre>#include <ctype.h> /* for islower */ #include <stdio.h> /* for printf */ int main(void) { int ch; ch = 'B'; if (islower(ch)) printf("B is lower case\n"); else printf("B is NOT lower case\n"); ch = 'b'; if (islower(ch)) printf("b is lower case\n"); else printf("b is NOT lower case\n"); }</pre>

islower (Continued)

Output:

B is NOT lower case
b is lower case

isprint

Description:	Test for a printable character (includes a space).
Include:	<ctype.h>
Prototype:	int isprint (int c);
Argument:	c character to test
Return Value:	Returns a non-zero integer value if the character is printable; otherwise, returns zero.
Remarks:	A character is considered to be a printable character if it is in the range, 0x20 to 0x7e inclusive.
Example:	<pre>#include <ctype.h> /* for isprint */ #include <stdio.h> /* for printf */ int main(void) { int ch; ch = '&'; if (isprint(ch)) printf("& is a printable character\n"); else printf("& is NOT a printable character\n"); ch = '\t'; if (isprint(ch)) printf("a tab is a printable character\n"); else printf("a tab is NOT a printable character\n"); }</pre> Output: & is a printable character a tab is NOT a printable character

ispunct

Description:	Test for a punctuation character.
Include:	<ctype.h>
Prototype:	int ispunct (int c);
Argument:	c character to test
Return Value:	Returns a non-zero integer value if the character is a punctuation character; otherwise, returns zero.
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. Punctuation characters consist of the following: ! " # \$ % & ' ( ) ; < = > ? @ [ \ \] * + , - . / : ^ _ { | } ~

ispunct (Continued)

Example:

```
#include <ctype.h> /* for ispunct */
#include <stdio.h> /* for printf */

int main(void)
{
    int ch;

    ch = '&';
    if (ispunct(ch))
        printf("& is a punctuation character\n");
    else
        printf("& is NOT a punctuation character\n");

    ch = '\t';
    if (ispunct(ch))
        printf("a tab is a punctuation character\n");
    else
        printf("a tab is NOT a punctuation character\n");
}
```

Output:

```
& is a punctuation character
a tab is NOT a punctuation character
```

isspace

Description: Test for a white-space character.

Include: <ctype.h>

Prototype: int isspace (int c);

Argument: c character to test

Return Value: Returns a non-zero integer value if the character is a white-space character; otherwise, returns zero.

Remarks: A character is considered to be a white-space character if it is one of the following: space (' '), form feed ('\f'), newline ('\n'), carriage return ('\r'), horizontal tab ('\t'), or vertical tab ('\v').

Example:

```
#include <ctype.h> /* for isspace */
#include <stdio.h> /* for printf */

int main(void)
{
    int ch;

    ch = '&';
    if (isspace(ch))
        printf("& is a white-space character\n");
    else
        printf("& is NOT a white-space character\n");

    ch = '\t';
    if (isspace(ch))
        printf("a tab is a white-space character\n");
    else
        printf("a tab is NOT a white-space character\n");
}
```

isspace (Continued)

Output:

& is NOT a white-space character
a tab is a white-space character

isupper

Description: Test for an upper case letter.

Include: <ctype.h>

Prototype: int isupper (int c);

Argument: c character to test

Return Value: Returns a non-zero integer value if the character is an upper case alphabetic character; otherwise, returns zero.

Remarks: A character is considered to be an upper case alphabetic character if it is in the range of 'A'-'Z'.

Example:

```
#include <ctype.h> /* for isupper */
#include <stdio.h> /* for printf */
```

```
int main(void)
{
    int ch;

    ch = 'B';
    if (isupper(ch))
        printf("B is upper case\n");
    else
        printf("B is NOT upper case\n");

    ch = 'b';
    if (isupper(ch))
        printf("b is upper case\n");
    else
        printf("b is NOT upper case\n");
}
```

Output:

B is upper case
b is NOT upper case

isxdigit

Description: Test for a hexadecimal digit.

Include: <ctype.h>

Prototype: int isxdigit (int c);

Argument: c character to test

Return Value: Returns a non-zero integer value if the character is a hexadecimal digit; otherwise, returns zero.

Remarks: A character is considered to be a hexadecimal digit character if it is in the range of '0'-'9', 'A'-'F', or 'a'-'f'. Note: The list does not include the leading 0x because 0x is the prefix for a hexadecimal number but is not an actual hexadecimal digit.

isxdigit (Continued)

Example:

```
#include <ctype.h> /* for isxdigit */
#include <stdio.h> /* for printf */

int main(void)
{
    int ch;

    ch = 'B';
    if (isxdigit(ch))
        printf("B is a hexadecimal digit\n");
    else
        printf("B is NOT a hexadecimal digit\n");

    ch = 't';
    if (isxdigit(ch))
        printf("t is a hexadecimal digit\n");
    else
        printf("t is NOT a hexadecimal digit\n");
}
```

Output:

```
B is a hexadecimal digit
t is NOT a hexadecimal digit
```

tolower

Description: Convert a character to a lower case alphabetical character.

Include: <ctype.h>

Prototype: int tolower (int c);

Argument: c The character to convert to lower case.

Return Value: Returns the corresponding lower case alphabetical character if the argument was originally upper case; otherwise, returns the original character.

Remarks: Only upper case alphabetical characters may be converted to lower case.

Example:

```
#include <ctype.h> /* for tolower */
#include <stdio.h> /* for printf */

int main(void)
{
    int ch;

    ch = 'B';
    printf("B changes to lower case %c\n",
        tolower(ch));

    ch = 'b';
    printf("b remains lower case %c\n",
        tolower(ch));

    ch = '@';
    printf("@ has no lower case, ");
    printf("so %c is returned\n", tolower(ch));
}
```

tolower (Continued)

Output:

B changes to lower case b
b remains lower case b
@ has no lower case, so @ is returned

toupper

Description: Convert a character to an upper case alphabetical character.

Include: <ctype.h>

Prototype: int toupper (int c);

Argument: c The character to convert to upper case.

Return Value: Returns the corresponding upper case alphabetical character if the argument was originally lower case; otherwise, returns the original character.

Remarks: Only lower case alphabetical characters may be converted to upper case.

Example:

```
#include <ctype.h> /* for toupper */
#include <stdio.h> /* for printf */

int main(void)
{

    int ch;

    ch = 'b';
    printf("b changes to upper case %c\n",
          toupper(ch));

    ch = 'B';
    printf("B remains upper case %c\n",
          toupper(ch));

    ch = '@';
    printf("@ has no upper case, ");
    printf("so %c is returned\n", toupper(ch));
}
```

Output:

b changes to upper case B
B remains upper case B
@ has no upper case, so @ is returned

2.5 <ERRNO.H> ERRORS

The header file, `errno.h`, consists of macros that provide error codes that are reported by certain library functions (see individual functions). The variable, `errno`, may return any value greater than zero. To test if a library function encounters an error, the program should store the zero value in `errno` immediately before calling the library function. The value should be checked before another function call could change the value. At program start-up, `errno` is zero. Library functions will never set `errno` to zero.

EDOM

Description:	Represents a domain error.
Include:	<code><errno.h></code>
Remarks:	EDOM represents a domain error, which occurs when an input argument is outside the domain in which the function is defined.

ERANGE

Description:	Represents an overflow or underflow error.
Include:	<code><errno.h></code>
Remarks:	ERANGE represents an overflow or underflow error, which occurs when a result is too large or too small to be stored.

errno

Description:	Contains the value of an error when an error occurs in a function.
Include:	<code><errno.h></code>
Remarks:	The variable, <code>errno</code> , is set to a non-zero integer value by a library function when an error occurs. At program start-up, <code>errno</code> is set to zero. <code>Errno</code> should be reset to zero prior to calling a function that sets it.

16-Bit Language Tools Libraries

2.6 <FLOAT.H> FLOATING-POINT CHARACTERISTICS

The header file, `float.h`, consists of macros that specify various properties of floating-point types. These properties include number of significant figures, size limits and what rounding mode is used.

DBL_DIG

Description:	Number of decimal digits of precision in a double precision floating-point value.
Include:	<code><float.h></code>
Value:	6 by default, 15 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_EPSILON

Description:	The difference between 1.0 and the next larger representable double precision floating-point value
Include:	<code><float.h></code>
Value:	1.192093e-07 by default, 2.220446e-16 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MANT_DIG

Description:	Number of base-FLT_RADIX digits in a double precision floating-point significand.
Include:	<code><float.h></code>
Value:	24 by default, 53 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MAX

Description:	Maximum finite double precision floating-point value.
Include:	<code><float.h></code>
Value:	3.402823e+38 by default, 1.797693e+308 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MAX_10_EXP

Description:	Maximum integer value for a double precision floating-point exponent in base 10.
Include:	<float.h>
Value:	38 by default, 308 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MAX_EXP

Description:	Maximum integer value for a double precision floating-point exponent in base FLT_RADIX.
Include:	<float.h>
Value:	128 by default, 1024 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MIN

Description:	Minimum double precision floating-point value.
Include:	<float.h>
Value:	1.175494e-38 by default, 2.225074e-308 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MIN_10_EXP

Description:	Minimum negative integer value for a double precision floating-point exponent in base 10.
Include:	<float.h>
Value:	-37 by default, -307 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

16-Bit Language Tools Libraries

DBL_MIN_EXP

Description:	Minimum negative integer value for a double precision floating-point exponent in base <code>FLT_RADIX</code> .
Include:	<code><float.h></code>
Value:	-125 by default, -1021 if the switch <code>-fno-short-double</code> is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The <code>-fno-short-double</code> switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

FLT_DIG

Description:	Number of decimal digits of precision in a single precision floating-point value.
Include:	<code><float.h></code>
Value:	6

FLT_EPSILON

Description:	The difference between 1.0 and the next larger representable single precision floating-point value.
Include:	<code><float.h></code>
Value:	1.192093e-07

FLT_MANT_DIG

Description:	Number of base- <code>FLT_RADIX</code> digits in a single precision floating-point significand.
Include:	<code><float.h></code>
Value:	24

FLT_MAX

Description:	Maximum finite single precision floating-point value.
Include:	<code><float.h></code>
Value:	3.402823e+38

FLT_MAX_10_EXP

Description:	Maximum integer value for a single precision floating-point exponent in base 10.
Include:	<code><float.h></code>
Value:	38

FLT_MAX_EXP

Description: Maximum integer value for a single precision floating-point exponent in base FLT_RADIX.

Include: <float.h>

Value: 128

FLT_MIN

Description: Minimum single precision floating-point value.

Include: <float.h>

Value: 1.175494e-38

FLT_MIN_10_EXP

Description: Minimum negative integer value for a single precision floating-point exponent in base 10.

Include: <float.h>

Value: -37

FLT_MIN_EXP

Description: Minimum negative integer value for a single precision floating-point exponent in base FLT_RADIX.

Include: <float.h>

Value: -125

FLT_RADIX

Description: Radix of exponent representation.

Include: <float.h>

Value: 2

Remarks: The base representation of the exponent is base-2 or binary.

FLT_ROUNDS

Description: Represents the rounding mode for floating-point operations.

Include: <float.h>

Value: 1

Remarks: Rounds to the nearest representable value.

LDBL_DIG

Description: Number of decimal digits of precision in a long double precision floating-point value.

Include: <float.h>

Value: 15

16-Bit Language Tools Libraries

LDBL_EPSILON

Description: The difference between 1.0 and the next larger representable long double precision floating-point value.

Include: `<float.h>`

Value: 2.220446e-16

LDBL_MANT_DIG

Description: Number of base-FLT_RADIX digits in a long double precision floating-point significand.

Include: `<float.h>`

Value: 53

LDBL_MAX

Description: Maximum finite long double precision floating-point value.

Include: `<float.h>`

Value: 1.797693e+308

LDBL_MAX_10_EXP

Description: Maximum integer value for a long double precision floating-point exponent in base 10.

Include: `<float.h>`

Value: 308

LDBL_MAX_EXP

Description: Maximum integer value for a long double precision floating-point exponent in base FLT_RADIX.

Include: `<float.h>`

Value: 1024

LDBL_MIN

Description: Minimum long double precision floating-point value.

Include: `<float.h>`

Value: 2.225074e-308

LDBL_MIN_10_EXP

Description: Minimum negative integer value for a long double precision floating-point exponent in base 10.

Include: `<float.h>`

Value: -307

LDBL_MIN_EXP

Description: Minimum negative integer value for a long double precision floating-point exponent in base `FLT_RADIX`.

Include: `<float.h>`

Value: -1021

2.7 <LIMITS.H> IMPLEMENTATION-DEFINED LIMITS

The header file, `limits.h`, consists of macros that define the minimum and maximum values of integer types. Each of these macros can be used in `#if` preprocessing directives.

CHAR_BIT

Description: Number of bits to represent type `char`.

Include: `<limits.h>`

Value: 8

CHAR_MAX

Description: Maximum value of a `char`.

Include: `<limits.h>`

Value: 127

CHAR_MIN

Description: Minimum value of a `char`.

Include: `<limits.h>`

Value: -128

INT_MAX

Description: Maximum value of an `int`.

Include: `<limits.h>`

Value: 32767

INT_MIN

Description: Minimum value of an `int`.

Include: `<limits.h>`

Value: -32768

LLONG_MAX

Description: Maximum value of a long long `int`.

Include: `<limits.h>`

Value: 9223372036854775807

16-Bit Language Tools Libraries

LLONG_MIN

Description: Minimum value of a long long int.
Include: <limits.h>
Value: -9223372036854775808

LONG_MAX

Description: Maximum value of a long int.
Include: <limits.h>
Value: 2147483647

LONG_MIN

Description: Minimum value of a long int.
Include: <limits.h>
Value: -2147483648

MB_LEN_MAX

Description: Maximum number of bytes in a multibyte character.
Include: <limits.h>
Value: 1

SCHAR_MAX

Description: Maximum value of a signed char.
Include: <limits.h>
Value: 127

SCHAR_MIN

Description: Minimum value of a signed char.
Include: <limits.h>
Value: -128

SHRT_MAX

Description: Maximum value of a short int.
Include: <limits.h>
Value: 32767

SHRT_MIN

Description: Minimum value of a short int.
Include: <limits.h>
Value: -32768

UCHAR_MAX

Description: Maximum value of an unsigned char.
Include: <limits.h>
Value: 255

UINT_MAX

Description: Maximum value of an unsigned int.
Include: <limits.h>
Value: 65535

ULLONG_MAX

Description: Maximum value of a long long unsigned int.
Include: <limits.h>
Value: 18446744073709551615

ULONG_MAX

Description: Maximum value of a long unsigned int.
Include: <limits.h>
Value: 4294967295

USHRT_MAX

Description: Maximum value of an unsigned short int.
Include: <limits.h>
Value: 65535

2.8 <LOCALE.H> LOCALIZATION

This compiler defaults to the C locale and does not support any other locales; therefore, it does not support the header file, `locale.h`. The following would normally be found in this file:

- struct lconv
- NULL
- LC_ALL
- LC_COLLATE
- LC_CTYPE
- LC_MONETARY
- LC_NUMERIC
- LC_TIME
- localeconv
- setlocale

16-Bit Language Tools Libraries

2.9 <SETJMP.H> NON-LOCAL JUMPS

The header file, `setjmp.h`, consists of a type, a macro and a function that allow control transfers to occur that bypass the normal function call and return process.

`jmp_buf`

Description: A type that is an array used by `setjmp` and `longjmp` to save and restore the program environment.

Include: `<setjmp.h>`

Prototype: `typedef int jmp_buf[_NSETJMP];`

Remarks: `_NSETJMP` is defined as `16 + 2` that represents 16 registers and a 32-bit return address.

`setjmp`

Description: A macro that saves the current state of the program for later use by `longjmp`.

Include: `<setjmp.h>`

Prototype: `#define setjmp(jmp_buf env)`

Argument: `env` variable where environment is stored

Return Value: If the return is from a direct call, `setjmp` returns zero. If the return is from a call to `longjmp`, `setjmp` returns a non-zero value.
Note: If the argument `val` from `longjmp` is 0, `setjmp` returns 1.

Example: See `longjmp`.

`longjmp`

Description: A function that restores the environment saved by `setjmp`.

Include: `<setjmp.h>`

Prototype: `void longjmp(jmp_buf env, int val);`

Arguments: `env` variable where environment is stored
`val` value to be returned to `setjmp` call.

Remarks: The value parameter, `val`, should be non-zero. If `longjmp` is invoked from a nested signal handler (that is, invoked as a result of a signal raised during the handling of another signal), the behavior is undefined.

2.10 <SIGNAL.H> SIGNAL HANDLING

The header file, `signal.h`, consists of a type, several macros and two functions that specify how the program handles signals while it is executing. A signal is a condition that may be reported during the program execution. Signals are synchronous, occurring under software control via the `raise` function.

A signal may be handled by:

- Default handling (`SIG_DFL`); the signal is treated as a fatal error and execution stops
- Ignoring the signal (`SIG_IGN`); the signal is ignored and control is returned to the user application
- Handling the signal with a function designated via `signal`.

By default, all signals are handled by the default handler, which is identified by `SIG_DFL`.

The type `sig_atomic_t` is an integer type that the program access atomically. When this type is used with the keyword `volatile`, the signal handler can share the data objects with the rest of the program.

sig_atomic_t

Description:	A type used by a signal handler.
Include:	<code><signal.h></code>
Prototype:	<code>typedef int sig_atomic_t;</code>

SIG_DFL

Description:	Used as the second argument and/or the return value for <code>signal</code> to specify that the default handler should be used for a specific signal.
Include:	<code><signal.h></code>

SIG_ERR

Description:	Used as the return value for <code>signal</code> when it cannot complete a request due to an error.
Include:	<code><signal.h></code>

SIG_IGN

Description:	Used as the second argument and/or the return value for <code>signal</code> to specify that the signal should be ignored.
Include:	<code><signal.h></code>

16-Bit Language Tools Libraries

SIGABRT

Description:	Name for the abnormal termination signal.
Include:	<code><signal.h></code>
Prototype:	<code>#define SIGABRT</code>
Remarks:	<p>SIGABRT represents an abnormal termination signal and is used in conjunction with <code>raise</code> or <code>signal</code>. The default <code>raise</code> behavior (action identified by <code>SIG_DFL</code>) is to output to the standard error stream:</p> <pre>abort - terminating</pre> <p>See the example accompanying <code>signal</code> to see general usage of signal names and signal handling.</p>
Example:	<pre>#include <signal.h> /* for raise, SIGABRT */ #include <stdio.h> /* for printf */ int main(void) { raise(SIGABRT); printf("Program never reaches here."); }</pre> <p>Output: ABRT</p> <p>Explanation: ABRT stands for “abort”.</p>

SIGFPE

Description:	Signals floating-point, error such as for division by zero or result out of range.
Include:	<code><signal.h></code>
Prototype:	<code>#define SIGFPE</code>
Remarks:	<p>SIGFPE is used as an argument for <code>raise</code> and/or <code>signal</code>. When used, the default behavior is to print an arithmetic error message and terminate the calling program. This may be overridden by a user function that defines the signal handler actions. See <code>signal</code> for an example of a user-defined function.</p>
Example:	<pre>#include <signal.h> /* for raise, SIGFPE */ #include <stdio.h> /* for printf */ int main(void) { raise(SIGFPE); printf("Program never reaches here"); }</pre> <p>Output: FPE</p> <p>Explanation: FPE stands for “floating-point error”.</p>

SIGILL

Description:	Signals illegal instruction.
Include:	<code><signal.h></code>
Prototype:	<code>#define SIGILL</code>
Remarks:	<code>SIGILL</code> is used as an argument for <code>raise</code> and/or <code>signal</code> . When used, the default behavior is to print an invalid executable code message and terminate the calling program. This may be overridden by a user function that defines the signal handler actions. See <code>signal</code> for an example of a user-defined function.
Example:	<pre>#include <signal.h> /* for raise, SIGILL */ #include <stdio.h> /* for printf */ int main(void) { raise(SIGILL); printf("Program never reaches here"); }</pre> <p>Output: ILL</p> <p>Explanation: ILL stands for “illegal instruction”.</p>

SIGINT

Description:	Interrupt signal.
Include:	<code><signal.h></code>
Prototype:	<code>#define SIGINT</code>
Remarks:	<code>SIGINT</code> is used as an argument for <code>raise</code> and/or <code>signal</code> . When used, the default behavior is to print an interruption message and terminate the calling program. This may be overridden by a user function that defines the signal handler actions. See <code>signal</code> for an example of a user-defined function.
Example:	<pre>#include <signal.h> /* for raise, SIGINT */ #include <stdio.h> /* for printf */ int main(void) { raise(SIGINT); printf("Program never reaches here."); }</pre> <p>Output: INT</p> <p>Explanation: INT stands for “interruption”.</p>

SIGSEGV

Description:	Signals invalid access to storage.
Include:	<signal.h>
Prototype:	#define SIGSEGV
Remarks:	SIGSEGV is used as an argument for <code>raise</code> and/or <code>signal</code> . When used, the default behavior is to print an invalid storage request message and terminate the calling program. This may be overridden by a user function that defines the signal handler actions. See <code>signal</code> for an example of a user-defined function.
Example:	<pre>#include <signal.h> /* for raise, SIGSEGV */ #include <stdio.h> /* for printf */ int main(void) { raise(SIGSEGV); printf("Program never reaches here."); }</pre> <p>Output: SEGV</p> <p>Explanation: SEGV stands for “invalid storage access”.</p>

SIGTERM

Description:	Signals a termination request.
Include:	<signal.h>
Prototype:	#define SIGTERM
Remarks:	SIGTERM is used as an argument for <code>raise</code> and/or <code>signal</code> . When used, the default behavior is to print a termination request message and terminate the calling program. This may be overridden by a user function that defines the signal handler actions. See <code>signal</code> for an example of a user-defined function.
Example:	<pre>#include <signal.h> /* for raise, SIGTERM */ #include <stdio.h> /* for printf */ int main(void) { raise(SIGTERM); printf("Program never reaches here."); }</pre> <p>Output: TERM</p> <p>Explanation: TERM stands for “termination request”.</p>

raise

Description:	Reports a synchronous signal.
Include:	<signal.h>
Prototype:	int raise(int sig);
Argument:	sig signal name
Return Value:	Returns a 0 if successful; otherwise, returns a non-zero value.
Remarks:	raise sends the signal identified by sig to the executing program.
Example:	

```
#include <signal.h>    /* for raise, signal, */
                        /* SIGILL, SIG_DFL    */
#include <stdlib.h>     /* for div, div_t    */
#include <stdio.h>      /* for printf        */
#include <p30f6014.h>   /* for INTCON1bits */
```

```
void __attribute__((__interrupt__))
_MathError(void)
{
    raise(SIGILL);
    INTCON1bits.MATHERR = 0;
}
```

```
void illegalinsn(int idsig)
{
    printf("Illegal instruction executed\n");
    exit(1);
}
```

```
int main(void)
{
    int x, y;
    div_t z;

    signal(SIGILL, illegalinsn);
    x = 7;
    y = 0;
    z = div(x, y);
    printf("Program never reaches here");
}
```

Output:

Illegal instruction executed

Explanation:

This example requires the linker script, p30f6014.gld. There are three parts to this example.

First, an interrupt handler is written for the interrupt vector, _MathError, to handle a math error by sending an illegal instruction, signal (SIGILL), to the executing program. The last statement in the interrupt handler clears the exception flag.

Second, the function, illegalinsn, will print an error message and call exit.

Third, in main, signal (SIGILL, illegalinsn) sets the handler for SIGILL to the function, illegalinsn.

When a math error occurs, due to a divide by zero, the _MathError interrupt vector is called, which in turn, will raise a signal that will call the handler function for SIGILL, which is the function, illegalinsn. Thus, error messages are printed and the program is terminated.

signal

Description: Controls interrupt signal handling.

Include: <signal.h>

Prototype: void (*signal(int sig, void(*func)(int)))(int);

Arguments: *sig* signal name
func function to be executed

Return Value: Returns the previous value of *func*.

Example:

```
#include <signal.h> /* for signal, raise, */
                        /* SIGINT, SIGILL, */
                        /* SIG_IGN, and SIGFPE */
#include <stdio.h> /* for printf */

/* Signal handler function */
void mysigint(int id)
{
    printf("SIGINT received\n");
}

int main(void)
{
    /* Override default with user defined function */
    signal(SIGINT, mysigint);
    raise(SIGINT);

    /* Ignore signal handler */
    signal(SIGILL, SIG_IGN);
    raise(SIGILL);
    printf("SIGILL was ignored\n");

    /* Use default signal handler */
    raise(SIGFPE);
    printf("Program never reaches here.");
}
```

Output:

```
SIGINT received
SIGILL was ignored
FPE
```

Explanation:

The function, `mysigint`, is the user-defined signal handler for `SIGINT`. Inside the main program, the function, `signal`, is called to set up the signal handler (`mysigint`) for the signal `SIGINT` that will override the default actions. The function, `raise`, is called to report the signal `SIGINT`. This causes the signal handler for `SIGINT` to use the user-defined function (`mysigint`) as the signal handler so it prints the "SIGINT received" message.

Next, the function, `signal`, is called to set up the signal handler `SIG_IGN` for the signal `SIGILL`. The constant `SIG_IGN` is used to indicate the signal should be ignored. The function, `raise`, is called to report the signal, `SIGILL` that is ignored.

The function, `raise`, is called again to report the signal, `SIGFPE`. Since there is no user-defined function for `SIGFPE`, the default signal handler is used so the message "FPE" is printed (which stands for "arithmetic error - terminating"). Then, the calling program is terminated. The `printf` statement is never reached.

2.11 <STDARG.H> VARIABLE ARGUMENT LISTS

The header file, `stdarg.h`, supports functions with variable argument lists. This allows functions to have arguments without corresponding parameter declarations. There must be at least one named argument. The variable arguments are represented by ellipses (...). An object of type, `va_list`, must be declared inside the function to hold the arguments. `va_start` will initialize the variable to an argument list, `va_arg` will access the argument list, and `va_end` will end the use of the argument.

`va_list`

Description: The type `va_list` declares a variable that will refer to each argument in a variable-length argument list.

Include: `<stdarg.h>`

Example: See `va_arg`.

`va_arg`

Description: Gets the current argument.

Include: `<stdarg.h>`

Prototype: `#define va_arg(va_list ap, Ty)`

Argument: `ap` pointer to list of arguments
`Ty` type of argument to be retrieved

Return Value: Returns the current argument

Remarks: `va_start` must be called before `va_arg`.

Example:

```
#include <stdio.h>    /* for printf */
#include <stdarg.h>    /* for va_arg, va_start,
                        va_list, va_end */

void tprint(const char *fmt, ...)
{
    va_list ap;

    va_start(ap, fmt);
    while (*fmt)
    {
        switch (*fmt)
        {
```

va_arg (Continued)

```
        case '%':
            fmt++;
            if (*fmt == 'd')
            {
                int d = va_arg(ap, int);
                printf("<%d> is an integer\n", d);
            }
            else if (*fmt == 's')
            {
                char *s = va_arg(ap, char*);
                printf("<%s> is a string\n", s);
            }
            else
            {
                printf("%%%c is an unknown format\n",
                    *fmt);
            }
            fmt++;
            break;
        default:
            printf("%c is unknown\n", *fmt);
            fmt++;
            break;
    }
}
va_end(ap);
}
```

```
int main(void)
{
    tprint("%d%s.%c", 83, "This is text.", 'a');
}
```

Output:

```
<83> is an integer
<This is text.> is a string
. is unknown
%c is an unknown format
```

va_end

Description:	Ends the use of <i>ap</i> .
Include:	<stdarg.h>
Prototype:	#define va_end(va_list ap)
Argument:	<i>ap</i> pointer to list of arguments
Remarks:	After a call to <i>va_end</i> , the argument list pointer, <i>ap</i> , is considered to be invalid. Further calls to <i>va_arg</i> should not be made until the next <i>va_start</i> . In the 16-bit compiler, <i>va_end</i> does nothing, so this call is not necessary but should be used for readability and portability.
Example:	See <i>va_arg</i> .

va_start

Description:	Sets the argument pointer <i>ap</i> to first optional argument in the variable-length argument list.
Include:	<stdarg.h>
Prototype:	#define va_start(va_list ap, last_arg)
Argument:	<i>ap</i> pointer to list of arguments <i>last_arg</i> last named argument before the optional arguments
Example:	See <i>va_arg</i> .

2.12 <STDDEF.H> COMMON DEFINITIONS

The header file, *stddef.h*, consists of several types and macros that are of general use in programs.

ptrdiff_t

Description:	The type of the result of subtracting two pointers.
Include:	<stddef.h>

size_t

Description:	The type of the result of the <i>sizeof</i> operator.
Include:	<stddef.h>

wchar_t

Description:	A type that holds a wide character value.
Include:	<stddef.h>

NULL

Description:	The value of a null pointer constant.
Include:	<stddef.h>

offsetof

Description:	Gives the offset of a structure member from the beginning of the structure.
Include:	<code><stddef.h></code>
Prototype:	<code>#define offsetof(T, mbr)</code>
Arguments:	<i>T</i> name of structure <i>mbr</i> name of member in structure <i>T</i>
Return Value:	Returns the offset in bytes of the specified member (<i>mbr</i>) from the beginning of the structure.
Remarks:	The macro <code>offsetof</code> is undefined for bitfields. An error message will occur if bitfields are used.

Example:

```
#include <stddef.h> /* for offsetof */
#include <stdio.h>  /* for printf */

struct info {
    char item1[5];
    int item2;
    char item3;
    float item4;
};

int main(void)
{
    printf("Offset of item1 = %d\n",
           offsetof(struct info,item1));
    printf("Offset of item2 = %d\n",
           offsetof(struct info,item2));
    printf("Offset of item3 = %d\n",
           offsetof(struct info,item3));
    printf("Offset of item4 = %d\n",
           offsetof(struct info,item4));
}
```

Output:

```
Offset of item1 = 0
Offset of item2 = 6
Offset of item3 = 8
Offset of item4 = 10
```

Explanation:

This program shows the offset in bytes of each structure member from the start of the structure. Although `item1` is only 5 bytes (`char item1[5]`), padding is added so the address of `item2` falls on an even boundary. The same occurs with `item3`; it is 1 byte (`char item3`) with 1 byte of padding.

2.13 <STDIO.H> INPUT AND OUTPUT

The header file, `stdio.h`, consists of types, macros and functions that provide support to perform input and output operations on files and streams. When a file is opened it is associated with a stream. A stream is a pipeline for the flow of data into and out of files. Because different systems use different properties, the stream provides more uniform properties to allow reading and writing of the files.

Streams can be text streams or binary streams. Text streams consist of a sequence of characters divided into lines. Each line is terminated with a newline ('`\n`') character. The characters may be altered in their internal representation, particularly in regards to line endings. Binary streams consist of sequences of bytes of information. The bytes transmitted to the binary stream are not altered. There is no concept of lines - the file is just a series of bytes.

At start-up three streams are automatically opened: `stdin`, `stdout`, and `stderr`. `stdin` provides a stream for standard input, `stdout` is standard output and `stderr` is the standard error. Additional streams may be created with the `fopen` function. See `fopen` for the different types of file access that are permitted. These access types are used by `fopen` and `freopen`.

The type `FILE` is used to store information about each opened file stream. It includes such things as error indicators, end-of-file indicators, file position indicators, and other internal status information needed to control a stream. Many functions in the `stdio` use `FILE` as an argument.

There are three types of buffering: unbuffered, line buffered and fully buffered. Unbuffered means a character or byte is transferred one at a time. Line buffered collects and transfers an entire line at a time (i.e., the newline character indicates the end of a line). Fully buffered allows blocks of an arbitrary size to be transmitted. The functions, `setbuf` and `setvbuf`, control file buffering.

The `stdio.h` file also contains functions that use input and output formats. The input formats, or scan formats, are used for reading data. Their descriptions can be found under `scanf`, but they are also used by `fscanf` and `sscanf`. The output formats, or print formats, are used for writing data. Their descriptions can be found under `printf`. These print formats are also used by `fprintf`, `sprintf`, `vfprintf`, `vprintf` and `vsprintf`.

2.13.1 Compiler Options

Certain compiler options may affect how standard I/O performs. In an effort to provide a more tailored version of the formatted I/O routines, the tool chain may convert a call to a `printf` or `scanf` style function to a different call. The options are summarized below:

- The `-msmart-io` option, when enabled, will attempt to convert `printf`, `scanf` and other functions that use the input output formats to an integer only variant. The functionality is the same as that of the C standard forms, minus the support for floating-point output. `-msmart-io=0` disables this feature and no conversion will take place. `-msmart-io=1` or `-msmart-io` (the default) will convert a function call if it can be proven that an I/O function will never be presented with a floating-point conversion. `-msmart-io=2` is more optimistic than the default and will assume that non-constant format strings or otherwise unknown format strings will not contain a floating-point format. In the event that `-msmart-io=2` is used with a floating-point format, the format letter will appear as literal text and its corresponding argument will not be consumed.

- `-fno-short-double` will cause the compiler to generate calls to formatted I/O routines that support `double` as if it were a `long double` type.

Mixing modules compiled with these options may result in a larger executable size, or incorrect execution if large and small double-sized data is shared across modules.

2.13.2 Customizing STDIO

The standard I/O relies on helper functions described in **Chapter 4. “Standard C Libraries - Support Functions”**. These functions include `read()`, `write()`, `open()`, and `close()` which are called to read, write, open or close handles that are associated with standard I/O `FILE` pointers. The sources for these libraries are provided for you to customize as you wish.

The simplest way to redirect standard I/O to the peripheral of your choice is to select one of the default handles already in use. Also, you could open files with a specific name, via `fopen()`, by rewriting `open()` to return a new handle to be recognized by `read()` or `write()`, as appropriate.

If only a specific peripheral is required, then you could associate handle `1 == stdout`, or `2 == stderr`, to another peripheral by writing the correct code to talk to the interested peripheral.

A complete generic solution might be:

```
/* should be in a header file */
enum my_handles {
    handle_stdin,
    handle_stdout,
    handle_stderr,
    handle_can1,
    handle_can2,
    handle_spi1,
    handle_spi2,
};

int __attribute__((__weak__, __section__(".libc"))) open(const char
*name, int access, int mode) {
    switch (name[0]) {
        case 'i' : return handle_stdin;
        case 'o' : return handle_stdout;
        case 'e' : return handle_stderr;
        case 'c' : return handle_can1;
        case 'C' : return handle_can2;
        case 's' : return handle_spi1;
        case 'S' : return handle_spi2;
        default: return handle_stderr;
    }
}
```

Single letters were used in this example because they are faster to check and use less memory. However, if memory is not an issue, you could use `strcmp` to compare full names.

In `write()`, you would write:

```
write(int handle, void *buffer, unsigned int len) {
    int i;
    volatile UxMODEBITS *umode = &U1MODEbits;
    volatile UxSTABITS *ustatus = &U1STABits;
    volatile unsigned int *txreg = &U1TXREG;
    volatile unsigned int *brg = &U1BRG;

    switch (handle)
```



```

{
default:
case 0:
case 1:
case 2:
    if ((__C30_UART != 1) && (&U2BRG)) {
        umode = &U2MODEbits;
        ustatus = &U2STABits;
        txreg = &U2TXREG;
        brg = &U2BRG;
    }
    if ((umode->UARTEN) == 0)
    {
        *brg = 0;
        umode->UARTEN = 1;
    }
    if ((ustatus->UTXEN) == 0)
    {
        ustatus->UTXEN = 1;
    }
    for (i = len; i; --i)
    {
        while ((ustatus->TRMT) ==0);
        *txreg = *(char*)buffer++;
    }
    break;
case handle_can1: /* code to support can1 */
    break;
case handle_can2: /* code to support can2 */
    break;
case handle_spi1: /* code to support spi1 */
    break;
case handle_spi2: /* code to support spi2 */
    break;
}
return(len);
}

```

where you would fill in the appropriate code as specified in the comments.

Now you can use the generic C STDIO features to write to another port:

```

FILE *can1 = fopen("c","w");
fprintf(can1,"This will be output through the can\n");

```

2.13.3 STDIO Functions

FILE

Description: Stores information for a file stream.
Include: <stdio.h>

fpos_t

Description: Type of a variable used to store a file position.
Include: <stdio.h>

16-Bit Language Tools Libraries

size_t

Description: The result type of the `sizeof` operator.
Include: `<stdio.h>`

_IOFBF

Description: Indicates full buffering.
Include: `<stdio.h>`
Remarks: Used by the function, `setvbuf`.

_IOLBF

Description: Indicates line buffering.
Include: `<stdio.h>`
Remarks: Used by the function, `setvbuf`.

_IONBF

Description: Indicates no buffering.
Include: `<stdio.h>`
Remarks: Used by the function, `setvbuf`.

BUFSIZ

Description: Defines the size of the buffer used by the function, `setbuf`.
Include: `<stdio.h>`
Value: 512

EOF

Description: A negative number indicating the end-of-file has been reached or to report an error condition.
Include: `<stdio.h>`
Remarks: If an end-of-file is encountered, the end-of-file indicator is set. If an error condition is encountered, the error indicator is set. Error conditions include write errors and input or read errors.

FILENAME_MAX

Description: Maximum number of characters in a filename including the null terminator.
Include: `<stdio.h>`
Value: 260

FOPEN_MAX

Description: Defines the maximum number of files that can be simultaneously open.

FOPEN_MAX (Continued)

Include: `<stdio.h>`
Value: 8
Remarks: `stderr`, `stdin` and `stdout` are included in the `FOPEN_MAX` count.

L_tmpnam

Description: Defines the number of characters for the longest temporary filename created by the function, `tmpnam`.
Include: `<stdio.h>`
Value: 16
Remarks: `L_tmpnam` is used to define the size of the array used by `tmpnam`.

NULL

Description: The value of a null pointer constant.
Include: `<stdio.h>`

SEEK_CUR

Description: Indicates that `fseek` should seek from the current position of the file pointer.
Include: `<stdio.h>`
Example: See example for `fseek`.

16-Bit Language Tools Libraries

SEEK_END

Description: Indicates that `fseek` should seek from the end of the file.
Include: `<stdio.h>`
Example: See example for `fseek`.

SEEK_SET

Description: Indicates that `fseek` should seek from the beginning of the file.
Include: `<stdio.h>`
Example: See example for `fseek`.

stderr

Description: File pointer to the standard error stream.
Include: `<stdio.h>`

stdin

Description: File pointer to the standard input stream.
Include: `<stdio.h>`

stdout

Description: File pointer to the standard output stream.
Include: `<stdio.h>`

TMP_MAX

Description: The maximum number of unique filenames the function `tmpnam` can generate.
Include: `<stdio.h>`
Value: 32

clearerr

Description: Resets the error indicator for the stream.

Include: <stdio.h>

Prototype: void clearerr(FILE *stream);

Argument: *stream* stream to reset error indicators

Remarks: The function clears the end-of-file and error indicators for the given stream (i.e., feof and ferror will return false after the function clearerr is called).

Example:

```
/* This program tries to write to a file that is */
/* readonly. This causes the error indicator to */
/* be set. The function ferror is used to check */
/* the error indicator. The function clearerr is */
/* used to reset the error indicator so the next */
/* time ferror is called it will not report an */
/* error. */
#include <stdio.h> /* for ferror, clearerr, */
                  /* printf, fprintf, fopen, */
                  /* fclose, FILE, NULL */

int main(void)
{
    FILE *myfile;

    if ((myfile = fopen("samclearerr.c", "r")) ==
        NULL)
        printf("Cannot open file\n");
    else
    {
        fprintf(myfile, "Write this line to the "
                    "file.\n");
        if (ferror(myfile))
            printf("Error\n");
        else
            printf("No error\n");
        clearerr(myfile);
        if (ferror(myfile))
            printf("Still has Error\n");
        else
            printf("Error indicator reset\n");

        fclose(myfile);
    }
}
```

Output:

```
Error
Error indicator reset
```

fclose

Description: Close a stream.

Include: <stdio.h>

Prototype: int fclose(FILE *stream);

Argument: *stream* pointer to the stream to close

Return Value: Returns 0 if successful; otherwise, returns EOF if any errors were detected.

Remarks: fclose writes any buffered output to the file.

Example:

```
#include <stdio.h> /* for fopen, fclose,      */
                  /* printf, FILE, NULL, EOF */

int main(void)
{
    FILE *myfile1, *myfile2;
    int y;

    if ((myfile1 = fopen("afile1", "w+")) == NULL)
        printf("Cannot open afile1\n");
    else
    {
        printf("afile1 was opened\n");

        y = fclose(myfile1);
        if (y == EOF)
            printf("afile1 was not closed\n");
        else
            printf("afile1 was closed\n");
    }
}
```

Output:

```
afile1 was opened
afile1 was closed
```

feof

Description: Tests for end-of-file.

Include: `<stdio.h>`

Prototype: `int feof(FILE *stream);`

Argument: *stream* stream to check for end-of-file

Return Value: Returns non-zero if stream is at the end-of-file; otherwise, returns zero.

Example:

```
#include <stdio.h> /* for feof, fgetc, fputc, */
                  /* fopen, fclose, FILE, */
                  /* NULL */
```

```
int main(void)
{
    FILE *myfile;
    int y = 0;

    if( (myfile = fopen( "afile.txt", "rb" )) == NULL )
        printf( "Cannot open file\n" );
    else
    {
        for (;;)
        {
            y = fgetc(myfile);
            if (feof(myfile))
                break;
            fputc(y, stdout);
        }
        fclose( myfile );
    }
}
```

Input:

Contents of afile.txt (used as input):
This is a sentence.

Output:

This is a sentence.

fprintf

Description: Tests if error indicator is set.

Include: <stdio.h>

Prototype: int fprintf(FILE *stream);

Argument: *stream* pointer to FILE structure

Return Value: Returns a non-zero value if error indicator is set; otherwise, returns a zero.

Example:

```
/* This program tries to write to a file that is */
/* readonly. This causes the error indicator to */
/* be set. The function fprintf is used to check */
/* the error indicator and find the error. The */
/* function clearerr is used to reset the error */
/* indicator so the next time fprintf is called */
/* it will not report an error. */
```

```
#include <stdio.h> /* for fprintf, clearerr, */
                  /* printf, fprintf, */
                  /* fopen, fclose, */
                  /* FILE, NULL */

int main(void)
{
    FILE *myfile;

    if ((myfile = fopen("sampclearerr.c", "r")) ==
        NULL)
        printf("Cannot open file\n");
    else
    {
        fprintf(myfile, "Write this line to the "
                    "file.\n");
        if (fprintf(myfile))
            printf("Error\n");
        else
            printf("No error\n");
        clearerr(myfile);
        if (fprintf(myfile))
            printf("Still has Error\n");
        else
            printf("Error indicator reset\n");

        fclose(myfile);
    }
}
```

Output:

```
Error
Error indicator reset
```


fflush

Description:	Flushes the buffer in the specified stream.
Include:	<stdio.h>
Prototype:	int fflush(FILE *stream);
Argument:	stream pointer to the stream to flush.
Return Value:	Returns EOF if a write error occurs; otherwise, returns zero for success.
Remarks:	If stream is a null pointer, all output buffers are written to files. fflush has no effect on an unbuffered stream.

fgetc

Description:	Get a character from a stream
Include:	<stdio.h>
Prototype:	int fgetc(FILE *stream);
Argument:	stream pointer to the open stream
Return Value:	Returns the character read or EOF if a read error occurs or end-of-file is reached.
Remarks:	The function reads the next character from the input stream, advances the file-position indicator and returns the character as an unsigned char converted to an int.

Example:

```
#include <stdio.h> /* for fgetc, printf, */
                  /* fclose, FILE, */
                  /* NULL, EOF */
```

```
int main(void)
{
    FILE *buf;
    char y;

    if ((buf = fopen("afile.txt", "r")) == NULL)
        printf("Cannot open afile.txt\n");
    else
    {
        y = fgetc(buf);
        while (y != EOF)
        {
            printf("%c|", y);
            y = fgetc(buf);
        }
        fclose(buf);
    }
}
```

Input:

Contents of afile.txt (used as input):

Short

Longer string

Output:

```
S|h|o|r|t|
|L|o|n|g|e|r| |s|t|r|i|n|g|
|
```

fgetpos

Description:	Gets the stream's file position.
Include:	<stdio.h>
Prototype:	int fgetpos(FILE *stream, fpos_t *pos);
Arguments:	<i>stream</i> target stream <i>pos</i> position-indicator storage
Return Value:	Returns 0 if successful; otherwise, returns a non-zero value.
Remarks:	The function stores the file-position indicator for the given stream in *pos if successful, otherwise, fgetpos sets errno.
Example:	<pre>/* This program opens a file and reads bytes at */ /* several different locations. The fgetpos */ /* function notes the 8th byte. 21 bytes are */ /* read then 18 bytes are read. Next the */ /* fsetpos function is set based on the */ /* fgetpos position and the previous 21 bytes */ /* are reread. */ #include <stdio.h> /* for fgetpos, fread, */ /* printf, fopen, fclose, */ /* FILE, NULL, perror, */ /* fpos_t, sizeof */ int main(void) { FILE *myfile; fpos_t pos; char buf[25]; if ((myfile = fopen("sampfgetpos.c", "rb")) == NULL) printf("Cannot open file\n"); else { fread(buf, sizeof(char), 8, myfile); if (fgetpos(myfile, &pos) != 0) perror("fgetpos error"); else { fread(buf, sizeof(char), 21, myfile); printf("Bytes read: %.21s\n", buf); fread(buf, sizeof(char), 18, myfile); printf("Bytes read: %.18s\n", buf); } if (fsetpos(myfile, &pos) != 0) perror("fsetpos error"); fread(buf, sizeof(char), 21, myfile); printf("Bytes read: %.21s\n", buf); fclose(myfile); } }</pre> <p>Output:</p> <pre>Bytes read: program opens a file Bytes read: and reads bytes at Bytes read: program opens a file</pre>

fgets

Description:	Get a string from a stream.
Include:	<stdio.h>
Prototype:	char *fgets(char *s, int n, FILE *stream);
Arguments:	<p><i>s</i> pointer to the storage string</p> <p><i>n</i> maximum number of characters to read</p> <p><i>stream</i> pointer to the open stream.</p>
Return Value:	Returns a pointer to the string <i>s</i> if successful; otherwise, returns a null pointer.
Remarks:	The function reads characters from the input stream and stores them into the string pointed to by <i>s</i> until it has read <i>n</i> -1 characters, stores a newline character or sets the end-of-file or error indicators. If any characters were stored, a null character is stored immediately after the last read character in the next element of the array. If <i>fgets</i> sets the error indicator, the array contents are indeterminate.
Example:	<pre>#include <stdio.h> /* for fgets, printf, */ /* fopen, fclose, */ /* FILE, NULL */ #define MAX 50 int main(void) { FILE *buf; char s[MAX]; if ((buf = fopen("afile.txt", "r")) == NULL) printf("Cannot open afile.txt\n"); else { while (fgets(s, MAX, buf) != NULL) { printf("%s|", s); } fclose(buf); } }</pre> <p>Input: Contents of afile.txt (used as input): Short Longer string</p> <p>Output: Short |Longer string |</p>

fopen

Description:	Opens a file.
Include:	<stdio.h>
Prototype:	FILE *fopen(const char *filename, const char *mode);
Arguments:	<i>filename</i> name of the file <i>mode</i> type of access permitted
Return Value:	Returns a pointer to the open stream. If the function fails a null pointer is returned.
Remarks:	Following are the types of file access: r - opens an existing text file for reading w - opens an empty text file for writing. (An existing file will be overwritten.) a - opens a text file for appending. (A file is created if it doesn't exist.) rb - opens an existing binary file for reading. wb - opens an empty binary file for writing. (An existing file will be overwritten.) ab - opens a binary file for appending. (A file is created if it doesn't exist.) r+ - opens an existing text file for reading and writing. w+ - opens an empty text file for reading and writing. (An existing file will be overwritten.) a+ - opens a text file for reading and appending. (A file is created if it doesn't exist.) r+b or rb+ - opens an existing binary file for reading and writing. w+b or wb+ - opens an empty binary file for reading and writing. (An existing file will be overwritten.) a+b or ab+ - opens a binary file for reading and appending. (A file is created if it doesn't exist.)
Example:	<pre>#include <stdio.h> /* for fopen, fclose, */ /* printf, FILE, */ /* NULL, EOF */ int main(void) { FILE *myfile1, *myfile2; int y;</pre>

fopen (Continued)

```
if ((myfile1 = fopen("afile1", "r")) == NULL)
    printf("Cannot open afile1\n");
else
{
    printf("afile1 was opened\n");
    y = fclose(myfile1);
    if (y == EOF)
        printf("afile1 was not closed\n");
    else
        printf("afile1 was closed\n");
}

if ((myfile1 = fopen("afile1", "w+")) == NULL)
    printf("Second try, cannot open afile1\n");
else
{
    printf("Second try, afile1 was opened\n");
    y = fclose(myfile1);
    if (y == EOF)
        printf("afile1 was not closed\n");
    else
        printf("afile1 was closed\n");
}

if ((myfile2 = fopen("afile2", "w+")) == NULL)
    printf("Cannot open afile2\n");
else
{
    printf("afile2 was opened\n");
    y = fclose(myfile2);
    if (y == EOF)
        printf("afile2 was not closed\n");
    else
        printf("afile2 was closed\n");
}
}
```

Output:

```
Cannot open afile1
Second try, afile1 was opened
afile1 was closed
afile2 was opened
afile2 was closed
```

Explanation:

afile1 must exist before it can be opened for reading (r) or the fopen function will fail. If the fopen function opens a file for writing (w+) it does not have to already exist. If it doesn't exist, it will be created and then opened.

fprintf

Description:	Prints formatted data to a stream.
Include:	<stdio.h>
Prototype:	int fprintf(FILE *stream, const char *format, ...);
Arguments:	<i>stream</i> pointer to the stream in which to output data <i>format</i> format control string ... optional arguments
Return Value:	Returns number of characters generated or a negative number if an error occurs.
Remarks:	The format argument has the same syntax and use that it has in printf.

Example:

```
#include <stdio.h> /* for fopen, fclose, */
                  /* fprintf, printf,   */
                  /* FILE, NULL        */

int main(void)
{
    FILE *myfile;
    int y;
    char s[]="Print this string";
    int x = 1;
    char a = '\n';

    if ((myfile = fopen("afile", "w")) == NULL)
        printf("Cannot open afile\n");
    else
    {
        y = fprintf(myfile, "%s %d time%c", s, x, a);

        printf("Number of characters printed "
               "to file = %d",y);

        fclose(myfile);
    }
}
```

Output:

Number of characters printed to file = 25
Contents of afile:
Print this string 1 time

fputc

Description:	Puts a character to the stream.
Include:	<stdio.h>
Prototype:	int fputc(int <i>c</i> , FILE * <i>stream</i>);
Arguments:	<i>c</i> character to be written <i>stream</i> pointer to the open stream
Return Value:	Returns the character written or EOF if a write error occurs.
Remarks:	The function writes the character to the output stream, advances the file-position indicator and returns the character as an unsigned char converted to an int.
Example:	<pre>#include <stdio.h> /* for fputc, EOF, stdout */ int main(void) { char *y; char buf[] = "This is text\n"; int x; x = 0; for (y = buf; (x != EOF) && (*y != '\0'); y++) { x = fputc(*y, stdout); fputc('|', stdout); } }</pre>

Output:

```
T|h|i|s| |i|s| |t|e|x|t|
|
```

fputs

Description:	Puts a string to the stream.
Include:	<stdio.h>
Prototype:	int fputs(const char * <i>s</i> , FILE * <i>stream</i>);
Arguments:	<i>s</i> string to be written <i>stream</i> pointer to the open stream
Return Value:	Returns a non-negative value if successful; otherwise, returns EOF.
Remarks:	The function writes characters to the output stream up to but not including the null character.
Example:	<pre>#include <stdio.h> /* for fputs, stdout */ int main(void) { char buf[] = "This is text\n"; fputs(buf, stdout); fputs("|", stdout); }</pre>

Output:

```
This is text
|
```

fread

Description:	Reads data from the stream.								
Include:	<stdio.h>								
Prototype:	<pre>size_t fread(void *ptr, size_t size, size_t nelem, FILE *stream);</pre>								
Arguments:	<table><tr><td><i>ptr</i></td><td>pointer to the storage buffer</td></tr><tr><td><i>size</i></td><td>size of item</td></tr><tr><td><i>nelem</i></td><td>maximum number of items to be read</td></tr><tr><td><i>stream</i></td><td>pointer to the stream</td></tr></table>	<i>ptr</i>	pointer to the storage buffer	<i>size</i>	size of item	<i>nelem</i>	maximum number of items to be read	<i>stream</i>	pointer to the stream
<i>ptr</i>	pointer to the storage buffer								
<i>size</i>	size of item								
<i>nelem</i>	maximum number of items to be read								
<i>stream</i>	pointer to the stream								
Return Value:	Returns the number of complete elements read up to <i>nelem</i> whose size is specified by <i>size</i> .								
Remarks:	The function reads characters from a given stream into the buffer pointed to by <i>ptr</i> until the function stores <i>size</i> * <i>nelem</i> characters or sets the end-of-file or error indicator. <i>fread</i> returns <i>n/size</i> where <i>n</i> is the number of characters it read. If <i>n</i> is not a multiple of <i>size</i> , the value of the last element is indeterminate. If the function sets the error indicator, the file-position indicator is indeterminate.								
Example:	<pre>#include <stdio.h> /* for fread, fwrite, */ /* printf, fopen, fclose, */ /* sizeof, FILE, NULL */ int main(void) { FILE *buf; int x, numwrote, numread; double nums[10], readnums[10]; if ((buf = fopen("afile.out", "w+")) != NULL) { for (x = 0; x < 10; x++) { nums[x] = 10.0/(x + 1); printf("10.0/%d = %f\n", x+1, nums[x]); } numwrote = fwrite(nums, sizeof(double), 10, buf); printf("Wrote %d numbers\n\n", numwrote); fclose(buf); } else printf("Cannot open afile.out\n"); }</pre>								

fread (Continued)

```
if ((buf = fopen("afile.out", "r+")) != NULL)
{
    numread = fread(readnums, sizeof(double),
                    10, buf);
    printf("Read %d numbers\n", numread);
    for (x = 0; x < 10; x++)
    {
        printf("%d * %f = %f\n", x+1, readnums[x],
              (x + 1) * readnums[x]);
    }
    fclose(buf);
}
else
    printf("Cannot open afile.out\n");
}
```

Output:

```
10.0/1 = 10.000000
10.0/2 = 5.000000
10.0/3 = 3.333333
10.0/4 = 2.500000
10.0/5 = 2.000000
10.0/6 = 1.666667
10.0/7 = 1.428571
10.0/8 = 1.250000
10.0/9 = 1.111111
10.0/10 = 1.000000
Wrote 10 numbers
```

```
Read 10 numbers
1 * 10.000000 = 10.000000
2 * 5.000000 = 10.000000
3 * 3.333333 = 10.000000
4 * 2.500000 = 10.000000
5 * 2.000000 = 10.000000
6 * 1.666667 = 10.000000
7 * 1.428571 = 10.000000
8 * 1.250000 = 10.000000
9 * 1.111111 = 10.000000
10 * 1.000000 = 10.000000
```

Explanation:

This program uses `fwrite` to save 10 numbers to a file in binary form. This allows the numbers to be saved in the same pattern of bits as the program is using which provides more accuracy and consistency. Using `fprintf` would save the numbers as text strings which could cause the numbers to be truncated. Each number is divided into 10 to produce a variety of numbers. Retrieving the numbers with `fread` to a new array and multiplying them by the original number shows the numbers were not truncated in the save process.

16-Bit Language Tools Libraries

freopen

Description:	Reassigns an existing stream to a new file.
Include:	<stdio.h>
Prototype:	FILE *freopen(const char *filename, const char *mode, FILE *stream);
Arguments:	<i>filename</i> name of the new file <i>mode</i> type of access permitted <i>stream</i> pointer to the currently open stream
Return Value:	Returns a pointer to the new open file. If the function fails a null pointer is returned.
Remarks:	The function closes the file associated with the stream as though fclose was called. Then it opens the new file as though fopen was called. freopen will fail if the specified stream is not open. See fopen for the possible types of file access.
Example:	<pre>#include <stdio.h> /* for fopen, freopen, */ /* printf, fclose, */ /* FILE, NULL */ int main(void) { FILE *myfile1, *myfile2; int y; if ((myfile1 = fopen("afile1", "w+")) == NULL) printf("Cannot open afile1\n"); else { printf("afile1 was opened\n"); if ((myfile2 = freopen("afile2", "w+", myfile1)) == NULL) { printf("Cannot open afile2\n"); fclose(myfile1); } else { printf("afile2 was opened\n"); fclose(myfile2); } } }</pre> <p>Output: afile1 was opened afile2 was opened</p> <p>Explanation: This program uses myfile2 to point to the stream when freopen is called so if an error occurs, myfile1 will still point to the stream and can be closed properly. If the freopen call is successful, myfile2 can be used to close the stream properly.</p>

fscanf

Description:	Scans formatted text from a stream.
Include:	<stdio.h>

fscanf (Continued)

Prototype:	<code>int fscanf(FILE *stream, const char *format, ...);</code>
Arguments:	<p><i>stream</i> pointer to the open stream from which to read data</p> <p><i>format</i> format control string</p> <p>... optional arguments</p>
Return Value:	Returns the number of items successfully converted and assigned. If no items are assigned, a 0 is returned. EOF is returned if end-of-file is encountered before the first conversion or if an error occurs.
Remarks:	The format argument has the same syntax and use that it has in <code>scanf</code> .

Example:

```
#include <stdio.h> /* for fopen, fscanf, */
                  /* fclose, fprintf, */
                  /* fseek, printf, FILE, */
                  /* NULL, SEEK_SET */
```

```
int main(void)
{
    FILE *myfile;
    char s[30];
    int x;
    char a;

    if ((myfile = fopen("afile", "w+")) == NULL)
        printf("Cannot open afile\n");
    else
    {
        fprintf(myfile, "%s %d times%c",
                "Print this string", 100, '\n');

        fseek(myfile, 0L, SEEK_SET);

        fscanf(myfile, "%s", s);
        printf("%s\n", s);
        fscanf(myfile, "%s", s);
        printf("%s\n", s);
        fscanf(myfile, "%s", s);
        printf("%s\n", s);
        fscanf(myfile, "%d", &x);
        printf("%d\n", x);
        fscanf(myfile, "%s", s);
        printf("%s\n", s);
        fscanf(myfile, "%c", a);
        printf("%c\n", a);

        fclose(myfile);
    }
}
```

Input:

Contents of afile:

Print this string 100 times

Output:

Print
this
string
100
times

fseek

Description:	Moves file pointer to a specific location.						
Include:	<stdio.h>						
Prototype:	<code>int fseek(FILE *stream, long offset, int mode);</code>						
Arguments:	<table><tr><td><i>stream</i></td><td>stream in which to move the file pointer.</td></tr><tr><td><i>offset</i></td><td>value to add to the current position</td></tr><tr><td><i>mode</i></td><td>type of seek to perform</td></tr></table>	<i>stream</i>	stream in which to move the file pointer.	<i>offset</i>	value to add to the current position	<i>mode</i>	type of seek to perform
<i>stream</i>	stream in which to move the file pointer.						
<i>offset</i>	value to add to the current position						
<i>mode</i>	type of seek to perform						
Return Value:	Returns 0 if successful; otherwise, returns a non-zero value and set errno.						
Remarks:	mode can be one of the following: SEEK_SET – seeks from the beginning of the file SEEK_CUR – seeks from the current position of the file pointer SEEK_END – seeks from the end of the file						
Example:	<pre>#include <stdio.h> /* for fseek, fgets, */ /* printf, fopen, fclose, */ /* FILE, NULL, perror, */ /* SEEK_SET, SEEK_CUR, */ /* SEEK_END */ int main(void) { FILE *myfile; char s[70]; int y; myfile = fopen("afile.out", "w+"); if (myfile == NULL) printf("Cannot open afile.out\n"); else { fprintf(myfile, "This is the beginning, " "this is the middle and " "this is the end."); y = fseek(myfile, 0L, SEEK_SET); if (y) perror("Fseek failed"); else { fgets(s, 22, myfile); printf("\n%s\n\n", s); } y = fseek(myfile, 2L, SEEK_CUR); if (y) perror("Fseek failed"); else { fgets(s, 70, myfile); printf("\n%s\n\n", s); } } }</pre>						

fseek (Continued)

```
        y = fseek(myfile, -16L, SEEK_END);
        if (y)
            perror("Fseek failed");
        else
        {
            fgets(s, 70, myfile);
            printf("\n%s\n", s);
        }
        fclose(myfile);
    }
}
```

Output:

"This is the beginning"

"this is the middle and this is the end."

"this is the end."

Explanation:

The file, `afile.out`, is created with the text, "This is the beginning, this is the middle and this is the end".

The function, `fseek`, uses an offset of zero and `SEEK_SET` to set the file pointer to the beginning of the file. `fgets` then reads 22 characters which are "This is the beginning", and adds a null character to the string.

Next, `fseek` uses an offset of two and `SEEK_CURRENT` to set the file pointer to the current position plus two (skipping the comma and space). `fgets` then reads up to the next 70 characters. The first 39 characters are "this is the middle and this is the end". It stops when it reads EOF and adds a null character to the string.

Finally, `fseek` uses an offset of negative 16 characters and `SEEK_END` to set the file pointer to 16 characters from the end of the file. `fgets` then reads up to 70 characters. It stops at the EOF after reading 16 characters "this is the end". and adds a null character to the string.

fsetpos

Description:	Sets the stream's file position.				
Include:	<code><stdio.h></code>				
Prototype:	<code>int fsetpos(FILE *stream, const fpos_t *pos);</code>				
Arguments:	<table><tr><td><i>stream</i></td><td>target stream</td></tr><tr><td><i>pos</i></td><td>position-indicator storage as returned by an earlier call to <code>fgetpos</code></td></tr></table>	<i>stream</i>	target stream	<i>pos</i>	position-indicator storage as returned by an earlier call to <code>fgetpos</code>
<i>stream</i>	target stream				
<i>pos</i>	position-indicator storage as returned by an earlier call to <code>fgetpos</code>				
Return Value:	Returns 0 if successful; otherwise, returns a non-zero value.				
Remarks:	The function sets the file-position indicator for the given stream in <i>pos</i> if successful; otherwise, <code>fsetpos</code> sets <code>errno</code> .				

fsetpos (Continued)

Example:

```
/* This program opens a file and reads bytes at */
/* several different locations. The fgetpos      */
/* function notes the 8th byte. 21 bytes are     */
/* read then 18 bytes are read. Next the        */
/* fsetpos function is set based on the          */
/* fgetpos position and the previous 21 bytes   */
/* are reread.                                  */

#include <stdio.h> /* for fgetpos, fread,      */
                  /* printf, fopen, fclose,   */
                  /* FILE, NULL, perror,      */
                  /* fpos_t, sizeof           */

int main(void)
{
    FILE    *myfile;
    fpos_t   pos;
    char     buf[25];

    if ((myfile = fopen("sampfgetpos.c", "rb")) ==
        NULL)
        printf("Cannot open file\n");
    else
    {
        fread(buf, sizeof(char), 8, myfile);
        if (fgetpos(myfile, &pos) != 0)
            perror("fgetpos error");
        else
        {
            fread(buf, sizeof(char), 21, myfile);
            printf("Bytes read: %.21s\n", buf);
            fread(buf, sizeof(char), 18, myfile);
            printf("Bytes read: %.18s\n", buf);
        }

        if (fsetpos(myfile, &pos) != 0)
            perror("fsetpos error");

        fread(buf, sizeof(char), 21, myfile);
        printf("Bytes read: %.21s\n", buf);
        fclose(myfile);
    }
}
```

Output:

```
Bytes read: program opens a file
Bytes read: and reads bytes at
Bytes read: program opens a file
```

ftell

Description: Gets the current position of a file pointer.
Include: <stdio.h>
Prototype: long ftell(FILE *stream);
Argument: *stream* stream in which to get the current file position
Return Value: Returns the position of the file pointer if successful; otherwise, returns -1.

Example:

```
#include <stdio.h> /* for ftell, fread,      */
                  /* fprintf, printf,      */
                  /* fopen, fclose, sizeof, */
                  /* FILE, NULL */

int main(void)
{
    FILE *myfile;
    char s[75];
    long y;

    myfile = fopen("afile.out", "w+");
    if (myfile == NULL)
        printf("Cannot open afile.out\n");
    else
    {
        fprintf(myfile, "This is a very long sentence "
                      "for input into the file named "
                      "afile.out for testing.");

        fclose(myfile);

        if ((myfile = fopen("afile.out", "rb")) != NULL)
        {
            printf("Read some characters:\n");
            fread(s, sizeof(char), 29, myfile);
            printf("\t\"%s\"\n", s);

            y = ftell(myfile);
            printf("The current position of the "
                  "file pointer is %ld\n", y);
            fclose(myfile);
        }
    }
}
```

Output:

Read some characters:
"This is a very long sentence "
The current position of the file pointer is 29

fwrite

Description:	Writes data to the stream.								
Include:	<stdio.h>								
Prototype:	<pre>size_t fwrite(const void *ptr, size_t size, size_t nelem, FILE *stream);</pre>								
Arguments:	<table><tr><td><i>ptr</i></td><td>pointer to the storage buffer</td></tr><tr><td><i>size</i></td><td>size of item</td></tr><tr><td><i>nelem</i></td><td>maximum number of items to be read</td></tr><tr><td><i>stream</i></td><td>pointer to the open stream</td></tr></table>	<i>ptr</i>	pointer to the storage buffer	<i>size</i>	size of item	<i>nelem</i>	maximum number of items to be read	<i>stream</i>	pointer to the open stream
<i>ptr</i>	pointer to the storage buffer								
<i>size</i>	size of item								
<i>nelem</i>	maximum number of items to be read								
<i>stream</i>	pointer to the open stream								
Return Value:	Returns the number of complete elements successfully written, which will be less than <i>nelem</i> only if a write error is encountered.								
Remarks:	The function writes characters to a given stream from a buffer pointed to by <i>ptr</i> up to <i>nelem</i> elements whose size is specified by <i>size</i> . The file position indicator is advanced by the number of characters successfully written. If the function sets the error indicator, the file-position indicator is indeterminate.								
Example:	<pre>#include <stdio.h> /* for fread, fwrite, */ /* printf, fopen, fclose, */ /* sizeof, FILE, NULL */ int main(void) { FILE *buf; int x, numwrote, numread; double nums[10], readnums[10]; if ((buf = fopen("afile.out", "w+")) != NULL) { for (x = 0; x < 10; x++) { nums[x] = 10.0/(x + 1); printf("10.0/%d = %f\n", x+1, nums[x]); } numwrote = fwrite(nums, sizeof(double), 10, buf); printf("Wrote %d numbers\n\n", numwrote); fclose(buf); } else printf("Cannot open afile.out\n"); }</pre>								

fwrite (Continued)

```
if ((buf = fopen("afile.out", "r+")) != NULL)
{
    numread = fread(readnums, sizeof(double),
                    10, buf);
    printf("Read %d numbers\n", numread);
    for (x = 0; x < 10; x++)
    {
        printf("%d * %f = %f\n", x+1, readnums[x],
              (x + 1) * readnums[x]);
    }
    fclose(buf);
}
else
    printf("Cannot open afile.out\n");
}
```

Output:

```
10.0/1 = 10.000000
10.0/2 = 5.000000
10.0/3 = 3.333333
10.0/4 = 2.500000
10.0/5 = 2.000000
10.0/6 = 1.666667
10.0/7 = 1.428571
10.0/8 = 1.250000
10.0/9 = 1.111111
10.0/10 = 1.000000
Wrote 10 numbers
```

```
Read 10 numbers
1 * 10.000000 = 10.000000
2 * 5.000000 = 10.000000
3 * 3.333333 = 10.000000
4 * 2.500000 = 10.000000
5 * 2.000000 = 10.000000
6 * 1.666667 = 10.000000
7 * 1.428571 = 10.000000
8 * 1.250000 = 10.000000
9 * 1.111111 = 10.000000
10 * 1.000000 = 10.000000
```

Explanation:

This program uses `fwrite` to save 10 numbers to a file in binary form. This allows the numbers to be saved in the same pattern of bits as the program is using which provides more accuracy and consistency. Using `fprintf` would save the numbers as text strings, which could cause the numbers to be truncated. Each number is divided into 10 to produce a variety of numbers. Retrieving the numbers with `fread` to a new array and multiplying them by the original number shows the numbers were not truncated in the save process.

getc

Description: Get a character from the stream.

Include: <stdio.h>

Prototype: int getc(FILE *stream);

Argument: *stream* pointer to the open stream

Return Value: Returns the character read or EOF if a read error occurs or end-of-file is reached.

Remarks: getc is the same as the function fgetc.

Example:

```
#include <stdio.h> /* for getc, printf, */
                  /* fopen, fclose, */
                  /* FILE, NULL, EOF */
```

```
int main(void)
{
    FILE *buf;
    char y;

    if ((buf = fopen("afile.txt", "r")) == NULL)
        printf("Cannot open afile.txt\n");
    else
    {
        y = getc(buf);
        while (y != EOF)
        {
            printf("%c|", y);
            y = getc(buf);
        }
        fclose(buf);
    }
}
```

Input:

Contents of afile.txt (used as input):

Short

Longer string

Output:

```
S|h|o|r|t|
|L|o|n|g|e|r| |s|t|r|i|n|g|
|
```

getchar

Description:	Get a character from <code>stdin</code> .
Include:	<code><stdio.h></code>
Prototype:	<code>int getchar(void);</code>
Return Value:	Returns the character read or EOF if a read error occurs or end-of-file is reached.
Remarks:	Same effect as <code>fgetc</code> with the argument <code>stdin</code> .
Example:	<pre>#include <stdio.h> /* for getchar, printf */ int main(void) { char y; y = getchar(); printf("%c|", y); y = getchar(); printf("%c|", y); y = getchar(); printf("%c|", y); y = getchar(); printf("%c|", y); y = getchar(); printf("%c ", y); }</pre>

Input:Contents of `UartIn.txt` (used as `stdin` input for simulator):

Short

Longer string

Output:

S|h|o|r|t|

gets

Description:	Get a string from <code>stdin</code> .
Include:	<code><stdio.h></code>
Prototype:	<code>char *gets(char *s);</code>
Argument:	<code>s</code> pointer to the storage string
Return Value:	Returns a pointer to the string <code>s</code> if successful; otherwise, returns a null pointer.
Remarks:	The function reads characters from the stream <code>stdin</code> and stores them into the string pointed to by <code>s</code> until it reads a newline character (which is not stored) or sets the end-of-file or error indicators. If any characters were read, a null character is stored immediately after the last read character in the next element of the array. If <code>gets</code> sets the error indicator, the array contents are indeterminate.

gets (Continued)

Example: `#include <stdio.h> /* for gets, printf */`

```
int main(void)
{
    char y[50];

    gets(y) ;
    printf("Text: %s\n", y);
}
```

Input:

Contents of UartIn.txt (used as stdin input for simulator):

Short

Longer string

Output:

Text: Short

perror

Description: Prints an error message to stderr.

Include: `<stdio.h>`

Prototype: `void perror(const char *s);`

Argument: `s` string to print

Return Value: None.

Remarks: The string `s` is printed followed by a colon and a space. Then, an error message based on `errno` is printed followed by an newline.

Example: `#include <stdio.h> /* for perror, fopen, */
/* fclose, printf, */
/* FILE, NULL */`

```
int main(void)
{
    FILE *myfile;

    if ((myfile = fopen("samp.fil", "r+")) == NULL)
        perror("Cannot open samp.fil");
    else
        printf("Success opening samp.fil\n");

    fclose(myfile);
}
```

Output:

Cannot open samp.fil: file open error

printf

Description:	Prints formatted text to <code>stdout</code> .
Include:	<code><stdio.h></code>
Prototype:	<code>int printf(const char *format, ...);</code>
Arguments:	<i>format</i> format control string ... optional arguments
Return Value:	Returns number of characters generated or a negative number if an error occurs.
Remarks:	<p>There must be exactly the same number of arguments as there are format specifiers. If there are less arguments than match the format specifiers, the output is undefined. If there are more arguments than match the format specifiers, the remaining arguments are discarded. Each format specifier begins with a percent sign followed by optional fields and a required type as shown here:</p> <pre>%[flags][width][.precision][size]type</pre> <p><i>flags</i></p> <ul style="list-style-type: none">- left justify the value within a given field width0 Use 0 for the pad character instead of space (which is the default)+ generate a plus sign for positive signed valuesspace generate a space or signed values that have neither a plus nor a minus sign# to prefix 0 on an octal conversion, to prefix 0x or 0X on a hexadecimal conversion, or to generate a decimal point and fraction digits that are otherwise suppressed on a floating-point conversion <p><i>width</i></p> <p>specify the number of characters to generate for the conversion. If the asterisk (*) is used instead of a decimal number, the next argument (which must be of type <code>int</code>) will be used for the field width. If the result is less than the field width, pad characters will be used on the left to fill the field. If the result is greater than the field width, the field is expanded to accommodate the value without padding.</p> <p><i>precision</i></p> <p>The field width can be followed with dot (.) and a decimal integer representing the precision that specifies one of the following:</p> <ul style="list-style-type: none">- minimum number of digits to generate on an integer conversion- number of fraction digits to generate on an e, E, or f conversion- maximum number of significant digits to generate on a g or G conversion- maximum number of characters to generate from a C string on an s conversion <p>If the period appears without the integer the integer is assumed to be zero. If the asterisk (*) is used instead of a decimal number, the next argument (which must be of type <code>int</code>) will be used for the precision.</p>

printf (Continued)

size	
h modifier –	used with type d, i, o, u, x, X; converts the value to a short int or unsigned short int
h modifier –	used with n; specifies that the pointer points to a short int
l modifier –	used with type d, i, o, u, x, X; converts the value to a long int or unsigned long int
l modifier –	used with n; specifies that the pointer points to a long int
l modifier –	used with c; specifies a wide character
l modifier –	used with type e, E, f, g, G; converts the value to a double
ll modifier –	used with type d, i, o, u, x, X; converts the value to a long long int or unsigned long long int
ll modifier –	used with n; specifies that the pointer points to a long long int
L modifier –	used with e, E, f, g, G; converts the value to a long double
type	
d, i	signed int
o	unsigned int in octal
u	unsigned int in decimal
x	unsigned int in lowercase hexadecimal
X	unsigned int in uppercase hexadecimal
e, E	double in scientific notation
f	double decimal notation
g, G	double (takes the form of e, E or f as appropriate)
c	char - a single character
s	string
p	value of a pointer
n	the associated argument shall be an integer pointer into which is placed the number of characters written so far. No characters are printed.
%	A % character is printed

Example:

```
#include <stdio.h> /* for printf */

int main(void)
{
    /* print a character right justified in a 3  */
    /* character space.                          */
    printf("%3c\n", 'a');

    /* print an integer, left justified (as      */
    /* specified by the minus sign in the format */
    /* string) in a 4 character space. Print a   */
    /* second integer that is right justified in */
    /* a 4 character space using the pipe (|) as */
    /* a separator between the integers.        */
    printf("%-4d|%4d\n", -4, 4);

    /* print a number converted to octal in 4    */
    /* digits.                                    */
    printf("%.4o\n", 10);
}
```

printf (Continued)

```

/* print a number converted to hexadecimal */
/* format with a 0x prefix. */
printf("%#x\n", 28);

/* print a float in scientific notation */
printf("%E\n", 1.1e20);

/* print a float with 2 fraction digits */
printf("%.2f\n", -3.346);

/* print a long float with %E, %e, or %f */
/* whichever is the shortest version */
printf("%Lg\n", .02L);
}

```

Output:

```

a
-4 | 4
0012
0x1c
1.100000E+20
-3.35
0.02

```

putc

Description: Puts a character to the stream.

Include: <stdio.h>

Prototype: int putc(int *c*, FILE **stream*);

Arguments: *c* character to be written
stream pointer to FILE structure

Return Value: Returns the character or EOF if an error occurs or end-of-file is reached.

Remarks: putc is the same as the function fputc.

Example: #include <stdio.h> /* for putc, EOF, stdout */

```

int main(void)
{
    char *y;
    char buf[] = "This is text\n";
    int x;

    x = 0;

    for (y = buf; (x != EOF) && (*y != '\0'); y++)
    {
        x = putc(*y, stdout);
        putc('|', stdout);
    }
}

```

Output:

```

T|h|i|s| |i|s| |t|e|x|t|
|

```

putchar

Description: Put a character to `stdout`.
Include: `<stdio.h>`
Prototype: `int putchar(int c);`
Argument: `c` character to be written
Return Value: Returns the character or EOF if an error occurs or end-of-file is reached.
Remarks: Same effect as `fputc` with `stdout` as an argument.
Example:

```
#include <stdio.h> /* for putchar, printf, */
                    /* EOF, stdout          */
```

```
int main(void)
{
    char *y;
    char buf[] = "This is text\n";
    int x;

    x = 0;

    for (y = buf; (x != EOF) && (*y != '\0'); y++)
        x = putchar(*y);
}
```

Output:
This is text

puts

Description: Put a string to `stdout`.
Include: `<stdio.h>`
Prototype: `int puts(const char *s);`
Argument: `s` string to be written
Return Value: Returns a non-negative value if successful; otherwise, returns EOF.
Remarks: The function writes characters to the stream `stdout`. A newline character is appended. The terminating null character is not written to the stream.
Example:

```
#include <stdio.h> /* for puts */
```

```
int main(void)
{
    char buf[] = "This is text\n";

    puts(buf);
    puts("|");
}
```

Output:
This is text

|

remove

Description: Deletes the specified file.

Include: `<stdio.h>`

Prototype: `int remove(const char *filename);`

Argument: *filename* name of file to be deleted

Return Value: Returns 0 if successful, -1 if not.

Remarks: If filename does not exist or is open, remove will fail.

Example:

```
#include <stdio.h> /* for remove, printf */

int main(void)
{
    if (remove("myfile.txt") != 0)
        printf("Cannot remove file");
    else
        printf("File removed");
}
```

Output:
File removed

rename

Description: Renames the specified file.

Include: `<stdio.h>`

Prototype: `int rename(const char *old, const char *new);`

Arguments: *old* pointer to the old name
new pointer to the new name

Return Value: Return 0 if successful, non-zero if not.

Remarks: The new name must not already exist in the current working directory, the old name must exist in the current working directory.

Example:

```
#include <stdio.h> /* for rename, printf */

int main(void)
{
    if (rename("myfile.txt", "newfile.txt") != 0)
        printf("Cannot rename file");
    else
        printf("File renamed");
}
```

Output:
File renamed

rewind

Description: Resets the file pointer to the beginning of the file.

Include: <stdio.h>

Prototype: void rewind(FILE *stream);

Argument: stream stream to reset the file pointer

Remarks: The function calls fseek(stream, 0L, SEEK_SET) and then clears the error indicator for the given stream.

Example:

```
#include <stdio.h> /* for rewind, fopen, */
                  /* fscanf, fclose, */
                  /* fprintf, printf, */
                  /* FILE, NULL */

int main(void)
{
    FILE *myfile;
    char s[] = "cookies";
    int x = 10;

    if ((myfile = fopen("afile", "w+")) == NULL)
        printf("Cannot open afile\n");
    else
    {
        fprintf(myfile, "%d %s", x, s);
        printf("I have %d %s.\n", x, s);

        /* set pointer to beginning of file */
        rewind(myfile);
        fscanf(myfile, "%d %s", &x, &s);
        printf("I ate %d %s.\n", x, s);

        fclose(myfile);
    }
}
```

Output:
I have 10 cookies.
I ate 10 cookies.

scanf

Description:	Scans formatted text from <code>stdin</code> .
Include:	<code><stdio.h></code>
Prototype:	<code>int scanf(const char *format, ...);</code>
Argument:	<i>format</i> format control string ... optional arguments
Return Value:	Returns the number of items successfully converted and assigned. If no items are assigned, a 0 is returned. EOF is returned if an input failure is encountered before the first.
Remarks:	Each format specifier begins with a percent sign followed by optional fields and a required type as shown here: <div style="margin-left: 40px;"> <code>%[*][width][modifier]type</code> <code>*</code> indicates assignment suppression. This will cause the input field to be skipped and no assignment made. <code>width</code> specify the maximum number of input characters to match for the conversion not including white space that can be skipped. <code>modifier</code> <code>h</code> modifier – used with type <code>d, i, o, u, x, X</code>; converts the value to a short int or unsigned short int. <code>h</code> modifier – used with <code>n</code>; specifies that the pointer points to a short int <code>l</code> modifier – used with type <code>d, i, o, u, x, X</code>; converts the value to a long int or unsigned long int <code>l</code> modifier – used with <code>n</code>; specifies that the pointer points to a long int <code>l</code> modifier – used with <code>c</code>; specifies a wide character <code>l</code> modifier – used with type <code>e, E, f, F, g, G</code>; converts the value to a double <code>ll</code> modifier – used with type <code>d, i, o, u, x, X</code>; converts the value to a long long int or unsigned long long int <code>ll</code> modifier – used with <code>n</code>; specifies that the pointer points to a long long int <code>L</code> modifier – used with <code>e, E, f, g, G</code>; converts the value to a long double </div>

scanf (Continued)

type	
d,i	signed int
o	unsigned int in octal
u	unsigned int in decimal
x	unsigned int in lowercase hexadecimal
X	unsigned int in uppercase hexadecimal
e,E	double in scientific notation
f	double decimal notation
g,G	double (takes the form of e, E or f as appropriate)
c	char - a single character
s	string
p	value of a pointer
n	the associated argument shall be an integer pointer into, which is placed the number of characters read so far. No characters are scanned.
[...]	character array. Allows a search of a set of characters. A caret (^) immediately after the left bracket ([) inverts the scanset and allows any ASCII character except those specified between the brackets. A dash character (-) may be used to specify a range beginning with the character before the dash and ending the character after the dash. A null character can not be part of the scanset.
%	A % character is scanned

Example:

```
For MPLAB SIM simulator.
#include <stdio.h> /* for scanf, printf */
#include <libpic30.h>

int main(void)
{
    int number, items;
    char letter;
    char color[30], string[30];
    float salary;

    __attach_input_file("UartIn.txt");
    printf("Enter your favorite number, "
           "favorite letter, ");
    printf("favorite color desired salary "
           "and SSN:\n");
    items = scanf("%d %c %[A-Za-z] %f %s", &number,
                  &letter, &color, &salary, &string);

    printf("Number of items scanned = %d\n", items);
    printf("Favorite number = %d, ", number);
    printf("Favorite letter = %c\n", letter);
    printf("Favorite color = %s, ", color);
    printf("Desired salary = $%.2f\n", salary);
    printf("Social Security Number = %s, ", string);
}

If not using the simulator, remove these lines:
#include <libpic30.h>
__attach_input_file("uart_in.txt");
```

Input:

Contents of UartIn.txt (used as stdin input for simulator):
5 T Green 300000 123-45-6789

scanf (Continued)

Output:

```
Enter your favorite number, favorite letter,  
favorite color, desired salary and SSN:  
Number of items scanned = 5  
Favorite number = 5, Favorite letter = T  
Favorite color = Green, Desired salary = $300000.00  
Social Security Number = 123-45-6789
```

setbuf

Description: Defines how a stream is buffered.

Include: <stdio.h>

Prototype: void setbuf(FILE *stream, char *buf);

Arguments: *stream* pointer to the open stream
buf user allocated buffer

Remarks: setbuf must be called after fopen but before any other function calls that operate on the stream. If *buf* is a null pointer, setbuf calls the function setvbuf(stream, 0, _IONBF, BUFSIZ) for no buffering; otherwise setbuf calls setvbuf(stream, buf, _IOFBF, BUFSIZ) for full buffering with a buffer of size BUFSIZ. See setvbuf.

Example:

```
#include <stdio.h> /* for setbuf, printf, */  
                  /* fopen, fclose,      */  
                  /* FILE, NULL, BUFSIZ */  
  
int main(void)  
{  
    FILE *myfile1, *myfile2;  
    char buf[BUFSIZ];  
  
    if ((myfile1 = fopen("afile1", "w+")) != NULL)  
    {  
        setbuf(myfile1, NULL);  
        printf("myfile1 has no buffering\n");  
        fclose(myfile1);  
    }  
  
    if ((myfile2 = fopen("afile2", "w+")) != NULL)  
    {  
        setbuf(myfile2, buf);  
        printf("myfile2 has full buffering");  
        fclose(myfile2);  
    }  
}
```

Output:

```
myfile1 has no buffering  
myfile2 has full buffering
```

setvbuf

Description:	Defines the stream to be buffered and the buffer size.								
Include:	<stdio.h>								
Prototype:	<code>int setvbuf(FILE *stream, char *buf, int mode, size_t size);</code>								
Arguments:	<table><tr><td><i>stream</i></td><td>pointer to the open stream</td></tr><tr><td><i>buf</i></td><td>user allocated buffer</td></tr><tr><td><i>mode</i></td><td>type of buffering</td></tr><tr><td><i>size</i></td><td>size of buffer</td></tr></table>	<i>stream</i>	pointer to the open stream	<i>buf</i>	user allocated buffer	<i>mode</i>	type of buffering	<i>size</i>	size of buffer
<i>stream</i>	pointer to the open stream								
<i>buf</i>	user allocated buffer								
<i>mode</i>	type of buffering								
<i>size</i>	size of buffer								
Return Value:	Returns 0 if successful								
Remarks:	setvbuf must be called after fopen but before any other function calls that operate on the stream. For mode use one of the following: _IOFBF – for full buffering _IOLBF – for line buffering _IONBF – for no buffering								

Example:

```
#include <stdio.h> /* for setvbuf, fopen, */
                    /* printf, FILE, NULL, */
                    /* _IONBF, _IOFBF      */

int main(void)
{
    FILE *myfile1, *myfile2;
    char buf[256];

    if ((myfile1 = fopen("afile1", "w+")) != NULL)
    {
        if (setvbuf(myfile1, NULL, _IONBF, 0) == 0)
            printf("myfile1 has no buffering\n");
        else
            printf("Unable to define buffer stream "
                  "and/or size\n");
    }
    fclose(myfile1);

    if ((myfile2 = fopen("afile2", "w+")) != NULL)
    {
        if (setvbuf(myfile2, buf, _IOFBF, sizeof(buf)) ==
            0)
            printf("myfile2 has a buffer of %d "
                  "characters\n", sizeof(buf));
        else
            printf("Unable to define buffer stream "
                  "and/or size\n");
    }
    fclose(myfile2);
}
```

Output:

```
myfile1 has no buffering
myfile2 has a buffer of 256 characters
```

sprintf

Description:	Prints formatted text to a string.
Include:	<stdio.h>
Prototype:	int sprintf(char * <i>s</i> , const char * <i>format</i> , ...);
Arguments:	<i>s</i> storage string for output <i>format</i> format control string ... optional arguments
Return Value:	Returns the number of characters stored in <i>s</i> excluding the terminating null character.
Remarks:	The format argument has the same syntax and use that it has in printf.
Example:	#include <stdio.h> /* for sprintf, printf */

```
int main(void)
{
    char sbuf[100], s[]="Print this string";
    int x = 1, y;
    char a = '\n';

    y = sprintf(sbuf, "%s %d time%c", s, x, a);

    printf("Number of characters printed to "
           "string buffer = %d\n", y);
    printf("String = %s\n", sbuf);
}
```

Output:

Number of characters printed to string buffer = 25
String = Print this string 1 time

sscanf

Description:	Scans formatted text from a string.
Include:	<stdio.h>
Prototype:	int sscanf(const char * <i>s</i> , const char * <i>format</i> , ...);
Arguments:	<i>s</i> storage string for input <i>format</i> format control string ... optional arguments
Return Value:	Returns the number of items successfully converted and assigned. If no items are assigned, a 0 is returned. EOF is returned if an input error is encountered before the first conversion.
Remarks:	The format argument has the same syntax and use that it has in scanf.

sscanf (Continued)

Example:

```
#include <stdio.h> /* for sscanf, printf */

int main(void)
{
    char s[] = "5 T green 3000000.00";
    int number, items;
    char letter;
    char color[10];
    float salary;

    items = sscanf(s, "%d %c %s %f", &number, &letter,
                  &color, &salary);

    printf("Number of items scanned = %d\n", items);
    printf("Favorite number = %d\n", number);
    printf("Favorite letter = %c\n", letter);
    printf("Favorite color = %s\n", color);
    printf("Desired salary = $%.2f\n", salary);
}

Output:
Number of items scanned = 4
Favorite number = 5
Favorite letter = T
Favorite color = green
Desired salary = $3000000.00
```

tmpfile

Description: Creates a temporary file.

Include: <stdio.h>

Prototype: FILE *tmpfile(void)

Return Value: Returns a stream pointer if successful; otherwise, returns a NULL pointer.

Remarks: tmpfile creates a file with a unique filename. The temporary file is opened in w+b (binary read/write) mode. It will automatically be removed when exit is called; otherwise the file will remain in the directory.

Example:

```
#include <stdio.h> /* for tmpfile, printf, */
                  /* FILE, NULL */

int main(void)
{
    FILE *mytmpfile;

    if ((mytmpfile = tmpfile()) == NULL)
        printf("Cannot create temporary file");
    else
        printf("Temporary file was created");
}

Output:
Temporary file was created
```

tmpnam

Description:	Creates a unique temporary filename.
Include:	<stdio.h>
Prototype:	char *tmpnam(char *s);
Argument:	s pointer to the temporary name
Return Value:	Returns a pointer to the filename generated and stores the filename in s. If it can not generate a filename, the NULL pointer is returned.
Remarks:	The created filename will not conflict with an existing file name. Use L_tmpnam to define the size of array the argument of tmpnam points to.
Example:	<pre>#include <stdio.h> /* for tmpnam, L_tmpnam, */ /* printf, NULL */ int main(void) { char *myfilename; char mybuf[L_tmpnam]; char *myptr = (char *) &mybuf; if ((myfilename = tmpnam(myptr)) == NULL) printf("Cannot create temporary file name"); else printf("Temporary file %s was created", myfilename); }</pre>

Output:

Temporary file ctm00001.tmp was created

ungetc

Description:	Pushes character back onto stream.
Include:	<stdio.h>
Prototype:	int ungetc(int c, FILE *stream);
Argument:	c character to be pushed back stream pointer to the open stream
Return Value:	Returns the pushed character if successful; otherwise, returns EOF.
Remarks:	The pushed back character will be returned by a subsequent read on the stream. If more than one character is pushed back, they will be returned in the reverse order of their pushing. A successful call to a file positioning function (fseek, fsetpos or rewind) cancels any pushed back characters. Only one character of push back is guaranteed. Multiple calls to ungetc without an intervening read or file positioning operation may cause a failure.

ungetc (Continued)

Example:

```
#include <stdio.h> /* for ungetc, fgetc, */
                  /* printf, fopen, fclose, */
                  /* FILE, NULL, EOF */

int main(void)
{
    FILE *buf;
    char y, c;

    if ((buf = fopen("afile.txt", "r")) == NULL)
        printf("Cannot open afile.txt\n");
    else
    {
        y = fgetc(buf);
        while (y != EOF)
        {
            if (y == 'r')
            {
                c = ungetc(y, buf);
                if (c != EOF)
                {
                    printf("2");
                    y = fgetc(buf);
                }
            }
            printf("%c", y);
            y = fgetc(buf);
        }
        fclose(buf);
    }
}
```

Input:

Contents of afile.txt (used as input):

Short

Longer string

Output:

Sho2rt

Longe2r st2ring

fprintf

Description: Prints formatted data to a stream using a variable length argument list.

Include: `<stdio.h>`
`<stdarg.h>`

Prototype: `int fprintf(FILE *stream, const char *format, va_list ap);`

Arguments: *stream* pointer to the open stream
format format control string
ap pointer to a list of arguments

Return Value: Returns number of characters generated or a negative number if an error occurs.

Remarks: The format argument has the same syntax and use that it has in `printf`.
To access the variable length argument list, the *ap* variable must be initialized by the macro `va_start` and may be reinitialized by additional calls to `va_arg`. This must be done before the `fprintf` function is called. Invoke `va_end` after the function returns. For more details, see `stdarg.h`.

Example:

```
#include <stdio.h> /* for fprintf, fopen, */
                  /* fclose, printf, */
                  /* FILE, NULL */

#include <stdarg.h> /* for va_start, */
                  /* va_list, va_end */

FILE *myfile;

void errormsg(const char *fmt, ...)
{
    va_list ap;

    va_start(ap, fmt);
    fprintf(myfile, fmt, ap);
    va_end(ap);
}

int main(void)
{
    int num = 3;

    if ((myfile = fopen("afile.txt", "w")) == NULL)
        printf("Cannot open afile.txt\n");
    else
    {
        errormsg("Error: The letter '%c' is not %s\n", 'a',
                "an integer value.");
        errormsg("Error: Requires %d%s%c", num,
                " or more characters.", '\n');
    }
    fclose(myfile);
}
```

Output:

Contents of `afile.txt`

Error: The letter 'a' is not an integer value.
Error: Requires 3 or more characters.

vprintf

Description:	Prints formatted text to <code>stdout</code> using a variable length argument list.
Include:	<code><stdio.h></code> <code><stdarg.h></code>
Prototype:	<code>int vprintf(const char *format, va_list ap);</code>
Arguments:	<i>format</i> format control string <i>ap</i> pointer to a list of arguments
Return Value:	Returns number of characters generated or a negative number if an error occurs.
Remarks:	The format argument has the same syntax and use that it has in <code>printf</code> . To access the variable length argument list, the <i>ap</i> variable must be initialized by the macro <code>va_start</code> and may be reinitialized by additional calls to <code>va_arg</code> . This must be done before the <code>vprintf</code> function is called. Invoke <code>va_end</code> after the function returns. For more details, see <code>stdarg.h</code>
Example:	<pre>#include <stdio.h> /* for vprintf, printf */ #include <stdarg.h> /* for va_start, */ /* va_list, va_end */ void errormsg(const char *fmt, ...) { va_list ap; va_start(ap, fmt); printf("Error: "); vprintf(fmt, ap); va_end(ap); } int main(void) { int num = 3; errormsg("The letter '%c' is not %s\n", 'a', "an integer value."); errormsg("Requires %d%s\n", num, " or more characters.\n"); }</pre> <p>Output: Error: The letter 'a' is not an integer value. Error: Requires 3 or more characters.</p>

vsprintf

Description:	Prints formatted text to a string using a variable length argument list.
Include:	<stdio.h> <stdarg.h>
Prototype:	int vsprintf(char * <i>s</i> , const char * <i>format</i> , va_list <i>ap</i>);
Arguments:	<i>s</i> storage string for output <i>format</i> format control string <i>ap</i> pointer to a list of arguments
Return Value:	Returns number of characters stored in <i>s</i> excluding the terminating null character.

Remarks: The format argument has the same syntax and use that it has in `printf`. To access the variable length argument list, the *ap* variable must be initialized by the macro `va_start` and may be reinitialized by additional calls to `va_arg`. This must be done before the `vsprintf` function is called. Invoke `va_end` after the function returns. For more details, see `stdarg.h`

Example:

```
#include <stdio.h>    /* for vsprintf, printf */
#include <stdarg.h>    /* for va_start,      */
                      /* va_list, va_end      */
```

```
void errmsg(const char *fmt, ...)
{
    va_list ap;
    char buf[100];

    va_start(ap, fmt);
    vsprintf(buf, fmt, ap);
    va_end(ap);
    printf("Error: %s", buf);
}

int main(void)
{
    int num = 3;

    errmsg("The letter '%c' is not %s\n", 'a',
           "an integer value.");
    errmsg("Requires %d%s\n", num,
           " or more characters.\n");
}
```

Output:

```
Error: The letter 'a' is not an integer value.
Error: Requires 3 or more characters.
```

16-Bit Language Tools Libraries

2.14 <STDLIB.H> UTILITY FUNCTIONS

The header file, `stdlib.h`, consists of types, macros and functions that provide text conversions, memory management, searching and sorting abilities, and other general utilities.

div_t

Description:	A type that holds a quotient and remainder of a signed integer division with operands of type <code>int</code> .
Include:	<code><stdlib.h></code>
Prototype:	<code>typedef struct { int quot, rem; } div_t;</code>
Remarks:	This is the structure type returned by the function, <code>div</code> .

ldiv_t

Description:	A type that holds a quotient and remainder of a signed integer division with operands of type <code>long</code> .
Include:	<code><stdlib.h></code>
Prototype:	<code>typedef struct { long quot, rem; } ldiv_t;</code>
Remarks:	This is the structure type returned by the function, <code>ldiv</code> .

size_t

Description:	The type of the result of the <code>sizeof</code> operator.
Include:	<code><stdlib.h></code>

wchar_t

Description:	A type that holds a wide character value.
Include:	<code><stdlib.h></code>

EXIT_FAILURE

Description:	Reports unsuccessful termination.
Include:	<code><stdlib.h></code>
Remarks:	<code>EXIT_FAILURE</code> is a value for the <code>exit</code> function to return an unsuccessful termination status.
Example:	See <code>exit</code> for example of use.

EXIT_SUCCESS

Description:	Reports successful termination.
Include:	<code><stdlib.h></code>
Remarks:	<code>EXIT_SUCCESS</code> is a value for the <code>exit</code> function to return a successful termination status.
Example:	See <code>exit</code> for example of use.

MB_CUR_MAX

Description: Maximum number of characters in a multibyte character.
Include: <stdlib.h>
Value: 1

NULL

Description: The value of a null pointer constant.
Include: <stdlib.h>

RAND_MAX

Description: Maximum value capable of being returned by the `rand` function.
Include: <stdlib.h>
Value: 32767

abort

Description: Aborts the current process.
Include: <stdlib.h>
Prototype: void abort(void);
Remarks: abort will cause the processor to reset.
Example:

```
#include <stdio.h> /* for fopen, fclose, */
                  /* printf, FILE, NULL */
#include <stdlib.h> /* for abort          */

int main(void)
{
    FILE *myfile;

    if ((myfile = fopen("samp.fil", "r")) == NULL)
    {
        printf("Cannot open samp.fil\n");
        abort();
    }
    else
        printf("Success opening samp.fil\n");

    fclose(myfile);
}
```

Output:
Cannot open samp.fil
ABRT

abs

Description: Calculates the absolute value.

Include: <stdlib.h>

Prototype: int abs(int i);

Argument: *i* integer value

Return Value: Returns the absolute value of *i*.

Remarks: A negative number is returned as positive; a positive number is unchanged.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for abs */

int main(void)
{
    int i;

    i = 12;
    printf("The absolute value of %d is %d\n",
        i, abs(i));

    i = -2;
    printf("The absolute value of %d is %d\n",
        i, abs(i));

    i = 0;
    printf("The absolute value of %d is %d\n",
        i, abs(i));
}
```

Output:

```
The absolute value of 12 is 12
The absolute value of -2 is 2
The absolute value of 0 is 0
```

atexit

Description: Registers the specified function to be called when the program terminates normally.

Include: <stdlib.h>

Prototype: int atexit(void (*func)(void));

Argument: *func* function to be called

Return Value: Returns a zero if successful; otherwise, returns a non-zero value.

Remarks: For the registered functions to be called, the program must terminate with the exit function call.

Example:

```
#include <stdio.h> /* for scanf, printf */
#include <stdlib.h> /* for atexit, exit */

void good_msg(void);
void bad_msg(void);
void end_msg(void);
```

atexit (Continued)

```
int main(void)
{
    int number;

    atexit(end_msg);
    printf("Enter your favorite number:");
    scanf("%d", &number);
    printf(" %d\n", number);
    if (number == 5)
    {
        printf("Good Choice\n");
        atexit(good_msg);
        exit(0);
    }
    else
    {
        printf("%d!?\n", number);
        atexit(bad_msg);
        exit(0);
    }
}

void good_msg(void)
{
    printf("That's an excellent number\n");
}

void bad_msg(void)
{
    printf("That's an awful number\n");
}

void end_msg(void)
{
    printf("Now go count something\n");
}
```

Input:

With contents of UartIn.txt (used as stdin input for simulator):

5

Output:

Enter your favorite number: 5
Good Choice
That's an excellent number
Now go count something

Input:

With contents of UartIn.txt (used as stdin input for simulator):

42

Output:

Enter your favorite number: 42
42!?
That's an awful number
Now go count something

atof

Description: Converts a string to a double precision floating-point value.

Include: `<stdlib.h>`

Prototype: `double atof(const char *s);`

Argument: `s` pointer to the string to be converted

Return Value: Returns the converted value if successful; otherwise, returns 0.

Remarks: The number may consist of the following:
[whitespace] [sign] digits [.digits]
[{ e | E } [sign] digits]
optional whitespace, followed by an optional sign then a sequence of one or more digits with an optional decimal point, followed by one or more optional digits and an optional e or E followed by an optional signed exponent. The conversion stops when the first unrecognized character is reached. The conversion is the same as strtod(s,0) except it does no error checking so errno will not be set.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for atof */

int main(void)
{
    char a[] = " 1.28";
    char b[] = "27.835e2";
    char c[] = "Number1";
    double x;

    x = atof(a);
    printf("String = \"%s\" float = %f\n", a, x);

    x = atof(b);
    printf("String = \"%s\" float = %f\n", b, x);

    x = atof(c);
    printf("String = \"%s\" float = %f\n", c, x);
}

Output:
String = "1.28" float = 1.280000
String = "27.835:e2" float = 2783.500000
String = "Number1" float = 0.000000
```

atoi

Description: Converts a string to an integer.

Include: `<stdlib.h>`

Prototype: `int atoi(const char *s);`

Argument: `s` string to be converted

Return Value: Returns the converted integer if successful; otherwise, returns 0.

Remarks: The number may consist of the following:
[whitespace] [sign] digits
optional whitespace, followed by an optional sign then a sequence of one or more digits. The conversion stops when the first unrecognized character is reached. The conversion is equivalent to `(int) strtol(s, 0, 10)` except it does no error checking so `errno` will not be set.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for atoi */

int main(void)
{
    char a[] = " -127";
    char b[] = "Number1";
    int x;

    x = atoi(a);
    printf("String = \"%s\" \tint = %d\n", a, x);

    x = atoi(b);
    printf("String = \"%s\" \tint = %d\n", b, x);
}
```

Output:

```
String = " -127"          int = -127
String = "Number1"       int = 0
```

atol

Description: Converts a string to a long integer.

Include: `<stdlib.h>`

Prototype: `long atol(const char *s);`

Argument: `s` string to be converted

Return Value: Returns the converted long integer if successful; otherwise, returns 0.

Remarks: The number may consist of the following:
[whitespace] [sign] digits
optional whitespace, followed by an optional sign then a sequence of one or more digits. The conversion stops when the first unrecognized character is reached. The conversion is equivalent to `(int) strtol(s, 0, 10)` except it does no error checking so `errno` will not be set.

atol (Continued)

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for atol */

int main(void)
{
    char a[] = " -123456";
    char b[] = "2Number";
    long x;

    x = atol(a);
    printf("String = \"%s\"   int = %ld\n", a, x);

    x = atol(b);
    printf("String = \"%s\"   int = %ld\n", b, x);
}
```

Output:

```
String = " -123456"      int = -123456
String = "2Number"      int = 2
```

bsearch

Description: Performs a binary search.

Include: <stdlib.h>

Prototype:

```
void *bsearch(const void *key, const void *base,
              size_t nelem, size_t size,
              int (*cmp)(const void *ck, const void *ce));
```

Arguments:

<i>key</i>	object to search for
<i>base</i>	pointer to the start of the search data
<i>nelem</i>	number of elements
<i>size</i>	size of elements
<i>cmp</i>	pointer to the comparison function
<i>ck</i>	pointer to the key for the search
<i>ce</i>	pointer to the element being compared with the key.

Return Value: Returns a pointer to the object being searched for if found; otherwise, returns NULL.

Remarks: The value returned by the compare function is <0 if *ck* is less than *ce*, 0 if *ck* is equal to *ce* or >0 if *ck* is greater than *ce*. In the following example, `qsort` is used to sort the list before `bsearch` is called. `bsearch` requires the list to be sorted according to the comparison function. This `comp` uses ascending order.

bsearch (Continued)

Example:

```
#include <stdlib.h> /* for bsearch, qsort */
#include <stdio.h>  /* for printf, sizeof */

#define NUM 7

int comp(const void *e1, const void *e2);

int main(void)
{
    int list[NUM] = {35, 47, 63, 25, 93, 16, 52};
    int x, y;
    int *r;

    qsort(list, NUM, sizeof(int), comp);

    printf("Sorted List:  ");
    for (x = 0; x < NUM; x++)
        printf("%d ", list[x]);

    y = 25;
    r = bsearch(&y, list, NUM, sizeof(int), comp);
    if (r)
        printf("\nThe value %d was found\n", y);
    else
        printf("\nThe value %d was not found\n", y);

    y = 75;
    r = bsearch(&y, list, NUM, sizeof(int), comp);
    if (r)
        printf("\nThe value %d was found\n", y);
    else
        printf("\nThe value %d was not found\n", y);
}

int comp(const void *e1, const void *e2)
{
    const int * a1 = e1;
    const int * a2 = e2;

    if (*a1 < *a2)
        return -1;
    else if (*a1 == *a2)
        return 0;
    else
        return 1;
}
```

Output:

```
Sorted List:  16  25  35  47  52  63  93
The value 25 was found

The value 75 was not found
```

calloc

Description: Allocates an array in memory and initializes the elements to 0.

Include: <stdlib.h>

Prototype: void *calloc(size_t *nelem*, size_t *size*);

Arguments: *nelem* number of elements
size length of each element

Return Value: Returns a pointer to the allocated space if successful; otherwise, returns a null pointer.

Remarks: Memory returned by `calloc` is aligned correctly for any size data element and is initialized to zero.

Example:

```
/* This program allocates memory for the      */
/* array 'i' of long integers and initializes */
/* them to zero.                             */
```

```
#include <stdio.h> /* for printf, NULL */
#include <stdlib.h> /* for calloc, free */
```

```
int main(void)
{
    int x;
    long *i;

    i = (long *)calloc(5, sizeof(long));
    if (i != NULL)
    {
        for (x = 0; x < 5; x++)
            printf("i[%d] = %ld\n", x, i[x]);
        free(i);
    }
    else
        printf("Cannot allocate memory\n");
}
```

Output:

```
i[0] = 0
i[1] = 0
i[2] = 0
i[3] = 0
i[4] = 0
```

div

Description: Calculates the quotient and remainder of two numbers.

Include: <stdlib.h>

Prototype: div_t div(int *numer*, int *denom*);

Arguments: *numer* numerator
denom denominator

Return Value: Returns the quotient and the remainder.

Remarks: The returned quotient will have the same sign as the numerator divided by the denominator. The sign for the remainder will be such that the quotient times the denominator plus the remainder will equal the numerator (quot * denom + rem = numer). Division by zero will invoke the math exception error, which by default, will cause a Reset. Write a math error handler to do something else.

div (Continued)

Example:

```
#include <stdlib.h> /* for div, div_t */
#include <stdio.h>  /* for printf */

void __attribute__((__interrupt__))
_MathError(void)
{
    printf("Illegal instruction executed\n");
    abort();
}

int main(void)
{
    int x, y;
    div_t z;

    x = 7;
    y = 3;
    printf("For div(%d, %d)\n", x, y);
    z = div(x, y);
    printf("The quotient is %d and the "
           "remainder is %d\n\n", z.quot, z.rem);

    x = 7;
    y = -3;
    printf("For div(%d, %d)\n", x, y);
    z = div(x, y);
    printf("The quotient is %d and the "
           "remainder is %d\n\n", z.quot, z.rem);

    x = -5;
    y = 3;
    printf("For div(%d, %d)\n", x, y);
    z = div(x, y);
    printf("The quotient is %d and the "
           "remainder is %d\n\n", z.quot, z.rem);

    x = 7;
    y = 7;
    printf("For div(%d, %d)\n", x, y);
    z = div(x, y);
    printf("The quotient is %d and the "
           "remainder is %d\n\n", z.quot, z.rem);

    x = 7;
    y = 0;
    printf("For div(%d, %d)\n", x, y);
    z = div(x, y);
    printf("The quotient is %d and the "
           "remainder is %d\n\n", z.quot, z.rem);
}
```

div (Continued)

Output:

```
For div(7, 3)
The quotient is 2 and the remainder is 1

For div(7, -3)
The quotient is -2 and the remainder is 1

For div(-5, 3)
The quotient is -1 and the remainder is -2

For div(7, 7)
The quotient is 1 and the remainder is 0

For div(7, 0)
Illegal instruction executed
ABRT
```

exit

Description:	Terminates program after clean up.
Include:	<stdlib.h>
Prototype:	void exit(int <i>status</i>);
Argument:	<i>status</i> exit status
Remarks:	exit calls any functions registered by atexit in reverse order of registration, flushes buffers, closes stream, closes any temporary files created with tmpfile, and resets the processor. This function is customizable. See pic30-libs.
Example:	<pre>#include <stdio.h> /* for fopen, printf, */ /* FILE, NULL */ #include <stdlib.h> /* for exit */ int main(void) { FILE *myfile; if ((myfile = fopen("samp.fil", "r")) == NULL) { printf("Cannot open samp.fil\n"); exit(EXIT_FAILURE); } else { printf("Success opening samp.fil\n"); exit(EXIT_SUCCESS); } printf("This will not be printed"); } Output: Cannot open samp.fil</pre>

free

Description: Frees memory.

Include: <stdlib.h>

Prototype: void free(void *ptr);

Argument: ptr points to memory to be freed

Remarks: Frees memory previously allocated with calloc, malloc, or realloc. If free is used on space that has already been deallocated (by a previous call to free or by realloc) or on space not allocated with calloc, malloc, or realloc, the behavior is undefined.

Example:

```
#include <stdio.h> /* for printf, sizeof, */
/* NULL */
#include <stdlib.h> /* for malloc, free */

int main(void)
{
    long *i;

    if ((i = (long *)malloc(50 * sizeof(long))) ==
        NULL)
        printf("Cannot allocate memory\n");
    else
    {
        printf("Memory allocated\n");
        free(i);
        printf("Memory freed\n");
    }
}
```

Output:
Memory allocated
Memory freed

getenv

Description: Get a value for an environment variable.

Include: <stdlib.h>

Prototype: char *getenv(const char *name);

Argument: name name of environment variable

Return Value: Returns a pointer to the value of the environment variable if successful; otherwise, returns a null pointer.

Remarks: This function must be customized to be used as described (see pic30-libs). By default there are no entries in the environment list for getenv to find.

getenv (Continued)

Example:

```
#include <stdio.h> /* for printf, NULL */
#include <stdlib.h> /* for getenv */

int main(void)
{
    char *incvar;

    incvar = getenv("INCLUDE");
    if (incvar != NULL)
        printf("INCLUDE environment variable = %s\n",
            incvar);
    else
        printf("Cannot find environment variable "
            "INCLUDE ");
}

Output:
Cannot find environment variable INCLUDE
```

labs

Description: Calculates the absolute value of a long integer.

Include: <stdlib.h>

Prototype: long labs(long i);

Argument: i long integer value

Return Value: Returns the absolute value of i.

Remarks: A negative number is returned as positive; a positive number is unchanged.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for labs */

int main(void)
{
    long i;

    i = 123456;
    printf("The absolute value of %7ld is %6ld\n",
        i, labs(i));

    i = -246834;
    printf("The absolute value of %7ld is %6ld\n",
        i, labs(i));

    i = 0;
    printf("The absolute value of %7ld is %6ld\n",
        i, labs(i));
}

Output:
The absolute value of 123456 is 123456
The absolute value of -246834 is 246834
The absolute value of 0 is 0
```

ldiv

Description:	Calculates the quotient and remainder of two long integers.
Include:	<stdlib.h>
Prototype:	<code>ldiv_t ldiv(long numer, long denom);</code>
Arguments:	<i>numer</i> numerator <i>denom</i> denominator
Return Value:	Returns the quotient and the remainder.
Remarks:	The returned quotient will have the same sign as the numerator divided by the denominator. The sign for the remainder will be such that the quotient times the denominator plus the remainder will equal the numerator (quot * denom + rem = numer). If the denominator is zero, the behavior is undefined.

Example:

```
#include <stdlib.h> /* for ldiv, ldiv_t */
#include <stdio.h>  /* for printf */

int main(void)
{
    long x,y;
    ldiv_t z;

    x = 7;
    y = 3;
    printf("For ldiv(%ld, %ld)\n", x, y);
    z = ldiv(x, y);
    printf("The quotient is %ld and the "
           "remainder is %ld\n\n", z.quot, z.rem);

    x = 7;
    y = -3;
    printf("For ldiv(%ld, %ld)\n", x, y);
    z = ldiv(x, y);
    printf("The quotient is %ld and the "
           "remainder is %ld\n\n", z.quot, z.rem);

    x = -5;
    y = 3;
    printf("For ldiv(%ld, %ld)\n", x, y);
    z = ldiv(x, y);
    printf("The quotient is %ld and the "
           "remainder is %ld\n\n", z.quot, z.rem);

    x = 7;
    y = 7;
    printf("For ldiv(%ld, %ld)\n", x, y);
    z = ldiv(x, y);
    printf("The quotient is %ld and the "
           "remainder is %ld\n\n", z.quot, z.rem);

    x = 7;
    y = 0;
    printf("For ldiv(%ld, %ld)\n", x, y);
    z = ldiv(x, y);
    printf("The quotient is %ld and the "
           "remainder is %ld\n\n",
           z.quot, z.rem);
}
```

ldiv (Continued)

Output:

```
For ldiv(7, 3)
The quotient is 2 and the remainder is 1

For ldiv(7, -3)
The quotient is -2 and the remainder is 1

For ldiv(-5, 3)
The quotient is -1 and the remainder is -2

For ldiv(7, 7)
The quotient is 1 and the remainder is 0

For ldiv(7, 0)
The quotient is -1 and the remainder is 7
```

Explanation:

In the last example (`ldiv(7,0)`) the denominator is zero, the behavior is undefined.

malloc

Description:	Allocates memory.
Include:	<code><stdlib.h></code>
Prototype:	<code>void *malloc(size_t size);</code>
Argument:	<code>size</code> number of characters to allocate
Return Value:	Returns a pointer to the allocated space if successful; otherwise, returns a null pointer.
Remarks:	<code>malloc</code> does not initialize memory it returns.
Example:	<pre>#include <stdio.h> /* for printf, sizeof, */ /* NULL */ #include <stdlib.h> /* for malloc, free */ int main(void) { long *i; if ((i = (long *)malloc(50 * sizeof(long))) == NULL) printf("Cannot allocate memory\n"); else { printf("Memory allocated\n"); free(i); printf("Memory freed\n"); } }</pre>
Output:	Memory allocated Memory freed

mblen

Description:	Gets the length of a multibyte character. (See Remarks.)
Include:	<stdlib.h>
Prototype:	int mblen(const char *s, size_t n);
Arguments:	<i>s</i> points to the multibyte character <i>n</i> number of bytes to check
Return Value:	Returns zero if <i>s</i> points to a null character; otherwise, returns 1.
Remarks:	The 16-bit compiler does not support multibyte characters with length greater than 1 byte.

mbstowcs

Description:	Converts a multibyte string to a wide character string. (See Remarks.)
Include:	<stdlib.h>
Prototype:	size_t mbstowcs(wchar_t *wcs, const char *s, size_t n);
Arguments:	<i>wcs</i> points to the wide character string <i>s</i> points to the multibyte string <i>n</i> the number of wide characters to convert.
Return Value:	Returns the number of wide characters stored excluding the null character.
Remarks:	<i>mbstowcs</i> converts <i>n</i> number of wide characters unless it encounters a null wide character first. The 16-bit compiler does not support multibyte characters with length greater than 1 byte.

mbtowc

Description:	Converts a multibyte character to a wide character. (See Remarks.)
Include:	<stdlib.h>
Prototype:	int mbtowc(wchar_t *pwc, const char *s, size_t n);
Arguments:	<i>pwc</i> points to the wide character <i>s</i> points to the multibyte character <i>n</i> number of bytes to check
Return Value:	Returns zero if <i>s</i> points to a null character; otherwise, returns 1.
Remarks:	The resulting wide character will be stored at <i>pwc</i> . The 16-bit compiler does not support multibyte characters with length greater than 1 byte.

qsort

Description:	Performs a quick sort.												
Include:	<stdlib.h>												
Prototype:	<pre>void qsort(void *base, size_t nelem, size_t size, int (*cmp)(const void *e1, const void *e2));</pre>												
Arguments:	<table><tr><td><i>base</i></td><td>pointer to the start of the array</td></tr><tr><td><i>nelem</i></td><td>number of elements</td></tr><tr><td><i>size</i></td><td>size of the elements</td></tr><tr><td><i>cmp</i></td><td>pointer to the comparison function</td></tr><tr><td><i>e1</i></td><td>pointer to the key for the search</td></tr><tr><td><i>e2</i></td><td>pointer to the element being compared with the key</td></tr></table>	<i>base</i>	pointer to the start of the array	<i>nelem</i>	number of elements	<i>size</i>	size of the elements	<i>cmp</i>	pointer to the comparison function	<i>e1</i>	pointer to the key for the search	<i>e2</i>	pointer to the element being compared with the key
<i>base</i>	pointer to the start of the array												
<i>nelem</i>	number of elements												
<i>size</i>	size of the elements												
<i>cmp</i>	pointer to the comparison function												
<i>e1</i>	pointer to the key for the search												
<i>e2</i>	pointer to the element being compared with the key												
Remarks:	qsort overwrites the array with the sorted array. The comparison function is supplied by the user. In the following example, the list is sorted according to the comparison function. This comp uses ascending order.												
Example:	<pre>#include <stdlib.h> /* for qsort */ #include <stdio.h> /* for printf */ #define NUM 7 int comp(const void *e1, const void *e2); int main(void) { int list[NUM] = {35, 47, 63, 25, 93, 16, 52}; int x; printf("Unsorted List: "); for (x = 0; x < NUM; x++) printf("%d ", list[x]); qsort(list, NUM, sizeof(int), comp); printf("\n"); printf("Sorted List: "); for (x = 0; x < NUM; x++) printf("%d ", list[x]); } int comp(const void *e1, const void *e2) { const int * a1 = e1; const int * a2 = e2; if (*a1 < *a2) return -1; else if (*a1 == *a2) return 0; else return 1; } Output: Unsorted List: 35 47 63 25 93 16 52 Sorted List: 16 25 35 47 52 63 93</pre>												

rand

Description:	Generates a pseudo-random integer.
Include:	<stdlib.h>
Prototype:	int rand(void);
Return Value:	Returns an integer between 0 and RAND_MAX.
Remarks:	Calls to this function return pseudo-random integer values in the range [0,RAND_MAX]. 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 no seeds are used (as in the example below) or when identical seed values are used. (See srand for seed example.)

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for rand */

int main(void)
{
    int x;

    for (x = 0; x < 5; x++)
        printf("Number = %d\n", rand());
}
```

Output:

```
Number = 21422
Number = 2061
Number = 16443
Number = 11617
Number = 9125
```

Notice if the program is run a second time, the numbers are the same. See the example for srand to seed the random number generator.

realloc

Description:	Reallocates memory to allow a size change.
Include:	<stdlib.h>
Prototype:	void *realloc(void *ptr, size_t size);
Arguments:	<i>ptr</i> points to previously allocated memory <i>size</i> new size to allocate to
Return Value:	Returns a pointer to the allocated space if successful; otherwise, returns a null pointer.
Remarks:	If the existing object is smaller than the new object, the entire existing object is copied to the new object and the remainder of the new object is indeterminate. If the existing object is larger than the new object, the function copies as much of the existing object as will fit in the new object. If realloc succeeds in allocating a new object, the existing object will be deallocated; otherwise, the existing object is left unchanged. Keep a temporary pointer to the existing object since realloc will return a null pointer on failure.

realloc (Continued)

Example:

```
#include <stdio.h> /* for printf, sizeof, NULL */
#include <stdlib.h> /* for realloc, malloc, free */

int main(void)
{
    long *i, *j;

    if ((i = (long *)malloc(50 * sizeof(long)))
        == NULL)
        printf("Cannot allocate memory\n");
    else
    {
        printf("Memory allocated\n");
        /* Temp pointer in case realloc() fails */
        j = i;

        if ((i = (long *)realloc(i, 25 * sizeof(long)))
            == NULL)
        {
            printf("Cannot reallocate memory\n");
            /* j pointed to allocated memory */
            free(j);
        }
        else
        {
            printf("Memory reallocated\n");
            free(i);
        }
    }
}
```

Output:

```
Memory allocated
Memory reallocated
```

srand

Description:	Set the starting seed for the pseudo-random number sequence.
Include:	<stdlib.h>
Prototype:	void srand(unsigned int <i>seed</i>);
Argument:	<i>seed</i> starting value for the pseudo-random number sequence
Return Value:	None.
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 with a seed value of 1, the sequence of numbers generated will be the same as if rand had been called without srand having been called first.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for rand, srand */

int main(void)
{
    int x;

    srand(7);
    for (x = 0; x < 5; x++)
        printf("Number = %d\n", rand());
}
```

Output:

```
Number = 16327
Number = 5931
Number = 23117
Number = 30985
Number = 29612
```

strtod

Description:	Converts a partial string to a floating-point number of type double.
Include:	<stdlib.h>
Prototype:	double strtod(const char * <i>s</i> , char ** <i>endptr</i>);
Arguments:	<i>s</i> string to be converted <i>endptr</i> pointer to the character at which the conversion stopped
Return Value:	Returns the converted number if successful; otherwise, returns 0.
Remarks:	The number may consist of the following: [<i>whitespace</i>] [<i>sign</i>] <i>digits</i> [<i>.digits</i>] [{ <i>e</i> | <i>E</i> } [<i>sign</i>] <i>digits</i>] optional <i>whitespace</i> , followed by an optional <i>sign</i> , then a sequence of one or more <i>digits</i> with an optional decimal point, followed by one or more optional <i>digits</i> and an optional <i>e</i> or <i>E</i> followed by an optional signed exponent. <i>strtod</i> converts the string until it reaches a character that cannot be converted to a number. <i>endptr</i> will point to the remainder of the string starting with the first unconverted character. If a range error occurs, <i>errno</i> will be set.

strtod (Continued)

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for strtod */

int main(void)
{
    char *end;
    char a[] = "1.28 inches";
    char b[] = "27.835e2i";
    char c[] = "Number1";
    double x;

    x = strtod(a, &end);
    printf("String = \"%s\" float = %f\n", a, x );
    printf("Stopped at: %s\n\n", end );

    x = strtod(b, &end);
    printf("String = \"%s\" float = %f\n", b, x );
    printf("Stopped at: %s\n\n", end );

    x = strtod(c, &end);
    printf("String = \"%s\" float = %f\n", c, x );
    printf("Stopped at: %s\n\n", end );
}
```

Output:

```
String = "1.28 inches" float = 1.280000
Stopped at: inches
```

```
String = "27.835e2i" float = 2783.500000
Stopped at: i
```

```
String = "Number1" float = 0.000000
Stopped at: Number1
```

strtol

Description: Converts a partial string to a long integer.

Include: `<stdlib.h>`

Prototype: `long strtol(const char *s, char **endptr, int base);`

Arguments:

<i>s</i>	string to be converted
<i>endptr</i>	pointer to the character at which the conversion stopped
<i>base</i>	number base to use in conversion

Return Value: Returns the converted number if successful; otherwise, returns 0.

Remarks: If *base* is zero, `strtol` attempts to determine the base automatically. It can be octal, determined by a leading zero, hexadecimal, determined by a leading 0x or 0X, or decimal in any other case. If *base* is specified `strtol` converts a sequence of digits and letters a-z (case insensitive), where a-z represents the numbers 10-36. Conversion stops when an out of base number is encountered. *endptr* will point to the remainder of the string starting with the first unconverted character. If a range error occurs, `errno` will be set.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for strtol */

int main(void)
{
    char *end;
    char a[] = "-12BGEE";
    char b[] = "1234Number";
    long x;

    x = strtol(a, &end, 16);
    printf("String = \"%s\"    long = %ld\n", a, x );
    printf("Stopped at: %s\n\n", end );

    x = strtol(b, &end, 4);
    printf("String = \"%s\"    long = %ld\n", b, x );
    printf("Stopped at: %s\n\n", end );
}
```

Output:

```
String = "-12BGEE"    long = -299
Stopped at: GEE
```

```
String = "1234Number"    long = 27
Stopped at: 4Number
```

strtoul

Description:	Converts a partial string to an unsigned long integer.
Include:	<stdlib.h>
Prototype:	unsigned long strtoul(const char *s, char **endptr, int base);
Arguments:	<i>s</i> string to be converted <i>endptr</i> pointer to the character at which the conversion stopped <i>base</i> number base to use in conversion
Return Value:	Returns the converted number if successful; otherwise, returns 0.
Remarks:	If <i>base</i> is zero, <i>strtoul</i> attempts to determine the base automatically. It can be octal, determined by a leading zero, hexadecimal, determined by a leading 0x or 0X, or decimal in any other case. If base is specified <i>strtoul</i> converts a sequence of digits and letters a-z (case insensitive), where a-z represents the numbers 10-36. Conversion stops when an out of base number is encountered. <i>endptr</i> will point to the remainder of the string starting with the first unconverted character. If a range error occurs, <i>errno</i> will be set.

Example:

```
#include <stdio.h> /* for printf */
#include <stdlib.h> /* for strtoul */

int main(void)
{
    char *end;
    char a[] = "12BGET3";
    char b[] = "0x1234Number";
    char c[] = "-123abc";
    unsigned long x;

    x = strtoul(a, &end, 25);
    printf("String = \"%s\" long = %lu\n", a, x );
    printf("Stopped at: %s\n\n", end );

    x = strtoul(b, &end, 0);
    printf("String = \"%s\" long = %lu\n", b, x );
    printf("Stopped at: %s\n\n", end );

    x = strtoul(c, &end, 0);
    printf("String = \"%s\" long = %lu\n", c, x );
    printf("Stopped at: %s\n\n", end );
}
```

Output:

```
String = "12BGET3" long = 429164
Stopped at: T3
```

```
String = "0x1234Number" long = 4660
Stopped at: Number
```

```
String = "-123abc" long = 4294967173
Stopped at: abc
```

system

Description: Execute a command.

Include: <stdlib.h>

Prototype: int system(const char *s);

Argument: s command to be executed

Remarks: This function must be customized to be used as described (see pic30-libs). By default, system will cause a Reset if called with anything other than NULL. system(NULL) will do nothing.

Example:

```
/* This program uses system */
/* to TYPE its source file. */

#include <stdlib.h> /* for system */

int main(void)
{
    system("type sampsystem.c");
}
```

Output:

System(type sampsystem.c) called: Aborting

wctomb

Description: Converts a wide character to a multibyte character. (See Remarks.)

Include: <stdlib.h>

Prototype: int wctomb(char *s, wchar_t wchar);

Arguments: s points to the multibyte character
wchar the wide character to be converted

Return Value: Returns zero if s points to a null character; otherwise, returns 1.

Remarks: The resulting multibyte character is stored at s. The 16-bit compiler does not support multibyte characters with length greater than 1 character.

wcstombs

Description: Converts a wide character string to a multibyte string. (See Remarks.)

Include: <stdlib.h>

Prototype: size_t wcstombs(char *s, const wchar_t *wcs, size_t n);

Arguments: s points to the multibyte string
wcs points to the wide character string
n the number of characters to convert

Return Value: Returns the number of characters stored excluding the null character.

Remarks: wcstombs converts n number of multibyte characters unless it encounters a null character first. The 16-bit compiler does not support multibyte characters with length greater than 1 character.

2.15 <STRING.H> STRING FUNCTIONS

The header file, `string.h`, consists of types, macros and functions that provide tools to manipulate strings.

size_t

Description: The type of the result of the `sizeof` operator.
Include: `<string.h>`

NULL

Description: The value of a null pointer constant.
Include: `<string.h>`

memchr

Description: Locates a character in a buffer.
Include: `<string.h>`
Prototype: `void *memchr(const void *s, int c, size_t n);`
Arguments:
 s pointer to the buffer
 c character to search for
 n number of characters to check
Return Value: Returns a pointer to the location of the match if successful; otherwise, returns null.
Remarks: `memchr` stops when it finds the first occurrence of *c* or after searching *n* number of characters.
Example:

```
#include <string.h> /* for memchr, NULL */
#include <stdio.h>  /* for printf          */
```

```
int main(void)
{
    char buf1[50] = "What time is it?";
    char ch1 = 'i', ch2 = 'y';
    char *ptr;
    int res;

    printf("buf1 : %s\n\n", buf1);

    ptr = memchr(buf1, ch1, 50);
    if (ptr != NULL)
    {
        res = ptr - buf1 + 1;
        printf("%c found at position %d\n", ch1, res);
    }
    else
        printf("%c not found\n", ch1);
}
```

memchr (Continued)

```
printf("\n");

ptr = memchr(buf1, ch2, 50);
if (ptr != NULL)
{
    res = ptr - buf1 + 1;
    printf("%c found at position %d\n", ch2, res);
}
else
    printf("%c not found\n", ch2);
}
```

Output:

buf1 : What time is it?

i found at position 7

y not found

memcmp

Description:	Compare the contents of two buffers.
Include:	<string.h>
Prototype:	int memcmp(const void *s1, const void *s2, size_t n);
Arguments:	<div>s1 first buffer</div> <div>s2 second buffer</div> <div>n number of characters to compare</div>
Return Value:	Returns a positive number if s1 is greater than s2, zero if s1 is equal to s2 or a negative number if s1 is less than s2.
Remarks:	This function compares the first n characters in s1 to the first n characters in s2 and returns a value indicating whether the buffers are less than, equal to or greater than each other.
Example:	<pre>#include <string.h> /* memcmp */ #include <stdio.h> /* for printf */ int main(void) { char buf1[50] = "Where is the time?"; char buf2[50] = "Where did they go?"; char buf3[50] = "Why?"; int res; printf("buf1 : %s\n", buf1); printf("buf2 : %s\n", buf2); printf("buf3 : %s\n\n", buf3); res = memcmp(buf1, buf2, 6); if (res < 0) printf("buf1 comes before buf2\n"); else if (res == 0) printf("6 characters of buf1 and buf2 " "are equal\n"); else printf("buf2 comes before buf1\n"); }</pre>

memcmp (Continued)

```
printf("\n");

res = memcmp(buf1, buf2, 20);
if (res < 0)
    printf("buf1 comes before buf2\n");
else if (res == 0)
    printf("20 characters of buf1 and buf2 "
           "are equal\n");
else
    printf("buf2 comes before buf1\n");

printf("\n");

res = memcmp(buf1, buf3, 20);
if (res < 0)
    printf("buf1 comes before buf3\n");
else if (res == 0)
    printf("20 characters of buf1 and buf3 "
           "are equal\n");
else
    printf("buf3 comes before buf1\n");
}
```

Output:

```
buf1 : Where is the time?
buf2 : Where did they go?
buf3 : Why?
```

```
6 characters of buf1 and buf2 are equal
```

```
buf2 comes before buf1
```

```
buf1 comes before buf3
```

memcpy

Description:	Copies characters from one buffer to another.
Include:	<string.h>
Prototype:	void *memcpy(void *dst , const void *src , size_t n);
Arguments:	<i>dst</i> buffer to copy characters to <i>src</i> buffer to copy characters from <i>n</i> number of characters to copy
Return Value:	Returns <i>dst</i> .
Remarks:	memcpy copies <i>n</i> characters from the source buffer <i>src</i> to the destination buffer <i>dst</i> . If the buffers overlap, the behavior is undefined.
Example:	<pre>#include <string.h> /* memcpy */ #include <stdio.h> /* for printf */ int main(void) { char buf1[50] = ""; char buf2[50] = "Where is the time?"; char buf3[50] = "Why?"; printf("buf1 : %s\n", buf1); printf("buf2 : %s\n", buf2); printf("buf3 : %s\n\n", buf3); memcpy(buf1, buf2, 6); printf("buf1 after memcpy of 6 chars of " "buf2: \n\t%s\n", buf1); printf("\n"); memcpy(buf1, buf3, 5); printf("buf1 after memcpy of 5 chars of " "buf3: \n\t%s\n", buf1); }</pre>

Output:

```
buf1 :
buf2 : Where is the time?
buf3 : Why?
```

```
buf1 after memcpy of 6 chars of buf2:
    Where
```

```
buf1 after memcpy of 5 chars of buf3:
    Why?
```

memmove

Description: Copies *n* characters of the source buffer into the destination buffer, even if the regions overlap.

Include: `<string.h>`

Prototype: `void *memmove(void *s1, const void *s2, size_t n);`

Arguments:

<i>s1</i>	buffer to copy characters to (destination)
<i>s2</i>	buffer to copy characters from (source)
<i>n</i>	number of characters to copy from <i>s2</i> to <i>s1</i>

Return Value: Returns a pointer to the destination buffer.

Remarks: If the buffers overlap, the effect is as if the characters are read first from *s2*, then written to *s1*, so the buffer is not corrupted.

Example:

```
#include <string.h> /* for memmove */
#include <stdio.h> /* for printf */

int main(void)
{
    char buf1[50] = "When time marches on";
    char buf2[50] = "Where is the time?";
    char buf3[50] = "Why?";

    printf("buf1 : %s\n", buf1);
    printf("buf2 : %s\n", buf2);
    printf("buf3 : %s\n\n", buf3);

    memmove(buf1, buf2, 6);
    printf("buf1 after memmove of 6 chars of "
           "buf2: \n\t%s\n", buf1);

    printf("\n");

    memmove(buf1, buf3, 5);
    printf("buf1 after memmove of 5 chars of "
           "buf3: \n\t%s\n", buf1);
}
```

Output:

```
buf1 : When time marches on
buf2 : Where is the time?
buf3 : Why?
```

```
buf1 after memmove of 6 chars of buf2:
    Where ime marches on
```

```
buf1 after memmove of 5 chars of buf3:
    Why?
```

memset

Description: Copies the specified character into the destination buffer.

Include: <string.h>

Prototype: void *memset(void *s, int c, size_t n);

Arguments:

<i>s</i>	buffer
<i>c</i>	character to put in buffer
<i>n</i>	number of times

Return Value: Returns the buffer with characters written to it.

Remarks: The character, *c*, is written to the buffer *n* times.

Example:

```
#include <string.h> /* for memset */
#include <stdio.h>  /* for printf */
```

```
int main(void)
{
    char buf1[20] = "What time is it?";
    char buf2[20] = "";
    char ch1 = '?', ch2 = 'y';
    char *ptr;
    int res;

    printf("memset(\"%s\", \"%c\",4);\n", buf1, ch1);
    memset(buf1, ch1, 4);
    printf("buf1 after memset: %s\n", buf1);

    printf("\n");
    printf("memset(\"%s\", \"%c\",10);\n", buf2, ch2);
    memset(buf2, ch2, 10);
    printf("buf2 after memset: %s\n", buf2);
}
```

Output:

```
memset("What time is it?", '?',4);
buf1 after memset: ??? time is it?

memset("", 'y',10);
buf2 after memset: yyyyyyyyyy
```

strcat

Description: Appends a copy of the source string to the end of the destination string.

Include: <string.h>

Prototype: char *strcat(char *s1, const char *s2);

Arguments: s1 null terminated destination string to copy to
s2 null terminated source string to be copied

Return Value: Returns a pointer to the destination string.

Remarks: This function appends the source string (including the terminating null character) to the end of the destination string. The initial character of the source string overwrites the null character at the end of the destination string. If the buffers overlap, the behavior is undefined.

Example:

```
#include <string.h> /* for strcat, strlen */
#include <stdio.h> /* for printf */

int main(void)
{
    char buf1[50] = "We're here";
    char buf2[50] = "Where is the time?";

    printf("buf1 : %s\n", buf1);
    printf("\t(%d characters)\n\n", strlen(buf1));
    printf("buf2 : %s\n", buf2);
    printf("\t(%d characters)\n\n", strlen(buf2));

    strcat(buf1, buf2);
    printf("buf1 after strcat of buf2: \n\t%s\n",
        buf1);
    printf("\t(%d characters)\n", strlen(buf1));

    printf("\n");

    strcat(buf1, "Why?");
    printf("buf1 after strcat of \"Why?\": \n\t%s\n",
        buf1);
    printf("\t(%d characters)\n", strlen(buf1));
}
```

Output:

```
buf1 : We're here
      (10 characters)

buf2 : Where is the time?
      (18 characters)

buf1 after strcat of buf2:
      We're hereWhere is the time?
      (28 characters)

buf1 after strcat of "Why?":
      We're hereWhere is the time?Why?
      (32 characters)
```

strchr

Description: Locates the first occurrence of a specified character in a string.

Include: <string.h>

Prototype: char *strchr(const char *s, int c);

Arguments: s pointer to the string
c character to search for

Return Value: Returns a pointer to the location of the match if successful; otherwise, returns a null pointer.

Remarks: This function searches the string *s* to find the first occurrence of the character, *c*.

Example:

```
#include <string.h> /* for strchr, NULL */
#include <stdio.h> /* for printf */

int main(void)
{
    char buf1[50] = "What time is it?";
    char ch1 = 'm', ch2 = 'y';
    char *ptr;
    int res;

    printf("buf1 : %s\n\n", buf1);

    ptr = strchr(buf1, ch1);
    if (ptr != NULL)
    {
        res = ptr - buf1 + 1;
        printf("%c found at position %d\n", ch1, res);
    }
    else
        printf("%c not found\n", ch1);

    printf("\n");

    ptr = strchr(buf1, ch2);
    if (ptr != NULL)
    {
        res = ptr - buf1 + 1;
        printf("%c found at position %d\n", ch2, res);
    }
    else
        printf("%c not found\n", ch2);
}
```

Output:

```
buf1 : What time is it?

m found at position 8

y not found
```

strcmp

Description:	Compares two strings.
Include:	<string.h>
Prototype:	int strcmp(const char *s1, const char *s2);
Arguments:	<i>s1</i> first string <i>s2</i> second string
Return Value:	Returns a positive number if <i>s1</i> is greater than <i>s2</i> , zero if <i>s1</i> is equal to <i>s2</i> or a negative number if <i>s1</i> is less than <i>s2</i> .
Remarks:	This function compares successive characters from <i>s1</i> and <i>s2</i> until they are not equal or the null terminator is reached.
Example:	<pre>#include <string.h> /* for strcmp */ #include <stdio.h> /* for printf */ int main(void) { char buf1[50] = "Where is the time?"; char buf2[50] = "Where did they go?"; char buf3[50] = "Why?"; int res; printf("buf1 : %s\n", buf1); printf("buf2 : %s\n", buf2); printf("buf3 : %s\n\n", buf3); res = strcmp(buf1, buf2); if (res < 0) printf("buf1 comes before buf2\n"); else if (res == 0) printf("buf1 and buf2 are equal\n"); else printf("buf2 comes before buf1\n"); printf("\n"); res = strcmp(buf1, buf3); if (res < 0) printf("buf1 comes before buf3\n"); else if (res == 0) printf("buf1 and buf3 are equal\n"); else printf("buf3 comes before buf1\n"); printf("\n"); res = strcmp("Why?", buf3); if (res < 0) printf("\\"Why?" comes before buf3\n"); else if (res == 0) printf("\\"Why?" and buf3 are equal\n"); else printf("buf3 comes before \"Why?\"\\n"); }</pre>

strcmp (Continued)

Output:

```
buf1 : Where is the time?
buf2 : Where did they go?
buf3 : Why?
```

```
buf2 comes before buf1
```

```
buf1 comes before buf3
```

```
"Why?" and buf3 are equal
```

strcoll

Description:	Compares one string to another. (See Remarks.)
Include:	<string.h>
Prototype:	int strcoll(const char *s1, const char *s2);
Arguments:	s1 first string s2 second string
Return Value:	Using the locale-dependent rules, it returns a positive number if s1 is greater than s2, zero if s1 is equal to s2 or a negative number if s1 is less than s2.
Remarks:	Since the 16-bit compiler does not support alternate locales, this function is equivalent to strcmp.

strcpy

Description:	Copy the source string into the destination string.
Include:	<string.h>
Prototype:	char *strcpy(char *s1, const char *s2);
Arguments:	s1 destination string to copy to s2 source string to copy from
Return Value:	Returns a pointer to the destination string.
Remarks:	All characters of s2 are copied, including the null terminating character. If the strings overlap, the behavior is undefined.
Example:	<pre>#include <string.h> /* for strcpy, strlen */ #include <stdio.h> /* for printf */ int main(void) { char buf1[50] = "We're here"; char buf2[50] = "Where is the time?"; char buf3[50] = "Why?"; printf("buf1 : %s\n", buf1); printf("buf2 : %s\n", buf2); printf("buf3 : %s\n\n", buf3); strcpy(buf1, buf2); printf("buf1 after strcpy of buf2: \n\t%s\n\n", buf1);</pre>

strcpy (Continued)

```
strcpy(buf1, buf3);
printf("buf1 after strcpy of buf3: \n\t%s\n",
      buf1);
}
```

Output:

```
buf1 : We're here
buf2 : Where is the time?
buf3 : Why?
```

```
buf1 after strcpy of buf2:
      Where is the time?
```

```
buf1 after strcpy of buf3:
      Why?
```

strcspn

Description: 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 *s1, const char *s2);

Arguments: s1 pointer to the string to be searched
s2 pointer to characters to search for

Return Value: Returns the length of the segment in s1 not containing characters found in s2.

Remarks: This function will determine the number of consecutive characters from the beginning of s1 that are not contained in s2.

Example: #include <string.h> /* for strcspn */
#include <stdio.h> /* for printf */

```
int main(void)
{
    char str1[20] = "hello";
    char str2[20] = "aeiou";
    char str3[20] = "animal";
    char str4[20] = "xyz";
    int res;

    res = strcspn(str1, str2);
    printf("strcspn(\"%s\", \"%s\") = %d\n",
          str1, str2, res);

    res = strcspn(str3, str2);
    printf("strcspn(\"%s\", \"%s\") = %d\n",
          str3, str2, res);

    res = strcspn(str3, str4);
    printf("strcspn(\"%s\", \"%s\") = %d\n",
          str3, str4, res);
}
```

Output:

```
strcspn("hello", "aeiou") = 1
strcspn("animal", "aeiou") = 0
strcspn("animal", "xyz") = 6
```

strcspn (Continued)

Explanation:

In the first result, *e* is in *s2* so it stops counting after *h*.

In the second result, *a* is in *s2*.

In the third result, none of the characters of *s1* are in *s2* so all characters are counted.

strerror

Description: Gets an internal error message.

Include: <string.h>

Prototype: char *strerror(int *errcode*);

Argument: *errcode* number of the error code

Return Value: Returns a pointer to an internal error message string corresponding to the specified error code *errcode*.

Remarks: The array pointed to by *strerror* may be overwritten by a subsequent call to this function.

Example:

```
#include <stdio.h> /* for fopen, fclose, */
                  /* printf, FILE, NULL */
#include <string.h> /* for strerror */
#include <errno.h> /* for errno */

int main(void)
{
    FILE *myfile;

    if ((myfile = fopen("samp.fil", "r+")) == NULL)
        printf("Cannot open samp.fil: %s\n",
               strerror(errno));
    else
        printf("Success opening samp.fil\n");
    fclose(myfile);
}
```

Output:

Cannot open samp.fil: file open error

strlen

Description: Finds the length of a string.

Include: <string.h>

Prototype: size_t strlen(const char **s*);

Argument: *s* the string

Return Value: Returns the length of a string.

Remarks: This function determines the length of the string, not including the terminating null character.

strlen (Continued)

Example:

```
#include <string.h> /* for strlen */
#include <stdio.h>  /* for printf */

int main(void)
{
    char str1[20] = "We are here";
    char str2[20] = "";
    char str3[20] = "Why me?";

    printf("str1 : %s\n", str1);
    printf("\t(string length = %d characters)\n\n",
        strlen(str1));
    printf("str2 : %s\n", str2);
    printf("\t(string length = %d characters)\n\n",
        strlen(str2));
    printf("str3 : %s\n", str3);
    printf("\t(string length = %d characters)\n\n",
        strlen(str3));
}

Output:
str1 : We are here
        (string length = 11 characters)

str2 :
        (string length = 0 characters)

str3 : Why me?
        (string length = 7 characters)
```

strncat

Description: Append a specified number of characters from the source string to the destination string.

Include: <string.h>

Prototype: char *strncat(char *s1, const char *s2, size_t n);

Arguments:

s1	destination string to copy to
s2	source string to copy from
n	number of characters to append

Return Value: Returns a pointer to the destination string.

Remarks: This function appends up to *n* characters (a null character and characters that follow it are not appended) from the source string to the end of the destination string. If a null character is not encountered, then a terminating null character is appended to the result. If the strings overlap, the behavior is undefined.

Example:

```
#include <string.h> /* for strncat, strlen */
#include <stdio.h>  /* for printf */

int main(void)
{
    char buf1[50] = "We're here";
    char buf2[50] = "Where is the time?";
    char buf3[50] = "Why?";
```

strncat (Continued)

```
printf("buf1 : %s\n", buf1);
printf("\t(%d characters)\n\n", strlen(buf1));
printf("buf2 : %s\n", buf2);
printf("\t(%d characters)\n\n", strlen(buf2));
printf("buf3 : %s\n", buf3);
printf("\t(%d characters)\n\n\n", strlen(buf3));

strncat(buf1, buf2, 6);
printf("buf1 after strncat of 6 characters "
      "of buf2: \n\t%s\n", buf1);
printf("\t(%d characters)\n", strlen(buf1));

printf("\n");

strncat(buf1, buf2, 25);
printf("buf1 after strncat of 25 characters "
      "of buf2: \n\t%s\n", buf1);
printf("\t(%d characters)\n", strlen(buf1));

printf("\n");

strncat(buf1, buf3, 4);
printf("buf1 after strncat of 4 characters "
      "of buf3: \n\t%s\n", buf1);
printf("\t(%d characters)\n", strlen(buf1));
}
```

Output:

buf1 : We're here
(10 characters)

buf2 : Where is the time?
(18 characters)

buf3 : Why?
(4 characters)

buf1 after strncat of 6 characters of buf2:
We're hereWhere
(16 characters)

buf1 after strncat of 25 characters of buf2:
We're hereWhere Where is the time?
(34 characters)

buf1 after strncat of 4 characters of buf3:
We're hereWhere Where is the time?Why?
(38 characters)

strcmp

Description:	Compare two strings, up to a specified number of characters.						
Include:	<string.h>						
Prototype:	<pre>int strcmp(const char *s1, const char *s2, size_t n);</pre>						
Arguments:	<table><tr><td><i>s1</i></td><td>first string</td></tr><tr><td><i>s2</i></td><td>second string</td></tr><tr><td><i>n</i></td><td>number of characters to compare</td></tr></table>	<i>s1</i>	first string	<i>s2</i>	second string	<i>n</i>	number of characters to compare
<i>s1</i>	first string						
<i>s2</i>	second string						
<i>n</i>	number of characters to compare						
Return Value:	Returns a positive number if <i>s1</i> is greater than <i>s2</i> , zero if <i>s1</i> is equal to <i>s2</i> or a negative number if <i>s1</i> is less than <i>s2</i> .						
Remarks:	strcmp returns a value based on the first character that differs between <i>s1</i> and <i>s2</i> . Characters that follow a null character are not compared.						
Example:	<pre>#include <string.h> /* for strcmp */ #include <stdio.h> /* for printf */ int main(void) { char buf1[50] = "Where is the time?"; char buf2[50] = "Where did they go?"; char buf3[50] = "Why?"; int res; printf("buf1 : %s\n", buf1); printf("buf2 : %s\n", buf2); printf("buf3 : %s\n\n", buf3); res = strcmp(buf1, buf2, 6); if (res < 0) printf("buf1 comes before buf2\n"); else if (res == 0) printf("6 characters of buf1 and buf2 " "are equal\n"); else printf("buf2 comes before buf1\n"); printf("\n"); res = strcmp(buf1, buf2, 20); if (res < 0) printf("buf1 comes before buf2\n"); else if (res == 0) printf("20 characters of buf1 and buf2 " "are equal\n"); else printf("buf2 comes before buf1\n");</pre>						

strncmp (Continued)

```
printf("\n");

res = strncmp(buf1, buf3, 20);
if (res < 0)
    printf("buf1 comes before buf3\n");
else if (res == 0)
    printf("20 characters of buf1 and buf3 "
           "are equal\n");
else
    printf("buf3 comes before buf1\n");
}
```

Output:

```
buf1 : Where is the time?
buf2 : Where did they go?
buf3 : Why?
```

```
6 characters of buf1 and buf2 are equal
```

```
buf2 comes before buf1
```

```
buf1 comes before buf3
```

strncpy

Description: Copy characters from the source string into the destination string, up to the specified number of characters.

Include: <string.h>

Prototype: char *strncpy(char *s1, const char *s2, size_t n);

Arguments:

s1	destination string to copy to
s2	source string to copy from
n	number of characters to copy

Return Value: Returns a pointer to the destination string.

Remarks: Copies *n* characters from the source string to the destination string. If the source string is less than *n* characters, the destination is filled with null characters to total *n* characters. If *n* characters were copied and no null character was found, then the destination string will not be null-terminated. If the strings overlap, the behavior is undefined.

Example:

```
#include <string.h> /* for strncpy, strlen */
#include <stdio.h>  /* for printf          */
```

```
int main(void)
{
    char buf1[50] = "We're here";
    char buf2[50] = "Where is the time?";
    char buf3[50] = "Why?";
    char buf4[7]  = "Where?";

    printf("buf1 : %s\n", buf1);
    printf("buf2 : %s\n", buf2);
    printf("buf3 : %s\n", buf3);
    printf("buf4 : %s\n", buf4);
}
```

strncpy (Continued)

```
strncpy(buf1, buf2, 6);
printf("buf1 after strncpy of 6 characters "
      "of buf2: \n\t%s\n", buf1);
printf("\t( %d characters)\n", strlen(buf1));

printf("\n");

strncpy(buf1, buf2, 18);
printf("buf1 after strncpy of 18 characters "
      "of buf2: \n\t%s\n", buf1);
printf("\t( %d characters)\n", strlen(buf1));

printf("\n");

strncpy(buf1, buf3, 5);
printf("buf1 after strncpy of 5 characters "
      "of buf3: \n\t%s\n", buf1);
printf("\t( %d characters)\n", strlen(buf1));

printf("\n");

strncpy(buf1, buf4, 9);
printf("buf1 after strncpy of 9 characters "
      "of buf4: \n\t%s\n", buf1);
printf("\t( %d characters)\n", strlen(buf1));
}
```

Output:

```
buf1 : We're here
buf2 : Where is the time?
buf3 : Why?
buf4 : Where?
buf1 after strncpy of 6 characters of buf2:
    Where here
    ( 10 characters)

buf1 after strncpy of 18 characters of buf2:
    Where is the time?
    ( 18 characters)

buf1 after strncpy of 5 characters of buf3:
    Why?
    ( 4 characters)

buf1 after strncpy of 9 characters of buf4:
    Where?
    ( 6 characters)
```

strncpy (Continued)

Explanation:

Each buffer contains the string shown, followed by null characters for a length of 50. Using `strlen` will find the length of the string up to, but not including, the first null character.

In the first example, 6 characters of `buf2` ("Where ") replace the first 6 characters of `buf1` ("We're ") and the rest of `buf1` remains the same ("here" plus null characters).

In the second example, 18 characters replace the first 18 characters of `buf1` and the rest remain null characters.

In the third example, 5 characters of `buf3` ("Why?" plus a null terminating character) replace the first 5 characters of `buf1`. `buf1` now actually contains ("Why?", 1 null character, " is the time?", 32 null characters). `strlen` shows 4 characters because it stops when it reaches the first null character.

In the fourth example, since `buf4` is only 7 characters `strncpy` uses 2 additional null characters to replace the first 9 characters of `buf1`. The result of `buf1` is 6 characters ("Where?") followed by 3 null characters, followed by 9 characters ("the time?"), followed by 32 null characters.

strpbrk

Description: Search a string for the first occurrence of a character from a specified set of characters.

Include: `<string.h>`

Prototype: `char *strpbrk(const char *s1, const char *s2);`

Arguments:
`s1` pointer to the string to be searched
`s2` pointer to characters to search for

Return Value: Returns a pointer to the matched character in `s1` if found; otherwise, returns a null pointer.

Remarks: This function will search `s1` for the first occurrence of a character contained in `s2`.

Example:

```
#include <string.h> /* for strpbrk, NULL */
#include <stdio.h>  /* for printf */

int main(void)
{
    char str1[20] = "What time is it?";
    char str2[20] = "xyz";
    char str3[20] = "eou?";
    char *ptr;
    int res;

    printf("strpbrk(\"%s\", \"%s\")\n", str1, str2);
    ptr = strpbrk(str1, str2);
    if (ptr != NULL)
    {
        res = ptr - str1 + 1;
        printf("match found at position %d\n", res);
    }
    else
        printf("match not found\n");
}
```

strpbrk (Continued)

```
printf("\n");

printf("strpbrk(\"%s\", \"%s\")\n", str1, str3);
ptr = strpbrk(str1, str3);
if (ptr != NULL)
{
    res = ptr - str1 + 1;
    printf("match found at position %d\n", res);
}
else
    printf("match not found\n");
}
```

Output:

```
strpbrk("What time is it?", "xyz")
match not found
```

```
strpbrk("What time is it?", "eou?")
match found at position 9
```

strrchr

Description: Search for the last occurrence of a specified character in a string.

Include: <string.h>

Prototype: char *strrchr(const char *s, int c);

Arguments: s pointer to the string to be searched
c character to search for

Return Value: Returns a pointer to the character if found; otherwise, returns a null pointer.

Remarks: The function searches the string s, including the terminating null character, to find the last occurrence of character c.

Example: #include <string.h> /* for strrchr, NULL */
#include <stdio.h> /* for printf */

```
int main(void)
{
    char buf1[50] = "What time is it?";
    char ch1 = 'm', ch2 = 'y';
    char *ptr;
    int res;

    printf("buf1 : %s\n\n", buf1);

    ptr = strrchr(buf1, ch1);
    if (ptr != NULL)
    {
        res = ptr - buf1 + 1;
        printf("%c found at position %d\n", ch1, res);
    }
    else
        printf("%c not found\n", ch1);
}
```


strrchr (Continued)

```
printf("\n");

ptr = strrchr(buf1, ch2);
if (ptr != NULL)
{
    res = ptr - buf1 + 1;
    printf("%c found at position %d\n", ch2, res);
}
else
    printf("%c not found\n", ch2);
}
```

Output:

buf1 : What time is it?

m found at position 8

y not found

strspn

Description:	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 *s1, const char *s2);
Arguments:	<p>s1 pointer to the string to be searched</p> <p>s2 pointer to characters to search for</p>
Return Value:	Returns the number of consecutive characters from the beginning of s1 that are contained in s2.
Remarks:	This function stops searching when a character from s1 is not in s2.
Example:	<pre>#include <string.h> /* for strspn */ #include <stdio.h> /* for printf */ int main(void) { char str1[20] = "animal"; char str2[20] = "aeioum"; char str3[20] = "aimnl"; char str4[20] = "xyz"; int res; res = strspn(str1, str2); printf("strspn(\"%s\", \"%s\") = %d\n", str1, str2, res); res = strspn(str1, str3); printf("strspn(\"%s\", \"%s\") = %d\n", str1, str3, res); res = strspn(str1, str4); printf("strspn(\"%s\", \"%s\") = %d\n", str1, str4, res); }</pre>

strspn (Continued)

Output:

```
strspn("animal", "aeioum") = 5
strspn("animal", "aimnl") = 6
strspn("animal", "xyz") = 0
```

Explanation:

In the first result, l is not in *s2*.

In the second result, the terminating null is not in *s2*.

In the third result, a is not in *s2*, so the comparison stops.

strstr

Description: Search for the first occurrence of a string inside another string.

Include: <string.h>

Prototype: char *strstr(const char *s1, const char *s2);

Arguments: *s1* pointer to the string to be searched
s2 pointer to substring to be searched for

Return Value: Returns the address of the first element that matches the substring if found; otherwise, returns a null pointer.

Remarks: This function will find the first occurrence of the string, *s2* (excluding the null terminator) within the string, *s1*. If *s2* points to a zero length string, *s1* is returned.

Example:

```
#include <string.h> /* for strstr, NULL */
#include <stdio.h> /* for printf */
```

```
int main(void)
{
    char str1[20] = "What time is it?";
    char str2[20] = "is";
    char str3[20] = "xyz";
    char *ptr;
    int res;

    printf("str1 : %s\n", str1);
    printf("str2 : %s\n", str2);
    printf("str3 : %s\n\n", str3);

    ptr = strstr(str1, str2);
    if (ptr != NULL)
    {
        res = ptr - str1 + 1;
        printf("\n%s\" found at position %d\n",
            str2, res);
    }
    else
        printf("\n%s\" not found\n", str2);
}
```

strstr (Continued)

```
printf("\n");

ptr = strstr(str1, str3);
if (ptr != NULL)
{
    res = ptr - str1 + 1;
    printf("\n%s\" found at position %d\n",
        str3, res);
}
else
    printf("\n%s\" not found\n", str3);
}
```

Output:

```
str1 : What time is it?
str2 : is
str3 : xyz
```

```
"is" found at position 11
```

```
"xyz" not found
```

strtok

Description: Break a string into substrings, or tokens, by inserting null characters in place of specified delimiters.

Include: <string.h>

Prototype: char *strtok(char *s1, const char *s2);

Arguments: *s1* pointer to the null terminated string to be searched
s2 pointer to characters to be searched for (used as delimiters)

Return Value: Returns a pointer to the first character of a token (the first character in *s1* that does not appear in the set of characters of *s2*). If no token is found, the null pointer is returned.

Remarks: A sequence of calls to this function can be used to split up a string into substrings (or tokens) by replacing specified characters with null characters. The first time this function is invoked on a particular string, that string should be passed in *s1*. After the first time, this function can continue parsing the string from the last delimiter by invoking it with a null value passed in *s1*.

It skips all leading characters that appear in the string, *s2* (delimiters), then skips all characters not appearing in *s2* (this segment of characters is the token), and then overwrites the next character with a null character, terminating the current token. The function, *strtok*, then saves a pointer to the character that follows, from which the next search will start. If *strtok* finds the end of the string before it finds a delimiter, the current token extends to the end of the string pointed to by *s1*. If this is the first call to *strtok*, it does not modify the string (no null characters are written to *s1*). The set of characters that is passed in *s2* need not be the same for each call to *strtok*.

If *strtok* is called with a non-null parameter for *s1* after the initial call, the string becomes the new string to search. The old string previously searched will be lost.

strtok (Continued)

Example:

```
#include <string.h> /* for strtok, NULL */
#include <stdio.h> / * for printf      */

int main(void)
{
    char str1[30] = "Here, on top of the world!";
    char delim[5] = ", .";
    char *word;
    int x;

    printf("str1 : %s\n", str1);
    x = 1;
    word = strtok(str1,delim);
    while (word != NULL)
    {
        printf("word %d: %s\n", x++, word);
        word = strtok(NULL, delim);
    }
}
```

Output:

```
str1 : Here, on top of the world!
word 1: Here
word 2: on
word 3: top
word 4: of
word 5: the
word 6: world!
```

strxfrm

Description:	Transforms a string using the locale-dependent rules. (See Remarks.)						
Include:	<string.h>						
Prototype:	size_t strxfrm(char *s1, const char *s2, size_t n);						
Arguments:	<table><tr><td>s1</td><td>destination string</td></tr><tr><td>s2</td><td>source string to be transformed</td></tr><tr><td>n</td><td>number of characters to transform</td></tr></table>	s1	destination string	s2	source string to be transformed	n	number of characters to transform
s1	destination string						
s2	source string to be transformed						
n	number of characters to transform						
Return Value:	Returns the length of the transformed string not including the terminating null character. If <i>n</i> is zero, the string is not transformed (<i>s1</i> may be a point null in this case) and the length of <i>s2</i> is returned.						
Remarks:	If the return value is greater than or equal to <i>n</i> , the content of <i>s1</i> is indeterminate. Since the 16-bit compiler does not support alternate locales, the transformation is equivalent to <code>strcpy</code> , except that the length of the destination string is bounded by <i>n</i> -1.						

2.16 <TIME.H> DATE AND TIME FUNCTIONS

The header file, `time.h`, consists of types, macros and functions that manipulate time.

clock_t

Description: Stores processor time values.
Include: `<time.h>`
Prototype: `typedef long clock_t`

size_t

Description: The type of the result of the `sizeof` operator.
Include: `<time.h>`

struct tm

Description: Structure used to hold the time and date (calendar time).
Include: `<time.h>`
Prototype:

```
struct tm {
    int tm_sec; /*seconds after the minute ( 0 to 61 )*/
                /*allows for up to two leap seconds*/
    int tm_min; /*minutes after the hour ( 0 to 59 )*/
    int tm_hour; /*hours since midnight ( 0 to 23 )*/
    int tm_mday; /*day of month ( 1 to 31 )*/
    int tm_mon; /*month ( 0 to 11 where January = 0 )*/
    int tm_year; /*years since 1900*/
    int tm_wday; /*day of week ( 0 to 6 where Sunday = 0 )*/
    int tm_yday; /*day of year ( 0 to 365 where January 1 = 0 )*/
    int tm_isdst; /*Daylight Savings Time flag*/
}
```

Remarks: If `tm_isdst` is a positive value, Daylight Savings is in effect. If it is zero, Daylight Saving Time is not in effect. If it is a negative value, the status of Daylight Saving Time is not known.

time_t

Description: Represents calendar time values.
Include: `<time.h>`
Prototype: `typedef long time_t`

CLOCKS_PER_SEC

Description: Number of processor clocks per second.
Include: `<time.h>`
Prototype: `#define CLOCKS_PER_SEC`
Value: 1
Remarks: The compiler returns clock ticks (instruction cycles) not actual time.

NULL

Description: The value of a null pointer constant.
Include: `<time.h>`

asctime

Description: Converts the time structure to a character string.
Include: `<time.h>`
Prototype: `char *asctime(const struct tm *tptr);`
Argument: `tptr` time/date structure
Return Value: Returns a pointer to a character string of the following format:
DDD MMM dd hh:mm:ss YYYY
DDD is day of the week
MMM is month of the year
dd is day of the month
hh is hour
mm is minute
ss is second
YYYY is year

Example:

```
#include <time.h> /* for asctime, tm */
#include <stdio.h> /* for printf */

volatile int i;

int main(void)
{
    struct tm when;
    time_t whattime;

    when.tm_sec = 30;
    when.tm_min = 30;
    when.tm_hour = 2;
    when.tm_mday = 1;
    when.tm_mon = 1;
    when.tm_year = 103;

    whattime = mktime(&when);
    printf("Day and time is %s\n", asctime(&when));
}

Output:
Day and time is Sat Feb 1 02:30:30 2003
```

clock

Description: Calculates the processor time.
Include: `<time.h>`
Prototype: `clock_t clock(void);`
Return Value: Returns the number of clock ticks of elapsed processor time.
Remarks: If the target environment cannot measure elapsed processor time, the function returns -1, cast as a `clock_t`. (i.e. `(clock_t) -1`). By default, the 16-bit compiler returns the time as instruction cycles.

clock (Continued)

Example:

```
#include <time.h> /* for clock */
#include <stdio.h> /* for printf */

volatile int i;

int main(void)
{
    clock_t start, stop;
    int ct;

    start = clock();
    for (i = 0; i < 10; i++)
        stop = clock();
    printf("start = %ld\n", start);
    printf("stop = %ld\n", stop);
}

Output:
start = 0
stop = 317
```

ctime

Description: Converts calendar time to a string representation of local time.

Include: `<time.h>`

Prototype: `char *ctime(const time_t *tod);`

Argument: `tod` pointer to stored time

Return Value: Returns the address of a string that represents the local time of the parameter passed.

Remarks: This function is equivalent to `asctime(localtime(tod))`.

Example:

```
#include <time.h> /* for mktime, tm, ctime */
#include <stdio.h> /* for printf */

int main(void)
{
    time_t whattime;
    struct tm nowtime;

    nowtime.tm_sec = 30;
    nowtime.tm_min = 30;
    nowtime.tm_hour = 2;
    nowtime.tm_mday = 1;
    nowtime.tm_mon = 1;
    nowtime.tm_year = 103;

    whattime = mktime(&nowtime);
    printf("Day and time %s\n", ctime(&whattime));
}

Output:
Day and time Sat Feb 1 02:30:30 2003
```

difftime

Description:	Find the difference between two times.
Include:	<time.h>
Prototype:	double difftime(time_t t1, time_t t0);
Arguments:	<i>t1</i> ending time <i>t0</i> beginning time
Return Value:	Returns the number of seconds between <i>t1</i> and <i>t0</i> .
Remarks:	By default, the 16-bit compiler returns the time as instruction cycles so difftime returns the number of ticks between <i>t1</i> and <i>t0</i> .
Example:	<pre>#include <time.h> /* for clock, difftime */ #include <stdio.h> /* for printf */ volatile int i; int main(void) { clock_t start, stop; double elapsed; start = clock(); for (i = 0; i < 10; i++) stop = clock(); printf("start = %ld\n", start); printf("stop = %ld\n", stop); elapsed = difftime(stop, start); printf("Elapsed time = %.0f\n", elapsed); }</pre> <p>Output: start = 0 stop = 317 Elapsed time = 317</p>

gmtime

Description:	Converts calendar time to time structure expressed as Universal Time Coordinated (UTC) also known as Greenwich Mean Time (GMT).
Include:	<time.h>
Prototype:	struct tm *gmtime(const time_t *tod);
Argument:	<i>tod</i> pointer to stored time
Return Value:	Returns the address of the time structure.
Remarks:	This function breaks down the <i>tod</i> value into the time structure of type tm. By default, the 16-bit compiler returns the time as instruction cycles. With this default, gmtime and localtime will be equivalent, except gmtime will return tm_isdst (Daylight Savings Time flag) as zero to indicate that Daylight Savings Time is not in effect.

gmtime (Continued)

Example:

```
#include <time.h> /* for gmtime, asctime, */
                  /* time_t, tm          */
#include <stdio.h> /* for printf          */

int main(void)
{
    time_t timer;
    struct tm *newtime;

    timer = 1066668182; /* Mon Oct 20 16:43:02 2003 */

    newtime = gmtime(&timer);
    printf("UTC time = %s\n", asctime(newtime));
}

Output:
UTC time = Mon Oct 20 16:43:02 2003
```

localtime

Description: Converts a value to the local time.

Include: `<time.h>`

Prototype: `struct tm *localtime(const time_t *tod);`

Argument: `tod` pointer to stored time

Return Value: Returns the address of the time structure.

Remarks: By default, the 16-bit compiler returns the time as instruction cycles. With this default, `localtime` and `gmtime` will be equivalent, except `localtime` will return `tm_isdst` (Daylight Savings Time flag) as -1 to indicate that the status of Daylight Savings Time is not known.

Example:

```
#include <time.h> /* for localtime,      */
                  /* asctime, time_t, tm */
#include <stdio.h> /* for printf          */

int main(void)
{
    time_t timer;
    struct tm *newtime;

    timer = 1066668182; /* Mon Oct 20 16:43:02 2003 */

    newtime = localtime(&timer);
    printf("Local time = %s\n", asctime(newtime));
}

Output:
Local time = Mon Oct 20 16:43:02 2003
```

mktime

Description: Converts local time to a calendar value.

Include: `<time.h>`

Prototype: `time_t mktime(struct tm *tptr);`

Argument: *tptr* a pointer to the time structure

Return Value: Returns the calendar time encoded as a value of `time_t`.

Remarks: If the calendar time cannot be represented, the function returns -1, cast as a `time_t` (i.e. `(time_t) -1`).

Example:

```
#include <time.h> /* for localtime, */
                  /* asctime, mktime, */
                  /* time_t, tm */
#include <stdio.h> /* for printf */

int main(void)
{
    time_t timer, whattime;
    struct tm *newtime;

    timer = 1066668182; /* Mon Oct 20 16:43:02 2003 */
    /* localtime allocates space for struct tm */
    newtime = localtime(&timer);
    printf("Local time = %s", asctime(newtime));

    whattime = mktime(newtime);
    printf("Calendar time as time_t = %ld\n",
           whattime);
}
```

Output:

Local time = Mon Oct 20 16:43:02 2003
Calendar time as time_t = 1066668182

strftime

Description: Formats the time structure to a string based on the format parameter.

Include: `<time.h>`

Prototype: `size_t strftime(char *s, size_t n, const char *format, const struct tm *tptr);`

Arguments: *s* output string
n maximum length of string
format format-control string
tptr pointer to tm data structure

Return Value: Returns the number of characters placed in the array, *s*, if the total, including the terminating null, is not greater than *n*. Otherwise, the function returns 0 and the contents of array, *s*, are indeterminate.

Remarks: The format parameters follow:

- %a** abbreviated weekday name
- %A** full weekday name
- %b** abbreviated month name
- %B** full month name
- %c** appropriate date and time representation
- %d** day of the month (01-31)
- %H** hour of the day (00-23)

strftime (Continued)

%I hour of the day (01-12)
%j day of the year (001-366)
%m month of the year (01-12)
%M minute of the hour (00-59)
%p AM/PM designator
%S second of the minute (00-61)
allowing for up to two leap seconds
%U week number of the year where Sunday is the first day of week 1
(00-53)
%w weekday where Sunday is day 0 (0-6)
%W week number of the year where Monday is the first day of week 1
(00-53)
%x appropriate date representation
%X appropriate time representation
%y year without century (00-99)
%Y year with century
%Z time zone (possibly abbreviated) or no characters if time zone is
unavailable
%% percent character %

Example:

```
#include <time.h> /* for strftime, */
                  /* localtime,   */
                  /* time_t, tm    */
#include <stdio.h> /* for printf   */

int main(void)
{
    time_t timer, whattime;
    struct tm *newtime;
    char buf[128];

    timer = 1066668182; /* Mon Oct 20 16:43:02 2003 */
    /* localtime allocates space for structure */
    newtime = localtime(&timer);

    strftime(buf, 128, "It was a %A, %d days into the "
                    "month of %B in the year %Y.\n", newtime);
    printf(buf);

    strftime(buf, 128, "It was %W weeks into the year "
                    "or %j days into the year.\n", newtime);
    printf(buf);
}
```

Output:

```
It was a Monday, 20 days into the month of October in
the year 2003.
It was 42 weeks into the year or 293 days into the
year.
```

16-Bit Language Tools Libraries

time

Description:	Calculates the current calendar time.
Include:	<time.h>
Prototype:	time_t time(time_t *tod);
Argument:	<i>tod</i> pointer to storage location for time
Return Value:	Returns the calendar time encoded as a value of time_t.
Remarks:	If the target environment cannot determine the time, the function returns -1, cast as a time_t. By default, the 16-bit compiler returns the time as instruction cycles. This function is customizable. See pic30-libs.
Example:	<pre>#include <time.h> /* for time */ #include <stdio.h> /* for printf */ volatile int i; int main(void) { time_t ticks; time(0); /* start time */ for (i = 0; i < 10; i++) /* waste time */ time(&ticks); /* get time */ printf("Time = %ld\n", ticks); }</pre> <p>Output: Time = 256</p>

Chapter 3. Standard C Libraries - Math Functions

3.1 INTRODUCTION

Standard ANSI C library math functions are contained in the file, `libm-omf.a`, where `omf` will be `coff` or `elf` depending upon the selected object module format.

3.1.1 Assembly Code Applications

A free version of the math functions library and header file is available from the Microchip web site. No source code is available with this free version.

3.1.2 C Code Applications

The MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs (formerly MPLAB C30) install directory (`c:\Program Files\Microchip\MPLAB C30`) contains the following subdirectories with library related files:

- `lib` – standard C library files
- `src\libm` – source code for math library functions, batch file to rebuild the library
- `support\h` – header files for libraries

In addition, there is a file, `ResourceGraphs.pdf`, which contains diagrams of resources used by each function, located in `lib`.

3.1.3 Chapter Organization

This chapter is organized as follows:

- Using the Standard C Libraries
- `<math.h>` mathematical functions

3.2 USING THE STANDARD C LIBRARIES

Building an application which utilizes the standard C libraries requires two types of files: header files and library files.

3.2.1 Header Files

All standard C library entities are declared or defined in one or more standard headers. (See list in **Section 3.1.3 “Chapter Organization”**.) To make use of a library entity in a program, write an include directive that names the relevant standard header.

The contents of a standard header are included by naming them in an include directive, as in:

```
#include <stdio.h> /* include I/O facilities */
```

The standard headers can be included in any order. Do not include a standard header within a declaration. Do not define macros that have the same names as keywords before including a standard header.

A standard header never includes another standard header.

3.2.2 Library Files

The archived library files contain all the individual object files for each library function. When linking an application, the library file must be provided as an input to the linker (using the `--library` or `-l` linker option), such that the functions used by the application may be linked into the application.

A typical C application will require three library files: `libc-omf.a`, `libm-omf.a`, and `libpic30-omf.a`. (See **Section 1.2 “OMF-Specific Libraries/Start-up Modules”** for more on OMF-specific libraries.) These libraries will be included automatically if linking is performed using the compiler.

Note: Some standard library functions require a heap. These include the standard I/O functions that open files and the memory allocation functions. See the “*MPLAB[®] Assembler, Linker and Utilities for PIC24 MCUs and dsPIC[®] DSCs User’s Guide*” (DS51317) and “*MPLAB[®] C Compiler for PIC24 MCUs and dsPIC[®] DSCs User’s Guide*” (DS51284) for more information on the heap.

3.3 <MATH.H> MATHEMATICAL FUNCTIONS

The header file, `math.h`, consists of a macro and various functions that calculate common mathematical operations. Error conditions may be handled with a domain error or range error (see `errno.h`).

A domain error occurs when the input argument is outside the domain over which the function is defined. The error is reported by storing the value of `EDOM` in `errno` and returning a particular value defined for each function.

A range error occurs when the result is too large or too small to be represented in the target precision. The error is reported by storing the value of `ERANGE` in `errno` and returning `HUGE_VAL` if the result overflowed (return value was too large) or a zero if the result underflowed (return value is too small).

Responses to special values, such as NaNs, zeros and infinities, may vary depending upon the function. Each function description includes a definition of the function's response to such values.

HUGE_VAL

Description:	<code>HUGE_VAL</code> is returned by a function on a range error (e.g., the function tries to return a value too large to be represented in the target precision).
Include:	<code><math.h></code>
Remarks:	<code>-HUGE_VAL</code> is returned if a function result is negative and is too large (in magnitude) to be represented in the target precision. When the printed result is <code>+/- HUGE_VAL</code> , it will be represented by <code>+/- inf</code> .

acos

Description:	Calculates the trigonometric arc cosine function of a double precision floating-point value.
Include:	<code><math.h></code>
Prototype:	<code>double acos (double x);</code>
Argument:	<code>x</code> value between -1 and 1 for which to return the arc cosine
Return Value:	Returns the arc cosine in radians in the range of 0 to pi (inclusive).
Remarks:	A domain error occurs if <code>x</code> is less than -1 or greater than 1.
Example:	<pre>#include <math.h> /* for acos */ #include <stdio.h> /* for printf, perror */ #include <errno.h> /* for errno */ int main(void) { double x,y; errno = 0; x = -2.0; y = acos (x); if (errno) perror("Error"); printf("The arccosine of %f is %f\n\n", x, y); }</pre>

acos (Continued)

```
    errno = 0;
    x = 0.10;
    y = acos (x);
    if (errno)
        perror("Error");
    printf("The arccosine of %f is %f\n\n", x, y);
}
```

Output:

Error: domain error

The arccosine of -2.000000 is nan

The arccosine of 0.100000 is 1.470629

acosf

Description: Calculates the trigonometric arc cosine function of a single precision floating-point value.

Include: <math.h>

Prototype: float acosf (float x);

Argument: x value between -1 and 1

Return Value: Returns the arc cosine in radians in the range of 0 to pi (inclusive).

Remarks: A domain error occurs if x is less than -1 or greater than 1.

Example:

```
#include <math.h> /* for acosf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;

    errno = 0;
    x = 2.0F;
    y = acosf (x);
    if (errno)
        perror("Error");
    printf("The arccosine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0F;
    y = acosf (x);
    if (errno)
        perror("Error");
    printf("The arccosine of %f is %f\n", x, y);
}
```

Output:

Error: domain error

The arccosine of 2.000000 is nan

The arccosine of 0.000000 is 1.570796

asin

Description: Calculates the trigonometric arc sine function of a double precision floating-point value.

Include: `<math.h>`

Prototype: `double asin (double x);`

Argument: `x` value between -1 and 1 for which to return the arc sine

Return Value: Returns the arc sine in radians in the range of -pi/2 to +pi/2 (inclusive).

Remarks: A domain error occurs if `x` is less than -1 or greater than 1.

Example:

```
#include <math.h> /* for asin          */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno        */

int main(void)
{
    double x, y;

    errno = 0;
    x = 2.0;
    y = asin (x);
    if (errno)
        perror("Error");
    printf("The arcsine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0;
    y = asin (x);
    if (errno)
        perror("Error");
    printf("The arcsine of %f is %f\n\n", x, y);
}
```

Output:

Error: domain error
The arcsine of 2.000000 is nan

The arcsine of 0.000000 is 0.000000

asinf

Description: Calculates the trigonometric arc sine function of a single precision floating-point value.

Include: `<math.h>`

Prototype: `float asinf (float x);`

Argument: `x` value between -1 and 1

Return Value: Returns the arc sine in radians in the range of -pi/2 to +pi/2 (inclusive).

Remarks: A domain error occurs if `x` is less than -1 or greater than 1.

Example:

```
#include <math.h> /* for asinf          */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno        */

int main(void)
{
    float x, y;
```

asinf (Continued)

```
    errno = 0;
    x = 2.0F;
    y = asinf(x);
    if (errno)
        perror("Error");
    printf("The arcsine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0F;
    y = asinf(x);
    if (errno)
        perror("Error");
    printf("The arcsine of %f is %f\n\n", x, y);
}
```

Output:

Error: domain error

The arcsine of 2.000000 is nan

The arcsine of 0.000000 is 0.000000

atan

Description: Calculates the trigonometric arc tangent function of a double precision floating-point value.

Include: <math.h>

Prototype: double atan (double x);

Argument: x value for which to return the arc tangent

Return Value: Returns the arc tangent in radians in the range of -pi/2 to +pi/2 (inclusive).

Remarks: No domain or range error will occur.

Example:

```
#include <math.h> /* for atan */
#include <stdio.h> /* for printf */

int main(void)
{
    double x, y;

    x = 2.0;
    y = atan (x);
    printf("The arctangent of %f is %f\n\n", x, y);

    x = -1.0;
    y = atan (x);
    printf("The arctangent of %f is %f\n\n", x, y);
}
```

Output:

The arctangent of 2.000000 is 1.107149

The arctangent of -1.000000 is -0.785398

atanf

Description: Calculates the trigonometric arc tangent function of a single precision floating-point value.

Include: <math.h>

Prototype: float atanf (float x);

Argument: x value for which to return the arc tangent

Return Value: Returns the arc tangent in radians in the range of -pi/2 to +pi/2 (inclusive).

Remarks: No domain or range error will occur.

Example:

```
#include <math.h> /* for atanf */
#include <stdio.h> /* for printf */

int main(void)
{
    float x, y;

    x = 2.0F;
    y = atanf (x);
    printf("The arctangent of %f is %f\n\n", x, y);

    x = -1.0F;
    y = atanf (x);
    printf("The arctangent of %f is %f\n\n", x, y);
}
```

Output:

The arctangent of 2.000000 is 1.107149

The arctangent of -1.000000 is -0.785398

atan2

Description: Calculates the trigonometric arc tangent function of y/x.

Include: <math.h>

Prototype: double atan2 (double y, double x);

Arguments: y y value for which to return the arc tangent

x x value for which to return the arc tangent

Return Value: Returns the arc tangent in radians in the range of -pi to pi (inclusive) with the quadrant determined by the signs of both parameters.

Remarks: A domain error occurs if both x and y are zero or both x and y are +/- infinity.

Example:

```
#include <math.h> /* for atan2 */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y, z;
```

atan2 (Continued)

```
    errno = 0;
    x = 0.0;
    y = 2.0;
    z = atan2(y, x);
    if (errno)
        perror("Error");
    printf("The arctangent of %f/%f is %f\n\n",
           y, x, z);

    errno = 0;
    x = -1.0;
    y = 0.0;
    z = atan2(y, x);
    if (errno)
        perror("Error");
    printf("The arctangent of %f/%f is %f\n\n",
           y, x, z);

    errno = 0;
    x = 0.0;
    y = 0.0;
    z = atan2(y, x);
    if (errno)
        perror("Error");
    printf("The arctangent of %f/%f is %f\n\n",
           y, x, z);
}
```

Output:

The arctangent of 2.000000/0.000000 is 1.570796

The arctangent of 0.000000/-1.000000 is 3.141593

Error: domain error

The arctangent of 0.000000/0.000000 is nan

atan2f

Description:	Calculates the trigonometric arc tangent function of y/x .
Include:	<math.h>
Prototype:	float atan2f (float y , float x);
Arguments:	y y value for which to return the arc tangent x x value for which to return the arc tangent
Return Value:	Returns the arc tangent in radians in the range of $-\pi$ to π with the quadrant determined by the signs of both parameters.
Remarks:	A domain error occurs if both x and y are zero or both x and y are \pm infinity.

Example:

```
#include <math.h> /* for atan2f          */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno          */

int main(void)
{
    float x, y, z;

    errno = 0;
    x = 2.0F;
    y = 0.0F;
    z = atan2f (y, x);
    if (errno)
        perror("Error");
    printf("The arctangent of %f/%f is %f\n\n",
           y, x, z);

    errno = 0;
    x = 0.0F;
    y = -1.0F;
    z = atan2f (y, x);
    if (errno)
        perror("Error");
    printf("The arctangent of %f/%f is %f\n\n",
           y, x, z);

    errno = 0;
    x = 0.0F;
    y = 0.0F;
    z = atan2f (y, x);
    if (errno)
        perror("Error");
    printf("The arctangent of %f/%f is %f\n\n",
           y, x, z);
}
```

Output:

The arctangent of 2.000000/0.000000 is 1.570796

The arctangent of 0.000000/-1.000000 is 3.141593

Error: domain error

The arctangent of 0.000000/0.000000 is nan

ceil

Description:	Calculates the ceiling of a value.
Include:	<math.h>
Prototype:	double ceil(double x);
Argument:	x a floating-point value for which to return the ceiling
Return Value:	Returns the smallest integer value greater than or equal to x.
Remarks:	No domain or range error will occur. See floor.
Example:	<pre>#include <math.h> /* for ceil */ #include <stdio.h> /* for printf */ int main(void) { double x[8] = {2.0, 1.75, 1.5, 1.25, -2.0, -1.75, -1.5, -1.25}; double y; int i; for (i=0; i<8; i++) { y = ceil (x[i]); printf("The ceiling for %f is %f\n", x[i], y); } }</pre> <p>Output:</p> <pre>The ceiling for 2.000000 is 2.000000 The ceiling for 1.750000 is 2.000000 The ceiling for 1.500000 is 2.000000 The ceiling for 1.250000 is 2.000000 The ceiling for -2.000000 is -2.000000 The ceiling for -1.750000 is -1.000000 The ceiling for -1.500000 is -1.000000 The ceiling for -1.250000 is -1.000000</pre>

ceilf

Description:	Calculates the ceiling of a value.
Include:	<math.h>
Prototype:	float ceilf(float x);
Argument:	x floating-point value
Return Value:	Returns the smallest integer value greater than or equal to x.
Remarks:	No domain or range error will occur. See floorf.
Example:	<pre>#include <math.h> /* for ceilf */ #include <stdio.h> /* for printf */ int main(void) { float x[8] = {2.0F, 1.75F, 1.5F, 1.25F, -2.0F, -1.75F, -1.5F, -1.25F}; float y; int i; for (i=0; i<8; i++) { y = ceilf (x[i]); printf("The ceiling for %f is %f\n", x[i], y); } }</pre> <p>Output:</p> <pre>The ceiling for 2.000000 is 2.000000 The ceiling for 1.750000 is 2.000000 The ceiling for 1.500000 is 2.000000 The ceiling for 1.250000 is 2.000000 The ceiling for -2.000000 is -2.000000 The ceiling for -1.750000 is -1.000000 The ceiling for -1.500000 is -1.000000 The ceiling for -1.250000 is -1.000000</pre>

COS

Description:	Calculates the trigonometric cosine function of a double precision floating-point value.
Include:	<math.h>
Prototype:	double cos (double x);
Argument:	x value for which to return the cosine
Return Value:	Returns the cosine of x in radians in the ranges of -1 to 1 inclusive.
Remarks:	A domain error will occur if x is a NaN or infinity.
Example:	<pre>#include <math.h> /* for cos */ #include <stdio.h> /* for printf, perror */ #include <errno.h> /* for errno */ int main(void) { double x,y;</pre>

cos (Continued)

```
    errno = 0;
    x = -1.0;
    y = cos (x);
    if (errno)
        perror("Error");
    printf("The cosine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0;
    y = cos (x);
    if (errno)
        perror("Error");
    printf("The cosine of %f is %f\n\n", x, y);
}
```

Output:

The cosine of -1.000000 is 0.540302

The cosine of 0.000000 is 1.000000

cosf

Description: Calculates the trigonometric cosine function of a single precision floating-point value.

Include: <math.h>

Prototype: float cosf (float x);

Argument: x value for which to return the cosine

Return Value: Returns the cosine of x in radians in the ranges of -1 to 1 inclusive.

Remarks: A domain error will occur if x is a NaN or infinity.

Example:

```
#include <math.h> /* for cosf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;

    errno = 0;
    x = -1.0F;
    y = cosf (x);
    if (errno)
        perror("Error");
    printf("The cosine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0F;
    y = cosf (x);
    if (errno)
        perror("Error");
    printf("The cosine of %f is %f\n\n", x, y);
}
```

cosf (Continued)

Output:

The cosine of -1.000000 is 0.540302

The cosine of 0.000000 is 1.000000

cosh

Description: Calculates the hyperbolic cosine function of a double precision floating-point value.

Include: <math.h>

Prototype: double cosh (double x);

Argument: x value for which to return the hyperbolic cosine

Return Value: Returns the hyperbolic cosine of x.

Remarks: A range error will occur if the magnitude of x is too large.

Example:

```
#include <math.h> /* for cosh */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = -1.5;
    y = cosh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic cosine of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 0.0;
    y = cosh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic cosine of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 720.0;
    y = cosh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic cosine of %f is %f\n\n",
        x, y);
}
```

Output:

The hyperbolic cosine of -1.500000 is 2.352410

The hyperbolic cosine of 0.000000 is 1.000000

Error: range error

The hyperbolic cosine of 720.000000 is inf

coshf

Description: Calculates the hyperbolic cosine function of a single precision floating-point value.

Include: <math.h>

Prototype: float coshf (float x);

Argument: x value for which to return the hyperbolic cosine

Return Value: Returns the hyperbolic cosine of x.

Remarks: A range error will occur if the magnitude of x is too large.

Example:

```
#include <math.h> /* for coshf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;

    errno = 0;
    x = -1.0F;
    y = coshf (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic cosine of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 0.0F;
    y = coshf (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic cosine of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 720.0F;
    y = coshf (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic cosine of %f is %f\n\n",
        x, y);
}
```

Output:

The hyperbolic cosine of -1.000000 is 1.543081

The hyperbolic cosine of 0.000000 is 1.000000

Error: range error

The hyperbolic cosine of 720.000000 is inf

exp

Description: Calculates the exponential function of x (e raised to the power x where x is a double precision floating-point value).

Include: `<math.h>`

Prototype: `double exp (double x);`

Argument: x value for which to return the exponential

Return Value: Returns the exponential of x . On an overflow, `exp` returns `inf` and on an underflow `exp` returns 0.

Remarks: A range error occurs if the magnitude of x is too large.

Example:

```
#include <math.h> /* for exp */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = 1.0;
    y = exp (x);
    if (errno)
        perror("Error");
    printf("The exponential of %f is %f\n\n", x, y);

    errno = 0;
    x = 1E3;
    y = exp (x);
    if (errno)
        perror("Error");
    printf("The exponential of %f is %f\n\n", x, y);

    errno = 0;
    x = -1E3;
    y = exp (x);
    if (errno)
        perror("Error");
    printf("The exponential of %f is %f\n\n", x, y);
}
```

Output:

The exponential of 1.000000 is 2.718282

Error: range error

The exponential of 1000.000000 is inf

Error: range error

The exponential of -1000.000000 is 0.000000

expf

Description: Calculates the exponential function of x (e raised to the power x where x is a single precision floating-point value).

Include: `<math.h>`

Prototype: `float expf (float x);`

Argument: x floating-point value for which to return the exponential

Return Value: Returns the exponential of x . On an overflow, `expf` returns `inf` and on an underflow `exp` returns 0.

Remarks: A range error occurs if the magnitude of x is too large.

Example:

```
#include <math.h> /* for expf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;

    errno = 0;
    x = 1.0F;
    y = expf (x);
    if (errno)
        perror("Error");
    printf("The exponential of %f is %f\n\n", x, y);

    errno = 0;
    x = 1.0E3F;
    y = expf (x);
    if (errno)
        perror("Error");
    printf("The exponential of %f is %f\n\n", x, y);

    errno = 0;
    x = -1.0E3F;
    y = expf (x);
    if (errno)
        perror("Error");
    printf("The exponential of %f is %f\n\n", x, y);
}
```

Output:

The exponential of 1.000000 is 2.718282

Error: range error

The exponential of 1000.000000 is inf

Error: range error

The exponential of -1000.000000 is 0.000000

fabs

Description: Calculates the absolute value of a double precision floating-point value.

Include: `<math.h>`

Prototype: `double fabs(double x);`

Argument: `x` floating-point value for which to return the absolute value

Return Value: Returns the absolute value of `x`. (A negative number is returned as positive, a positive number is unchanged.)

Remarks: No domain or range error will occur.

Example:

```
#include <math.h> /* for fabs */
#include <stdio.h> /* for printf */
```

```
int main(void)
{
    double x, y;

    x = 1.75;
    y = fabs (x);
    printf("The absolute value of %f is %f\n", x, y);

    x = -1.5;
    y = fabs (x);
    printf("The absolute value of %f is %f\n", x, y);
}
```

Output:

```
The absolute value of 1.750000 is 1.750000
The absolute value of -1.500000 is 1.500000
```

fabsf

Description: Calculates the absolute value of a single precision floating-point value.

Include: `<math.h>`

Prototype: `float fabsf(float x);`

Argument: `x` floating-point value for which to return the absolute value

Return Value: Returns the absolute value of `x`. (A negative number is returned as positive, a positive number is unchanged.)

Remarks: No domain or range error will occur.

Example:

```
#include <math.h> /* for fabsf */
#include <stdio.h> /* for printf */
```

```
int main(void)
{
    float x,y;

    x = 1.75F;
    y = fabsf (x);
    printf("The absolute value of %f is %f\n", x, y);

    x = -1.5F;
    y = fabsf (x);
    printf("The absolute value of %f is %f\n", x, y);
}
```

Output:

```
The absolute value of 1.750000 is 1.750000
The absolute value of -1.500000 is 1.500000
```

floor

Description:	Calculates the floor of a double precision floating-point value.
Include:	<math.h>
Prototype:	double floor (double x);
Argument:	x floating-point value for which to return the floor
Return Value:	Returns the largest integer value less than or equal to x.
Remarks:	No domain or range error will occur. See ceil.
Example:	<pre>#include <math.h> /* for floor */ #include <stdio.h> /* for printf */ int main(void) { double x[8] = {2.0, 1.75, 1.5, 1.25, -2.0, -1.75, -1.5, -1.25}; double y; int i; for (i=0; i<8; i++) { y = floor (x[i]); printf("The ceiling for %f is %f\n", x[i], y); } }</pre> <p>Output:</p> <pre>The floor for 2.000000 is 2.000000 The floor for 1.750000 is 1.000000 The floor for 1.500000 is 1.000000 The floor for 1.250000 is 1.000000 The floor for -2.000000 is -2.000000 The floor for -1.750000 is -2.000000 The floor for -1.500000 is -2.000000 The floor for -1.250000 is -2.000000</pre>

floorf

Description:	Calculates the floor of a single precision floating-point value.
Include:	<math.h>
Prototype:	float floorf(float x);
Argument:	x floating-point value
Return Value:	Returns the largest integer value less than or equal to x.
Remarks:	No domain or range error will occur. See ceilf.

floorf (Continued)

Example:

```
#include <math.h> /* for floorf */
#include <stdio.h> /* for printf */

int main(void)
{
    float x[8] = {2.0F, 1.75F, 1.5F, 1.25F,
                  -2.0F, -1.75F, -1.5F, -1.25F};
    float y;
    int i;

    for (i=0; i<8; i++)
    {
        y = floorf (x[i]);
        printf("The floor for  %f is  %f\n", x[i], y);
    }
}
```

Output:

```
The floor for  2.000000 is  2.000000
The floor for  1.750000 is  1.000000
The floor for  1.500000 is  1.000000
The floor for  1.250000 is  1.000000
The floor for -2.000000 is -2.000000
The floor for -1.750000 is -2.000000
The floor for -1.500000 is -2.000000
The floor for -1.250000 is -2.000000
```

fmod

Description: Calculates the remainder of x/y as a double precision value.

Include: `<math.h>`

Prototype: `double fmod(double x, double y);`

Arguments:

x	a double precision floating-point value
y	a double precision floating-point value

Return Value: Returns the remainder of x divided by y .

Remarks: If $y = 0$, a domain error occurs. If y is non-zero, the result will have the same sign as x and the magnitude of the result will be less than the magnitude of y .

Example:

```
#include <math.h> /* for fmod */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x,y,z;

    errno = 0;
    x = 7.0;
    y = 3.0;
    z = fmod(x, y);
    if (errno)
        perror("Error");
    printf("For fmod(%f, %f) the remainder is %f\n\n",
           x, y, z);
}
```

fmod (Continued)

```
        errno = 0;
        x = 7.0;
        y = 7.0;
        z = fmod(x, y);
        if (errno)
            perror("Error");
        printf("For fmod(%f, %f) the remainder is %f\n\n",
               x, y, z);

        errno = 0;
        x = -5.0;
        y = 3.0;
        z = fmod(x, y);
        if (errno)
            perror("Error");
        printf("For fmod(%f, %f) the remainder is %f\n\n",
               x, y, z);

        errno = 0;
        x = 5.0;
        y = -3.0;
        z = fmod(x, y);
        if (errno)
            perror("Error");
        printf("For fmod(%f, %f) the remainder is %f\n\n",
               x, y, z);

        errno = 0;
        x = -5.0;
        y = -5.0;
        z = fmod(x, y);
        if (errno)
            perror("Error");
        printf("For fmod(%f, %f) the remainder is %f\n\n",
               x, y, z);

        errno = 0;
        x = 7.0;
        y = 0.0;
        z = fmod(x, y);
        if (errno)
            perror("Error");
        printf("For fmod(%f, %f) the remainder is %f\n\n",
               x, y, z);
    }
```

fmod (Continued)

Output:

For fmod(7.000000, 3.000000) the remainder is
1.000000

For fmod(7.000000, 7.000000) the remainder is
0.000000

For fmod(-5.000000, 3.000000) the remainder is
-2.000000

For fmod(5.000000, -3.000000) the remainder is
2.000000

For fmod(-5.000000, -5.000000) the remainder is
-0.000000

Error: domain error

For fmod(7.000000, 0.000000) the remainder is nan

fmodf

Description: Calculates the remainder of x/y as a single precision value.

Include: <math.h>

Prototype: float fmodf(float x, float y);

Arguments:
x a single precision floating-point value
y a single precision floating-point value

Return Value: Returns the remainder of x divided by y .

Remarks: If $y = 0$, a domain error occurs. If y is non-zero, the result will have the same sign as x and the magnitude of the result will be less than the magnitude of y .

Example:

```
#include <math.h> /* for fmodf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x,y,z;

    errno = 0;
    x = 7.0F;
    y = 3.0F;
    z = fmodf (x, y);
    if (errno)
        perror("Error");
    printf("For fmodf (%f, %f) the remainder is"
           " %f\n\n", x, y, z);

    errno = 0;
    x = -5.0F;
    y = 3.0F;
    z = fmodf (x, y);
    if (errno)
        perror("Error");
    printf("For fmodf (%f, %f) the remainder is"
           " %f\n\n", x, y, z);
```

fmodf (Continued)

```
errno = 0;
x = 5.0F;
y = -3.0F;
z = fmodf (x, y);
if (errno)
    perror("Error");
printf("For fmodf (%f, %f) the remainder is"
      " %f\n\n", x, y, z);
```

```
errno = 0;
x = 5.0F;
y = -5.0F;
z = fmodf (x, y);
if (errno)
    perror("Error");
printf("For fmodf (%f, %f) the remainder is"
      " %f\n\n", x, y, z);
```

```
errno = 0;
x = 7.0F;
y = 0.0F;
z = fmodf (x, y);
if (errno)
    perror("Error");
printf("For fmodf (%f, %f) the remainder is"
      " %f\n\n", x, y, z);
```

```
errno = 0;
x = 7.0F;
y = 7.0F;
z = fmodf (x, y);
if (errno)
    perror("Error");
printf("For fmodf (%f, %f) the remainder is"
      " %f\n\n", x, y, z);
```

```
}
```

Output:

```
For fmodf (7.000000, 3.000000) the remainder is
1.000000
```

```
For fmodf (-5.000000, 3.000000) the remainder is
-2.000000
```

```
For fmodf (5.000000, -3.000000) the remainder is
2.000000
```

```
For fmodf (5.000000, -5.000000) the remainder is
0.000000
```

```
Error: domain error
```

```
For fmodf (7.000000, 0.000000) the remainder is nan
```

```
For fmodf (7.000000, 7.000000) the remainder is
0.000000
```

frexp

Description: Gets the fraction and the exponent of a double precision floating-point number.

Include: <math.h>

Prototype: double frexp (double x, int *exp);

Arguments: x floating-point value for which to return the fraction and exponent
exp pointer to a stored integer exponent

Return Value: Returns the fraction, exp points to the exponent. If x is 0, the function returns 0 for both the fraction and exponent.

Remarks: The absolute value of the fraction is in the range of 1/2 (inclusive) to 1 (exclusive). No domain or range error will occur.

Example:

```
#include <math.h> /* for frexp */
#include <stdio.h> /* for printf */

int main(void)
{
    double x,y;
    int n;

    x = 50.0;
    y = frexp (x, &n);
    printf("For frexp of %f\n the fraction is %f\n ",
           x, y);
    printf(" and the exponent is %d\n\n", n);

    x = -2.5;
    y = frexp (x, &n);
    printf("For frexp of %f\n the fraction is %f\n ",
           x, y);
    printf(" and the exponent is %d\n\n", n);

    x = 0.0;
    y = frexp (x, &n);
    printf("For frexp of %f\n the fraction is %f\n ",
           x, y);
    printf(" and the exponent is %d\n\n", n);
}
```

Output:

```
For frexp of 50.000000
the fraction is 0.781250
and the exponent is 6
```

```
For frexp of -2.500000
the fraction is -0.625000
and the exponent is 2
```

```
For frexp of 0.000000
the fraction is 0.000000
and the exponent is 0
```

frexpf

Description:	Gets the fraction and the exponent of a single precision floating-point number.
Include:	<math.h>
Prototype:	float frexpf (float x, int *exp);
Arguments:	<i>x</i> floating-point value for which to return the fraction and exponent <i>exp</i> pointer to a stored integer exponent
Return Value:	Returns the fraction, <i>exp</i> points to the exponent. If <i>x</i> is 0, the function returns 0 for both the fraction and exponent.
Remarks:	The absolute value of the fraction is in the range of 1/2 (inclusive) to 1 (exclusive). No domain or range error will occur.
Example:	<pre>#include <math.h> /* for frexpf */ #include <stdio.h> /* for printf */ int main(void) { float x,y; int n; x = 0.15F; y = frexpf (x, &n); printf("For frexpf of %f\n the fraction is %f\n ", x, y); printf(" and the exponent is %d\n\n", n); x = -2.5F; y = frexpf (x, &n); printf("For frexpf of %f\n the fraction is %f\n ", x, y); printf(" and the exponent is %d\n\n", n); x = 0.0F; y = frexpf (x, &n); printf("For frexpf of %f\n the fraction is %f\n ", x, y); printf(" and the exponent is %d\n\n", n); }</pre>

Output:

```
For frexpf of 0.150000
  the fraction is 0.600000
  and the exponent is -2

For frexpf of -2.500000
  the fraction is -0.625000
  and the exponent is 2

For frexpf of 0.000000
  the fraction is 0.000000
  and the exponent is 0
```

ldexp

Description: Calculates the result of a double precision floating-point number multiplied by an exponent of 2.

Include: <math.h>

Prototype: double ldexp(double x, int ex);

Arguments:
x floating-point value
ex integer exponent

Return Value: Returns $x * 2^{ex}$. On an overflow, ldexp returns inf and on an underflow, ldexp returns 0.

Remarks: A range error will occur on overflow or underflow.

Example:

```
#include <math.h> /* for ldexp */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x,y;
    int n;

    errno = 0;
    x = -0.625;
    n = 2;
    y = ldexp (x, n);
    if (errno)
        perror("Error");
    printf("For a number = %f and an exponent = %d\n",
           x, n);
    printf(" ldexp(%f, %d) = %f\n\n",
           x, n, y);

    errno = 0;
    x = 2.5;
    n = 3;
    y = ldexp (x, n);
    if (errno)
        perror("Error");
    printf("For a number = %f and an exponent = %d\n",
           x, n);
    printf(" ldexp(%f, %d) = %f\n\n",
           x, n, y);

    errno = 0;
    x = 15.0;
    n = 10000;
    y = ldexp (x, n);
    if (errno)
        perror("Error");
    printf("For a number = %f and an exponent = %d\n",
           x, n);
    printf(" ldexp(%f, %d) = %f\n\n",
           x, n, y);
}
```

ldexp (Continued)

Output:

For a number = -0.625000 and an exponent = 2
ldexp(-0.625000, 2) = -2.500000

For a number = 2.500000 and an exponent = 3
ldexp(2.500000, 3) = 20.000000

Error: range error

For a number = 15.000000 and an exponent = 10000
ldexp(15.000000, 10000) = inf

ldexpf

Description: Calculates the result of a single precision floating-point number multiplied by an exponent of 2.

Include: <math.h>

Prototype: float ldexpf(float x, int ex);

Arguments: x floating-point value
ex integer exponent

Return Value: Returns $x * 2^{ex}$. On an overflow, ldexp returns inf and on an underflow, ldexp returns 0.

Remarks: A range error will occur on overflow or underflow.

Example:

```
#include <math.h> /* for ldexpf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x,y;
    int n;

    errno = 0;
    x = -0.625F;
    n = 2;
    y = ldexpf (x, n);
    if (errno)
        perror("Error");
    printf("For a number = %f and an exponent = %d\n",
           x, n);
    printf(" ldexpf(%f, %d) = %f\n\n",
           x, n, y);

    errno = 0;
    x = 2.5F;
    n = 3;
    y = ldexpf (x, n);
    if (errno)
        perror("Error");
    printf("For a number = %f and an exponent = %d\n",
           x, n);
    printf(" ldexpf(%f, %d) = %f\n\n",
           x, n, y);
```

ldexpf (Continued)

```
    errno = 0;
    x = 15.0F;
    n = 10000;
    y = ldexpf (x, n);
    if (errno)
        perror("Error");
    printf("For a number = %f and an exponent = %d\n",
           x, n);
    printf("  ldexpf(%f, %d) = %f\n\n",
           x, n, y);
}
```

Output:

```
For a number = -0.625000 and an exponent = 2
  ldexpf(-0.625000, 2) = -2.500000
```

```
For a number = 2.500000 and an exponent = 3
  ldexpf(2.500000, 3) = 20.000000
```

```
Error: range error
```

```
For a number = 15.000000 and an exponent = 10000
  ldexpf(15.000000, 10000) = inf
```

log

Description: Calculates the natural logarithm of a double precision floating-point value.

Include: <math.h>

Prototype: double log(double x);

Argument: x any positive value for which to return the log

Return Value: Returns the natural logarithm of x. -inf is returned if x is 0 and NaN is returned if x is a negative number.

Remarks: A domain error occurs if $x \leq 0$.

Example:

```
#include <math.h> /* for log */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = 2.0;
    y = log (x);
    if (errno)
        perror("Error");
    printf("The natural logarithm of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 0.0;
    y = log (x);
    if (errno)
        perror("Error");
    printf("The natural logarithm of %f is %f\n\n",
        x, y);

    errno = 0;
    x = -2.0;
    y = log (x);
    if (errno)
        perror("Error");
    printf("The natural logarithm of %f is %f\n\n",
        x, y);
}
```

Output:

The natural logarithm of 2.000000 is 0.693147

The natural logarithm of 0.000000 is -inf

Error: domain error

The natural logarithm of -2.000000 is nan

log10

Description:	Calculates the base-10 logarithm of a double precision floating-point value.
Include:	<math.h>
Prototype:	double log10(double x);
Argument:	x any double precision floating-point positive number
Return Value:	Returns the base-10 logarithm of x. -inf is returned if x is 0 and NaN is returned if x is a negative number.
Remarks:	A domain error occurs if $x \leq 0$.
Example:	

```
#include <math.h> /* for log10          */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno          */

int main(void)
{
    double x, y;

    errno = 0;
    x = 2.0;
    y = log10 (x);
    if (errno)
        perror("Error");
    printf("The base-10 logarithm of %f is %f\n\n",
           x, y);

    errno = 0;
    x = 0.0;
    y = log10 (x);
    if (errno)
        perror("Error");
    printf("The base-10 logarithm of %f is %f\n\n",
           x, y);

    errno = 0;
    x = -2.0;
    y = log10 (x);
    if (errno)
        perror("Error");
    printf("The base-10 logarithm of %f is %f\n\n",
           x, y);
}
```

Output:

The base-10 logarithm of 2.000000 is 0.301030

The base-10 logarithm of 0.000000 is -inf

Error: domain error

The base-10 logarithm of -2.000000 is nan

log10f

Description: Calculates the base-10 logarithm of a single precision floating-point value.

Include: <math.h>

Prototype: float log10f(float x);

Argument: x any single precision floating-point positive number

Return Value: Returns the base-10 logarithm of x. -inf is returned if x is 0 and NaN is returned if x is a negative number.

Remarks: A domain error occurs if $x \leq 0$.

Example:

```
#include <math.h> /* for log10f */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;

    errno = 0;
    x = 2.0F;
    y = log10f(x);
    if (errno)
        perror("Error");
    printf("The base-10 logarithm of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 0.0F;
    y = log10f(x);
    if (errno)
        perror("Error");
    printf("The base-10 logarithm of %f is %f\n\n",
        x, y);

    errno = 0;
    x = -2.0F;
    y = log10f(x);
    if (errno)
        perror("Error");
    printf("The base-10 logarithm of %f is %f\n\n",
        x, y);
}
```

Output:

The base-10 logarithm of 2.000000 is 0.301030

Error: domain error

The base-10 logarithm of 0.000000 is -inf

Error: domain error

The base-10 logarithm of -2.000000 is nan

logf

Description:	Calculates the natural logarithm of a single precision floating-point value.
Include:	<math.h>
Prototype:	float logf(float x);
Argument:	x any positive value for which to return the log
Return Value:	Returns the natural logarithm of x. -inf is returned if x is 0 and NaN is returned if x is a negative number.
Remarks:	A domain error occurs if $x \leq 0$.
Example:	

```
#include <math.h> /* for logf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;

    errno = 0;
    x = 2.0F;
    y = logf (x);
    if (errno)
        perror("Error");
    printf("The natural logarithm of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 0.0F;
    y = logf (x);
    if (errno)
        perror("Error");
    printf("The natural logarithm of %f is %f\n\n",
        x, y);

    errno = 0;
    x = -2.0F;
    y = logf (x);
    if (errno)
        perror("Error");
    printf("The natural logarithm of %f is %f\n\n",
        x, y);
}
```

Output:

The natural logarithm of 2.000000 is 0.693147

The natural logarithm of 0.000000 is -inf

Error: domain error

The natural logarithm of -2.000000 is nan

modf

Description: Splits a double precision floating-point value into fractional and integer parts.

Include: <math.h>

Prototype: double modf(double *x*, double **pint*);

Arguments: *x* double precision floating-point value
pint pointer to a stored the integer part

Return Value: Returns the signed fractional part and *pint* points to the integer part.

Remarks: The absolute value of the fractional part is in the range of 0 (inclusive) to 1 (exclusive). No domain or range error will occur.

Example:

```
#include <math.h> /* for modf */
#include <stdio.h> /* for printf */

int main(void)
{
    double x,y,n;

    x = 0.707;
    y = modf (x, &n);
    printf("For %f the fraction is %f\n ", x, y);
    printf(" and the integer is %0.f\n\n", n);

    x = -15.2121;
    y = modf (x, &n);
    printf("For %f the fraction is %f\n ", x, y);
    printf(" and the integer is %0.f\n\n", n);
}
```

Output:

For 0.707000 the fraction is 0.707000
and the integer is 0

For -15.212100 the fraction is -0.212100
and the integer is -15

modff

Description: Splits a single precision floating-point value into fractional and integer parts.

Include: <math.h>

Prototype: float modff(float x, float *pint);

Arguments: x single precision floating-point value
pint pointer to stored integer part

Return Value: Returns the signed fractional part and *pint* points to the integer part.

Remarks: The absolute value of the fractional part is in the range of 0 (inclusive) to 1 (exclusive). No domain or range error will occur.

Example:

```
#include <math.h> /* for modff */
#include <stdio.h> /* for printf */

int main(void)
{
    float x,y,n;

    x = 0.707F;
    y = modff (x, &n);
    printf("For %f the fraction is %f\n ", x, y);
    printf(" and the integer is %0.f\n\n", n);

    x = -15.2121F;
    y = modff (x, &n);
    printf("For %f the fraction is %f\n ", x, y);
    printf(" and the integer is %0.f\n\n", n);
}
```

Output:

```
For 0.707000 the fraction is 0.707000
and the integer is 0
```

```
For -15.212100 the fraction is -0.212100
and the integer is -15
```

pow

Description: Calculates x raised to the power y .

Include: `<math.h>`

Prototype: `double pow(double x, double y);`

Arguments:
 x the base
 y the exponent

Return Value: Returns x raised to the power y (x^y).

Remarks: If y is 0, `pow` returns 1. If x is 0.0 and y is less than 0, `pow` returns `inf` and a domain error occurs. If the result overflows or underflows, a range error occurs.

Example:

```
#include <math.h> /* for pow */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x,y,z;

    errno = 0;
    x = -2.0;
    y = 3.0;
    z = pow (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);

    errno = 0;
    x = 3.0;
    y = -0.5;
    z = pow (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);

    errno = 0;
    x = 4.0;
    y = 0.0;
    z = pow (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);

    errno = 0;
    x = 0.0;
    y = -3.0;
    z = pow (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);
}
```

pow (Continued)

Output:

-2.000000 raised to 3.000000 is -8.000000

3.000000 raised to -0.500000 is 0.577350

4.000000 raised to 0.000000 is 1.000000

Error: domain error

0.000000 raised to -3.000000 is inf

powf

Description: Calculates x raised to the power y .

Include: <math.h>

Prototype: float powf(float x , float y);

Arguments: x base
 y exponent

Return Value: Returns x raised to the power y (x^y).

Remarks: If y is 0, powf returns 1. If x is 0.0 and y is less than 0, powf returns inf and a domain error occurs. If the result overflows or underflows, a range error occurs.

Example:

```
#include <math.h> /* for powf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x,y,z;

    errno = 0;
    x = -2.0F;
    y = 3.0F;
    z = powf (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);

    errno = 0;
    x = 3.0F;
    y = -0.5F;
    z = powf (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);

    errno = 0;
    x = 0.0F;
    y = -3.0F;
    z = powf (x, y);
    if (errno)
        perror("Error");
    printf("%f raised to %f is %f\n\n ", x, y, z);
}
```

powf (Continued)

Output:

-2.000000 raised to 3.000000 is -8.000000

3.000000 raised to -0.500000 is 0.577350

Error: domain error

0.000000 raised to -3.000000 is inf

sin

Description: Calculates the trigonometric sine function of a double precision floating-point value.

Include: <math.h>

Prototype: double sin (double x);

Argument: x value for which to return the sine

Return Value: Returns the sine of x in radians in the ranges of -1 to 1 inclusive.

Remarks: A domain error will occur if x is a NaN or infinity.

Example:

```
#include <math.h> /* for sin */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = -1.0;
    y = sin (x);
    if (errno)
        perror("Error");
    printf("The sine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0;
    y = sin (x);
    if (errno)
        perror("Error");
    printf("The sine of %f is %f\n\n", x, y);
}
```

Output:

The sine of -1.000000 is -0.841471

The sine of 0.000000 is 0.000000

sinf

Description: Calculates the trigonometric sine function of a single precision floating-point value.

Include: `<math.h>`

Prototype: `float sinf (float x);`

Argument: `x` value for which to return the sine

Return Value: Returns the sin of `x` in radians in the ranges of -1 to 1 inclusive.

Remarks: A domain error will occur if `x` is a NaN or infinity.

Example:

```
#include <math.h> /* for sinf          */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno        */

int main(void)
{
    float x, y;

    errno = 0;
    x = -1.0F;
    y = sinf (x);
    if (errno)
        perror("Error");
    printf("The sine of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0F;
    y = sinf (x);
    if (errno)
        perror("Error");
    printf("The sine of %f is %f\n\n", x, y);
}
```

Output:

The sine of -1.000000 is -0.841471

The sine of 0.000000 is 0.000000

sinh

Description: Calculates the hyperbolic sine function of a double precision floating-point value.

Include: <math.h>

Prototype: double sinh (double x);

Argument: x value for which to return the hyperbolic sine

Return Value: Returns the hyperbolic sine of x

Remarks: A range error will occur if the magnitude of x is too large.

Example:

```
#include <math.h> /* for sinh */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = -1.5;
    y = sinh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic sine of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 0.0;
    y = sinh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic sine of %f is %f\n\n",
        x, y);

    errno = 0;
    x = 720.0;
    y = sinh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic sine of %f is %f\n\n",
        x, y);
}
```

Output:

The hyperbolic sine of -1.500000 is -2.129279

The hyperbolic sine of 0.000000 is 0.000000

Error: range error

The hyperbolic sine of 720.000000 is inf

sinhf

Description: Calculates the hyperbolic sine function of a single precision floating-point value.

Include: <math.h>

Prototype: float sinh (float x);

Argument: x value for which to return the hyperbolic sine

Return Value: Returns the hyperbolic sine of x .

Remarks: A range error will occur if the magnitude of x is too large.

Example:

```
#include <math.h> /* for sinh      */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno      */

int main(void)
{
    float x, y;

    errno = 0;
    x = -1.0F;
    y = sinh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic sine of %f is %f\n\n",
           x, y);

    errno = 0;
    x = 0.0F;
    y = sinh (x);
    if (errno)
        perror("Error");
    printf("The hyperbolic sine of %f is %f\n\n",
           x, y);
}
```

Output:

The hyperbolic sine of -1.000000 is -1.175201

The hyperbolic sine of 0.000000 is 0.000000

sqrt

Description: Calculates the square root of a double precision floating-point value.

Include: <math.h>

Prototype: double sqrt(double x);

Argument: x a non-negative floating-point value

Return Value: Returns the non-negative square root of x.

Remarks: If x is negative, a domain error occurs.

Example:

```
#include <math.h> /* for sqrt */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = 0.0;
    y = sqrt (x);
    if (errno)
        perror("Error");
    printf("The square root of %f is %f\n\n", x, y);

    errno = 0;
    x = 9.5;
    y = sqrt (x);
    if (errno)
        perror("Error");
    printf("The square root of %f is %f\n\n", x, y);

    errno = 0;
    x = -25.0;
    y = sqrt (x);
    if (errno)
        perror("Error");
    printf("The square root of %f is %f\n\n", x, y);
}
```

Output:

The square root of 0.000000 is 0.000000

The square root of 9.500000 is 3.082207

Error: domain error

The square root of -25.000000 is nan

sqrtf

Description: Calculates the square root of a single precision floating-point value.

Include: <math.h>

Prototype: float sqrtf(float x);

Argument: x non-negative floating-point value

Return Value: Returns the non-negative square root of x.

Remarks: If x is negative, a domain error occurs.

Example:

```
#include <math.h> /* for sqrtf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x;

    errno = 0;
    x = sqrtf (0.0F);
    if (errno)
        perror("Error");
    printf("The square root of 0.0F is %f\n\n", x);

    errno = 0;
    x = sqrtf (9.5F);
    if (errno)
        perror("Error");
    printf("The square root of 9.5F is %f\n\n", x);

    errno = 0;
    x = sqrtf (-25.0F);
    if (errno)
        perror("Error");
    printf("The square root of -25F is %f\n", x);
}
```

Output:

The square root of 0.0F is 0.000000

The square root of 9.5F is 3.082207

Error: domain error

The square root of -25F is nan

tan

Description: Calculates the trigonometric tangent function of a double precision floating-point value.

Include: <math.h>

Prototype: double tan (double x);

Argument: x value for which to return the tangent

Return Value: Returns the tangent of x in radians.

Remarks: A domain error will occur if x is a NaN or infinity.

Example:

```
#include <math.h> /* for tan */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    double x, y;

    errno = 0;
    x = -1.0;
    y = tan (x);
    if (errno)
        perror("Error");
    printf("The tangent of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0;
    y = tan (x);
    if (errno)
        perror("Error");
    printf("The tangent of %f is %f\n\n", x, y);
}
```

Output:

The tangent of -1.000000 is -1.557408

The tangent of 0.000000 is 0.000000

tanf

Description: Calculates the trigonometric tangent function of a single precision floating-point value.

Include: <math.h>

Prototype: float tanf (float x);

Argument: x value for which to return the tangent

Return Value: Returns the tangent of x.

Remarks: A domain error will occur if x is a NaN or infinity.

Example:

```
#include <math.h> /* for tanf */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno */

int main(void)
{
    float x, y;
```

tanf (Continued)

```
    errno = 0;
    x = -1.0F;
    y = tanf (x);
    if (errno)
        perror("Error");
    printf("The tangent of %f is %f\n\n", x, y);

    errno = 0;
    x = 0.0F;
    y = tanf (x);
    if (errno)
        perror("Error");
    printf("The tangent of %f is %f\n", x, y);
}
```

Output:

The tangent of -1.000000 is -1.557408

The tangent of 0.000000 is 0.000000

tanh

Description:	Calculates the hyperbolic tangent function of a double precision floating-point value.
Include:	<math.h>
Prototype:	double tanh (double x);
Argument:	x value for which to return the hyperbolic tangent
Return Value:	Returns the hyperbolic tangent of x in the ranges of -1 to 1 inclusive.
Remarks:	No domain or range error will occur.
Example:	<pre>#include <math.h> /* for tanh */ #include <stdio.h> /* for printf */ int main(void) { double x, y; x = -1.0; y = tanh (x); printf("The hyperbolic tangent of %f is %f\n\n", x, y); x = 2.0; y = tanh (x); printf("The hyperbolic tangent of %f is %f\n\n", x, y); }</pre>

Output:

The hyperbolic tangent of -1.000000 is -0.761594

The hyperbolic tangent of 2.000000 is 0.964028

tanhf

Description: Calculates the hyperbolic tangent function of a single precision floating-point value.

Include: `<math.h>`

Prototype: `float tanhf (float x);`

Argument: `x` value for which to return the hyperbolic tangent

Return Value: Returns the hyperbolic tangent of `x` in the ranges of -1 to 1 inclusive.

Remarks: No domain or range error will occur.

Example:

```
#include <math.h> /* for tanhf */
#include <stdio.h> /* for printf */

int main(void)
{
    float x, y;

    x = -1.0F;
    y = tanhf (x);
    printf("The hyperbolic tangent of %f is %f\n\n",
          x, y);

    x = 0.0F;
    y = tanhf (x);
    printf("The hyperbolic tangent of %f is %f\n\n",
          x, y);
}
```

Output:

The hyperbolic tangent of -1.000000 is -0.761594

The hyperbolic tangent of 0.000000 is 0.000000

Chapter 4. Standard C Libraries - Support Functions

4.1 INTRODUCTION

This chapter describes support functions that either must be customized for correct operation of the Standard C Library in your target environment or are already customized for a Microchip target environment. The default behavior section describes what the function does as it is distributed. The description and remarks describe what it typically should do.

The corresponding object modules are distributed in the `libpic30-omf.a` archive and the source code (for the compiler) is available in the `src\pic30` folder.

4.1.1 Assembly Code Applications

A free version of this library and its associated header file is available from the Microchip web site. Source code is included.

4.1.2 C Code Applications

The MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs (formerly MPLAB C30) install directory (`c:\Program Files\Microchip\MPLAB C30`) contains the following subdirectories with library-related files:

- `lib` – standard C library files
- `src\pic30` – source code for library functions, batch file to rebuild the library
- `support\h` – header files for libraries

In addition, there is a file, `ResourceGraphs.pdf`, which contains diagrams of resources used by each function, located in `lib`.

4.1.3 Chapter Organization

This chapter is organized as follows:

- Using the Support Functions
- Standard C Library Helper Functions
- Standard C Library Functions That Require Modification
- Functions/Constants to Support A Simulated UART
- Functions for Erasing and Writing EEDATA Memory
- Functions for Erasing and Writing Flash Memory
- Functions for Specialized Copying and Initialization

4.2 USING THE SUPPORT FUNCTIONS

Building an application which utilizes the support functions requires two types of files: header files and library files.

- Rebuilding the libpic30-omf.a Library

4.2.1 Header Files

All standard C library entities are declared or defined in one or more standard headers (See list in **Section 4.1.3 “Chapter Organization”**.) To make use of a library entity in a program, write an include directive that names the relevant standard header.

The contents of a standard header is included by naming it in an include directive, as in:

```
#include <libpic30.h> /* include dsPIC30F facilities */
```

The standard headers can be included in any order. Do not include a standard header within a declaration. Do not define macros that have the same names as keywords before including a standard header.

A standard header never includes another standard header.

4.2.2 Library Files

The archived library files contain all the individual object files for each library function.

When linking an application, the library file must be provided as an input to the linker (using the `--library` or `-l` linker option), such that the functions used by the application may be linked into the application.

A typical C application will require three library files: `libc-omf.a`, `libm-omf.a` and `libpic30-omf.a`. (See **Section 1.2 “OMF-Specific Libraries/Start-up Modules”** for more on OMF-specific libraries.) These libraries will be included automatically if linking is performed using the compiler.

Note: Some standard library functions require a heap. These include the standard I/O functions that open files and the memory allocation functions. See the “MPLAB® Assembler, Linker and Utilities for PIC24 MCUs and dsPIC® DSCs User’s Guide” (DS51317) and “MPLAB® C Compiler for PIC24 MCUs and dsPIC® DSCs User’s Guide” (DS51284) for more information on the heap.

4.2.3 Rebuilding the libpic30-omf.a Library

By default, the helper functions listed in this chapter were written to work with the `sim30` simulator. The header file, `simio.h`, defines the interface between the library and the simulator. It is provided so you can rebuild the libraries and continue to use the simulator. However, your application should not use this interface since the simulator will not be available to an embedded application.

The helper functions must be modified and rebuilt for your target application. The `libpic30-omf.a` library can be rebuilt with the batch file named, `makelib.bat`, which has been provided with the sources in `src\pic30`. Execute the batch file from a command window. Be sure you are in the `src\pic30` directory. Then, copy the newly compiled file (`libpic30-omf.a`) into the `lib` directory.

4.3 STANDARD C LIBRARY HELPER FUNCTIONS

These functions are called by other functions in the standard C library and must be modified for the target application. The corresponding object modules are distributed in the `libpic30-omf.a` archive and the source code (for the compiler) is available in the `src\pic30` folder.

_exit

Description:	Terminate program execution.
Include:	None
Prototype:	<code>void _exit (int status);</code>
Argument:	<code>status</code> exit status
Remarks:	This is a helper function called by the <code>exit()</code> Standard C Library function.
Default Behavior:	As distributed, this function flushes stdout and terminates. The parameter <code>status</code> is the same as that passed to the <code>exit()</code> standard C library function.
File:	<code>_exit.c</code>

brk

Description:	Set the end of the process's data space.
Include:	None
Prototype:	<code>int brk(void *endds);</code>
Argument:	<code>endds</code> pointer to the end of the data segment
Return Value:	Returns '0' if successful, '-1' if not.
Remarks:	<code>brk()</code> is used to dynamically change the amount of space allocated for the calling process's data segment. The change is made by resetting the process's break value and allocating the appropriate amount of space. The break value is the address of the first location beyond the end of the data segment. The amount of allocated space increases as the break value increases. Newly allocated space is uninitialized. This helper function is used by the Standard C Library function, <code>malloc()</code> .

brk (Continued)

Default Behavior: If the argument, *ends*, is zero, the function sets the global variable, `__curbrk`, to the address of the start of the heap and returns zero. If the argument, *ends*, is non-zero, and has a value less than the address of the end of the heap, the function sets the global variable, `__curbrk`, to the value of *ends* and returns zero. Otherwise, the global variable, `__curbrk`, is unchanged and the function returns -1. The argument, *ends*, must be within the heap range (see data space memory map below).



Notice that, since the stack is located immediately above the heap, using `brk()` or `sbrk()` has little effect on the size of the dynamic memory pool. The `brk()` and `sbrk()` functions are primarily intended for use in run-time environments, where the stack grows downward and the heap grows upward.

The linker allocates a block of memory for the heap if the `-Wl,--heap=n` option is specified, where *n* is the desired heap size in characters. The starting and ending addresses of the heap are reported in variables, `_heap` and `_eheap`, respectively.

For the 16-bit compiler, using the linker's heap size option is the standard way of controlling heap size, rather than relying on `brk()` and `sbrk()`.

File: `brk.c`

close

Description: Close a file.

Include: None

Prototype: `int close(int handle);`

Argument: *handle* handle referring to an opened file

Return Value: Returns '0' if the file is successfully closed. A return value of '-1' indicates an error.

Remarks: This helper function is called by the `fclose()` Standard C Library function.

Default Behavior: As distributed, this function passes the file handle to the simulator, which issues a close in the host file system.

File: `close.c`

Standard C Libraries - Support Functions

lseek

Description:	Move a file pointer to a specified location.						
Include:	None						
Prototype:	<code>long lseek(int handle, long offset, int origin);</code>						
Argument:	<table><tr><td><i>handle</i></td><td>refers to an opened file</td></tr><tr><td><i>offset</i></td><td>the number of characters from the origin</td></tr><tr><td><i>origin</i></td><td>the position from which to start the seek. <i>origin</i> may be one of the following values (as defined in <code>stdio.h</code>): SEEK_SET – Beginning of file. SEEK_CUR – Current position of file pointer. SEEK_END – End-of-file.</td></tr></table>	<i>handle</i>	refers to an opened file	<i>offset</i>	the number of characters from the origin	<i>origin</i>	the position from which to start the seek. <i>origin</i> may be one of the following values (as defined in <code>stdio.h</code>): SEEK_SET – Beginning of file. SEEK_CUR – Current position of file pointer. SEEK_END – End-of-file.
<i>handle</i>	refers to an opened file						
<i>offset</i>	the number of characters from the origin						
<i>origin</i>	the position from which to start the seek. <i>origin</i> may be one of the following values (as defined in <code>stdio.h</code>): SEEK_SET – Beginning of file. SEEK_CUR – Current position of file pointer. SEEK_END – End-of-file.						
Return Value:	Returns the offset, in characters, of the new position from the beginning of the file. A return value of '-1L' indicates an error.						
Remarks:	This helper function is called by the Standard C Library functions, <code>fgetpos()</code> , <code>ftell()</code> , <code>fseek()</code> , <code>fsetpos</code> and <code>rewind()</code> .						
Default Behavior:	As distributed, the parameters are passed to the host file system through the simulator. The return value is the value returned by the host file system.						
File:	<code>lseek.c</code>						

open

Description:	Open a file.						
Include:	None						
Prototype:	<code>int open(const char *name, int access, int mode);</code>						
Argument:	<table><tr><td><i>name</i></td><td>name of the file to be opened</td></tr><tr><td><i>access</i></td><td>access method to open file</td></tr><tr><td><i>mode</i></td><td>type of access permitted</td></tr></table>	<i>name</i>	name of the file to be opened	<i>access</i>	access method to open file	<i>mode</i>	type of access permitted
<i>name</i>	name of the file to be opened						
<i>access</i>	access method to open file						
<i>mode</i>	type of access permitted						
Return Value:	If successful, the function returns a file handle, a small positive integer. This handle is then used on subsequent low-level file I/O operations. A return value of '-1' indicates an error.						
Remarks:	<p>The access flag is a union of one of the following access methods and zero or more access qualifiers:</p> <ul style="list-style-type: none">0 – Open a file for reading.1 – Open a file for writing.2 – Open a file for both reading and writing. <p>The following access qualifiers must be supported:</p> <ul style="list-style-type: none">0x0008 – Move file pointer to end-of-file before every write operation.0x0100 – Create and open a new file for writing.0x0200 – Open the file and truncate it to zero length.0x4000 – Open the file in text (translated) mode.0x8000 – Open the file in binary (untranslated) mode. <p>The mode parameter may be one of the following:</p> <ul style="list-style-type: none">0x0100 – Reading only permitted.0x0080 – Writing permitted (implies reading permitted). <p>This helper function is called by the Standard C Library functions, <code>fopen()</code> and <code>freopen()</code>.</p>						
Default Behavior:	As distributed, the parameters are passed to the host file system through the simulator. The return value is the value returned by the host file system. If the host system returns a value of '-1', the global variable, <code>errno</code> , is set to the value of the symbolic constant, <code>EFOPEN</code> , defined in <code><errno.h></code> .						
File:	<code>open.c</code>						

read

Description:	Read data from a file.						
Include:	None						
Prototype:	<pre>int read(int handle, void *buffer, unsigned int len);</pre>						
Argument:	<table><tr><td><i>handle</i></td><td>handle referring to an opened file</td></tr><tr><td><i>buffer</i></td><td>points to the storage location for read data</td></tr><tr><td><i>len</i></td><td>the maximum number of characters to read</td></tr></table>	<i>handle</i>	handle referring to an opened file	<i>buffer</i>	points to the storage location for read data	<i>len</i>	the maximum number of characters to read
<i>handle</i>	handle referring to an opened file						
<i>buffer</i>	points to the storage location for read data						
<i>len</i>	the maximum number of characters to read						
Return Value:	Returns the number of characters read, which may be less than <i>len</i> if there are fewer than <i>len</i> characters left in the file or if the file was opened in text mode, in which case, each carriage return-linefeed (CR-LF) pair is replaced with a single linefeed character. Only the single linefeed character is counted in the return value. The replacement does not affect the file pointer. If the function tries to read at end-of-file, it returns '0'. If the handle is invalid, or the file is not open for reading or the file is locked, the function returns '-1'.						
Remarks:	This helper function is called by the Standard C Library functions <code>fgetc()</code> , <code>fgets()</code> , <code>fread()</code> and <code>gets()</code> .						
Default Behavior:	As distributed, the parameters are passed to the host file system through the simulator. The return value is the value returned by the host file system.						
File:	<code>read.c</code>						

sbrk

Description:	Extend the process' data space by a given increment.		
Include:	None		
Prototype:	<pre>void * sbrk(int incr);</pre>		
Argument:	<table><tr><td><i>incr</i></td><td>number of characters to increment/decrement</td></tr></table>	<i>incr</i>	number of characters to increment/decrement
<i>incr</i>	number of characters to increment/decrement		
Return Value:	Return the start of the new space allocated or '-1' for errors.		
Remarks:	<p><code>sbrk()</code> adds <i>incr</i> characters to the break value and changes the allocated space accordingly. <i>incr</i> can be negative, in which case, the amount of allocated space is decreased.</p> <p><code>sbrk()</code> is used to dynamically change the amount of space allocated for the calling process's data segment. The change is made by resetting the process's break value and allocating the appropriate amount of space. The break value is the address of the first location beyond the end of the data segment. The amount of allocated space increases as the break value increases.</p> <p>This is a helper function called by the Standard C Library function, <code>malloc()</code>.</p>		
Default Behavior:	<p>If the global variable, <code>__curbrk</code>, is zero, the function calls <code>brk()</code> to initialize the break value. If <code>brk()</code> returns -1, so does this function.</p> <p>If the <i>incr</i> is zero, the current value of the global variable, <code>__curbrk</code>, is returned.</p> <p>If the <i>incr</i> is non-zero, the function checks that the address, <code>(__curbrk + incr)</code>, is less than the end address of the heap. If it is less, the global variable, <code>__curbrk</code>, is updated to that value and the function returns the unsigned value of <code>__curbrk</code>.</p> <p>Otherwise, the function returns -1.</p> <p>See the description of <code>brk()</code>.</p>		
File:	<code>sbrk.c</code>		

Standard C Libraries - Support Functions

write

Description:	Write data to a file.						
Include:	None						
Prototype:	<pre>int write(int <i>handle</i>, void *<i>buffer</i>, unsigned int <i>count</i>);</pre>						
Argument:	<table><tr><td><i>handle</i></td><td>refers to an opened file</td></tr><tr><td><i>buffer</i></td><td>points to the storage location of data to be written</td></tr><tr><td><i>count</i></td><td>the number of characters to write.</td></tr></table>	<i>handle</i>	refers to an opened file	<i>buffer</i>	points to the storage location of data to be written	<i>count</i>	the number of characters to write.
<i>handle</i>	refers to an opened file						
<i>buffer</i>	points to the storage location of data to be written						
<i>count</i>	the number of characters to write.						
Return Value:	If successful, write returns the number of characters actually written. A return value of '-1' indicates an error.						
Remarks:	<p>If the actual space remaining on the disk is less than the size of the buffer, the function is trying to write to the disk; write fails and does not flush any of the buffer's contents to the disk. If the file is opened in text mode, each linefeed character is replaced with a carriage return – linefeed pair in the output. The replacement does not affect the return value.</p> <p>This is a helper function called by the Standard C Library function, <code>fflush()</code>.</p>						
Default Behavior:	As distributed, the parameters are passed to the host file system through the simulator. The return value is the value returned by the host file system.						
File:	<code>write.c</code>						

16-Bit Language Tools Libraries

4.4 STANDARD C LIBRARY FUNCTIONS THAT REQUIRE MODIFICATION

Although these functions are part of the Standard C Library, the object modules are distributed in the `libpic30-omf.a` archive and the source code (for the compiler) is available in the `src\pic30` folder. These modules are not distributed as part of `libc-omf.a`.

getenv

Description:	Get a value for an environment variable.
Include:	<code><stdlib.h></code>
Prototype:	<code>char *getenv(const char *s);</code>
Argument:	<i>s</i> name of environment variable
Return Value:	Returns a pointer to the value of the environment variable if successful; otherwise, returns a null pointer.
Default Behavior:	As distributed, this function returns a null pointer. There is no support for environment variables.
File:	<code>getenv.c</code>

remove

Description:	Remove a file.
Include:	<code><stdio.h></code>
Prototype:	<code>int remove(const char *filename);</code>
Argument:	<i>filename</i> file to be removed
Return Value:	Returns '0' if successful, '-1' if unsuccessful.
Default Behavior:	As distributed, the parameters are passed to the host file system through the simulator. The return value is the value returned by the host file system.
File:	<code>remove.c</code>

rename

Description:	Rename a file or directory.
Include:	<code><stdio.h></code>
Prototype:	<code>int rename(const char *oldname, const char *newname);</code>
Argument:	<i>oldname</i> pointer to the old name <i>newname</i> pointer to the new name
Return Value:	Returns '0' if it is successful. On an error, the function returns a non-zero value.
Default Behavior:	As distributed, the parameters are passed to the host file system through the simulator. The return value is the value returned by the host file system.
File:	<code>rename.c</code>

system

Description:	Execute a command.
Include:	<code><stdlib.h></code>
Prototype:	<code>int system(const char *s);</code>
Argument:	<i>s</i> command to be executed

Standard C Libraries - Support Functions

system (Continued)

Default Behavior: As distributed, this function acts as a stub or placeholder for your function. If *s* is not NULL, an error message is written to stdout and the program will reset; otherwise, a value of -1 is returned.

File: system.c

time

Description: Get the system time.

Include: <time.h>

Prototype: time_t time(time_t *timer);

Argument: timer points to a storage location for time

Return Value: Returns the elapse time in seconds. There is no error return.

Default Behavior: As distributed, if Timer2 is not enabled, it is enabled in 32-bit mode. The return value is the current value of the 32-bit Timer2 register. Except in very rare cases, this return value is not the elapsed time in seconds.

File: time.c

4.5 FUNCTIONS/CONSTANTS TO SUPPORT A SIMULATED UART

These functions and constants support UART functionality in the MPLAB SIM simulator.

__attach_input_file

Description: Attach a hosted file to the standard input stream.

Include: <libpic30.h>

Prototype: int __attach_input_file(const char *p);

Argument: p pointer to file

Remarks: This function differs from the MPLAB IDE mechanism of providing an input file because it provides “on-demand” access to the file. That is, data will only be read from the file upon request and the asynchronous nature of the UART is not simulated. This function may be called more than once; any opened file will be closed. It is only appropriate to call this function in a simulated environment.

Default Behavior: Allows the programmer to attach a hosted file to the standard input stream, stdin.
The function will return 0 to indicate failure. If the file cannot be opened for whatever reason, standard in will remain connected (or be re-connected) to the simulated UART.

File: attach.c

__close_input_file

Description: Close a previously attached file.

Include: <libpic30.h>

Prototype: void __close_input_file(void);

Argument: None

Remarks: None.

Default Behavior: This function will close a previously attached file and re-attach stdin to the simulated UART. This should occur before a Reset to ensure that the file can be re-opened.

File: close.c

__delay32

Description:	Produce a delay of a specified number of clock cycles.
Include:	<libpic30.h>
Prototype:	void __delay32(unsigned long <i>cycles</i>);
Argument:	<i>cycles</i> number of cycles to delay
Remarks:	None.
Default Behavior:	This function will effect a delay of the requested number of cycles. The minimum supported delay is 12 cycles (an argument of less than 12 will result in 12 cycles). The delay includes the <code>call</code> and <code>return</code> statements, but not any cycles required to set up the argument (typically this would be two for a literal value).
File:	delay32.s

__delay_ms

Description:	Produce a delay of a specified number of milliseconds (ms).
Include:	<libpic30.h>
Prototype:	void __delay_ms(unsigned int <i>time</i>);
Argument:	<i>time</i> number of ms to delay
Remarks:	This function is implemented as a macro.
Default Behavior:	This function relies on a user-supplied definition of <code>FCY</code> to represent the instruction clock frequency. <code>FCY</code> must be defined before header file, <code>libpic30.h</code> , is included. The specified delay is converted to the equivalent number of instruction cycles and passed to <code>__delay32()</code> . If <code>FCY</code> is not defined, then <code>__delay_ms()</code> is declared external, causing the link to fail unless the user provides a function with that name.
File:	delay32.s

__delay_us

Description:	Produce a delay of a specified number of microseconds (us).
Include:	<libpic30.h>
Prototype:	void __delay_us(unsigned int <i>time</i>);
Argument:	<i>time</i> number of us to delay
Remarks:	This function is implemented as a macro. The minimum delay is equivalent to 12 instruction cycles.
Default Behavior:	This function relies on a user-supplied definition of <code>FCY</code> to represent the instruction clock frequency. <code>FCY</code> must be defined before header file, <code>libpic30.h</code> , is included. The specified delay is converted to the equivalent number of instruction cycles and passed to <code>__delay32()</code> . If <code>FCY</code> is not defined, then <code>__delay_us()</code> is declared external, causing the link to fail unless the user provides a function with that name.
File:	delay32.s

__C30_UART

Description:	Constant that defines the default UART.
Include:	N/A
Prototype:	int __C30_UART;

__C30_UART (Continued)

Argument:	N/A
Return Value:	N/A
Remarks:	Defines the default UART that <code>read()</code> and <code>write()</code> will use for <code>stdin</code> (unless a file has been attached), <code>stdout</code> and <code>stderr</code> .
Default Behavior:	By default, or with a value of 1, UART 1 will be used. Otherwise, UART 2 will be used. <code>read()</code> and <code>write()</code> are the eventual destinations of the C standard I/O functions.
File:	N/A

Examples of Use

EXAMPLE 4-1: UART1 I/O

```
#include <libpic30.h>          /* a new header file for
                                these definitions */
#include <stdio.h>

void main() {
    if (__attach_input_file("foo.txt")) {
        while (!feof(stdin)) {
            putchar(getchar());
        }
        __close_input_file();
    }
}
```

EXAMPLE 4-2: USING UART2

```
/* This program flashes a light and transmits a lot of messages at
   9600 8n1 through uart 2 using the default stdio provided
   by the 16-bit compiler. This is for a dsPIC33F DSC
   on an Explorer 16(tm) board (and isn't very pretty) */

#include <libpic30.h>          /* a new header file for these
                                definitions */
#include <stdio.h>

#ifdef __dsPIC33F__
#error this is a 33F demo for the explorer 16(tm) board
#endif
#include <p33Fxxxx.h>

_FOSCSEL(FNOSC_PRI );
_FOSC(FCKSM_CSDCMD & OSCIOFNC_OFF & POSCMD_XT);
_FWDT(FWDTEN_OFF);

main() {
    ODCA = 0;
    TRISAbits.TRISA6 = 0;
    __C30_UART=2;
    U2BRG = 38;
    U2MODEbits.UARTEN = 1;
    while (1) {
        __builtin_btg(&LATA,6);
        printf("Hello world %d\n",U2BRG);
    }
}
```

EXAMPLE 4-3: MILLISECOND DELAY

```
#define FCY 1000000UL
#include <libpic30.h>

int main()
{
    /* at 1MHz, these are equivalent */
    __delay_ms(1);
    __delay32(1000);
}
```

EXAMPLE 4-4: MICROSECOND DELAY

```
#define FCY 1000000UL
#include <libpic30.h>

int main()
{
    /* at 1MHz, these are equivalent */
    __delay_us(1000);
    __delay32(1000);
}
```

4.6 FUNCTIONS FOR ERASING AND WRITING EEDATA MEMORY

These functions support the erasing and writing of EEDATA memory for devices that have this type of memory.

_erase_eedata

Description:	Erase EEDATA memory on dsPIC30F and PIC24FXXKA devices.
Include:	<libpic30.h>
Prototype:	void _erase_eedata(_prog_addressT <i>dst</i> , int <i>len</i>);
Argument:	<i>dst</i> destination memory address <i>len</i> dsPIC30F: length may be _EE_WORD or _EE_ROW (bytes) PIC24FxxKA: length may be _EE_WORD, _EE_4WORDS or _EE_8WORDS (bytes)
Return Value:	None.
Remarks:	None.
Default Behavior:	Erase EEDATA memory as specified by parameters.
File:	eedata_helper.c

_erase_eedata_all

Description:	Erase the entire range of EEDATA memory on dsPIC30F and PIC24FXXKA devices.
Include:	<libpic30.h>
Prototype:	void _erase_eedata_all(void);
Argument:	None
Return Value:	None.
Remarks:	None.
Default Behavior:	Erase all EEDATA memory for the selected device.
File:	eedata_helper.c

Standard C Libraries - Support Functions

_wait_eedata

Description:	Wait for an erase or write operation to complete on dsPIC30F and PIC24FXXKA devices.
Include:	<libpic30.h>
Prototype:	void _wait_eedata(void);
Argument:	None
Return Value:	None.
Remarks:	None.
Default Behavior:	Wait for an erase or write operation to complete.
File:	eedata_helper.c

_write_eedata_word

Description:	Write 16 bits of EEDATA memory on dsPIC30F and PIC24FXXKA devices.
Include:	<libpic30.h>
Prototype:	void _write_eedata_word(_prog_addressT dst, int dat);
Argument:	<i>dst</i> destination memory address <i>dat</i> integer data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write one word of EEDATA memory for dsPIC30F devices.
File:	eedata_helper.c

_write_eedata_row

Description:	Write _EE_ROW bytes of EEDATA memory on dsPIC30F devices.
Include:	<libpic30.h>
Prototype:	void _write_eedata_row(_prog_addressT dst, int *src);
Argument:	<i>dst</i> destination memory address <i>*src</i> points to the storage location of data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write specified bytes of EEDATA memory.
File:	eedata_helper.c

Example of Use – dsPIC30F DSCs

```
#include "libpic30.h"
#include "p30fxxxx.h"

char __attribute__((space(eedata), aligned(_EE_ROW))) dat[_EE_ROW];

int main()
{
    char i, source[_EE_ROW];
    _prog_addressT p;

    for (i = 0; i < _EE_ROW; )
        source[i] = i++;                               /* initialize some data */
}
```

16-Bit Language Tools Libraries

```
_init_prog_address(p, dat);    /* get address in program space */

_erase_eedata(p, _EE_ROW);    /* erase a row */

_wait_eedata();                /* wait for operation to complete */

_write_eedata_row(p, source); /* write a row */
}
```

Example of Use – PIC24FXXKA MCUs

```
#include "libpic30.h" /* should use <> here */
#include "p24Fxxxx.h"

int __attribute__((space(eedata), aligned(_EE_4WORDS)))
    dat[_EE_4WORDS/2];

int main()
{
    _prog_addressT p;

    _init_prog_address(p, dat);    /* get address in program
                                     space */
    _erase_eedata(p, _EE_4WORDS); /* erase the dat[] array */
    _wait_eedata();                /* wait to complete */
    _write_eedata_word(p, 0x1234); /* write a word to dat[0] */
    _wait_eedata();

    p += 2;
    _write_eedata_word(p, 0x5678); /* write a word to dat[1] */
    _wait_eedata();
}
```

4.7 FUNCTIONS FOR ERASING AND WRITING FLASH MEMORY

These functions support the erasing and writing of Flash memory for devices that have this type of memory.

_erase_flash

Description:	Erase a page of Flash memory. The length of a page is <code>_FLASH_PAGE</code> words (1 word = 3 bytes = 2 PC address units).
Include:	<code><libpic30.h></code>
Prototype:	<code>void _erase_flash(_prog_addressT dst);</code>
Argument:	<code>dst</code> destination memory address
Return Value:	None.
Remarks:	None.
Default Behavior:	Erase a page of Flash memory.
File:	<code>flash_helper.c</code>

Standard C Libraries - Support Functions

_erase_flash (PIC24FXXKA Only)

Description:	Erase rows of Flash memory, either one, two or four rows.
Include:	<libpic30.h>
Prototype:	void _erase_flash(_prog_addressT <i>dst</i> , int <i>len</i>);
Argument:	<i>dst</i> destination memory address <i>len</i> length may be _FLASH_ROW, _FLASH_2ROWS or _FLASH_4ROWS (bytes)
Return Value:	None.
Remarks:	None.
Default Behavior:	Erase rows of Flash memory.
File:	flash_helper.c

_write_flash16

Description:	Write a row of Flash memory with 16-bit data. The length of a row is _FLASH_ROW words. The upper byte of each destination word is filled with 0xFF. Note that the row must be erased before any write can be successful.
Include:	<libpic30.h>
Prototype:	void _write_flash16(_prog_addressT <i>dst</i> , int * <i>src</i>);
Argument:	<i>dst</i> destination memory address <i>*src</i> points to the storage location of data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write a row of Flash memory with 16-bit data.
File:	flash_helper.c

_write_flash24

Description:	Write a row of Flash memory with 24-bit data. The length of a row is _FLASH_ROW words. Note that the row must be erased before any write can be successful.
Include:	<libpic30.h>
Prototype:	void _write_flash24(_prog_addressT <i>dst</i> , long * <i>src</i>);
Argument:	<i>dst</i> destination memory address <i>*src</i> points to the storage location of data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write a row of Flash memory with 24-bit data.
File:	flash_helper.c

_write_flash_word16

Description:	Write a word of Flash memory with 16-bit data. The upper byte of the destination word is filled with 0xFF. Note that the word must be erased before any write can be successful. This function is currently available only for PIC24F devices (excluding PIC24FXXKA MCUs).
Include:	<libpic30.h>
Prototype:	void _write_flash_word16(_prog_addressT dst, int dat);
Argument:	<i>dst</i> destination memory address <i>dat</i> integer data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write a word of Flash memory with 16-bit data for most PIC24 devices.
File:	flash_helper.c

_write_flash_word24

Description:	Write a word of Flash memory with 24-bit data. Note that the word must be erased before any write can be successful. This function is currently available only for PIC24F devices (excluding PIC24FXXKA MCUs).
Include:	<libpic30.h>
Prototype:	void _write_flash_word24(_prog_addressT dst, int dat);
Argument:	<i>dst</i> destination memory address <i>dat</i> integer data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write a word of Flash memory with 24-bit data for most PIC24 devices.
File:	flash_helper.c

Example of Use

```
#include "libpic30.h"
#include "p24Fxxxx.h"

int __attribute__((space(prog),aligned(_FLASH_PAGE*2)))
dat[_FLASH_PAGE];

int main()
{
    int i;
    int source1[_FLASH_ROW];
    long source2[_FLASH_ROW];
    _prog_addressT p;

    for (i = 0; i < _FLASH_ROW; ) {
        source1[i] = i;
        source2[i] = i++;
    } /* initialize some data */

    _init_prog_address(p, dat); /* get address in program space */

    _erase_flash(p); /* erase a page */

    _write_flash16(p, source1); /* write first row with 16-bit data */
}
```


Standard C Libraries - Support Functions

```
#if defined (__dsPIC30F__)
    _erase_flash(p);          /* on dsPIC30F, only 1 row per page */
#else
    p += (_FLASH_ROW * 2);    /* advance to next row */
#endif

    _write_flash24(p, source2); /* write second row with 24-bit data */
}
```

Example of Use – PIC24FXXKA MCUs

```
#include "libpic30.h" /* should use <> here */
#include "p24Fxxxx.h"

int __attribute__((space(prog),aligned(_FLASH_2ROWS*2)))
    dat[_FLASH_2ROWS];

int main()
{
    int i;
    int  source1[_FLASH_ROW];
    long source2[_FLASH_ROW];
    _prog_addressT p;

    for (i = 0; i < _FLASH_ROW; ) {
        source1[i] = i;
        source2[i] = i++;
    }

    _init_prog_address(p, dat); /* get address in program
                                space */
    _erase_flash(p, _FLASH_2ROWS); /* erase two rows */

    _write_flash16(p, source1); /* write first row with
                                16-bit data */
    p += (_FLASH_ROW * 2); /* advance to next row */

    _write_flash24(p, source2); /* write second row with
                                24-bit data */
}
```

4.8 FUNCTIONS FOR SPECIALIZED COPYING AND INITIALIZATION

These functions support specialized data copying and initialization.

_memcpy_p2d16

Description:	Copy 16 bits of data from each address in program memory to data memory. The next unused source address is returned.
Include:	<libpic30.h>
Prototype:	<code>_prog_addressT _memcpy_p2d16(char *dest, _prog_addressT src, unsigned int len);</code>
Argument:	<code>*dest</code> pointer to destination memory address <code>src</code> address of data to be written <code>len</code> length of program memory
Return Value:	The next unused source address.
Remarks:	None.

_memcpy_p2d16 (Continued)

Default Behavior: Copy 16 bits of data from each address in program memory to data memory.

File: memcpy_helper.c

_memcpy_p2d24

Description: Copy 24 bits of data from each address in program memory to data memory. The next unused source address is returned.

Include: <libpic30.h>

Prototype: `_prog_addressT _memcpy_p2d24(char *dest, _prog_addressT src, unsigned int len);`

Argument: **dest* pointer to destination memory address
src address of data to be written
len length of program memory

Return Value: The next unused source address.

Remarks: None.

Default Behavior: Copy 24 bits of data from each address in program memory to data memory.

File: memcpy_helper.c

_strncpy_p2d16

Description: Copy 16 bits of data from each address in program memory to data memory. The operation terminates early if a NULL char is copied. The next unused source address is returned.

Include: <libpic30.h>

Prototype: `_prog_addressT _strncpy_p2d16(char *dest, _prog_addressT src, unsigned int len);`

Argument: **dest* pointer to destination memory address
src address of data to be written
len length of program memory

Return Value: The next unused source address.

Remarks: None.

Default Behavior: Copy 16 bits of data from each address in program memory to data memory.

File: memcpy_helper.c

_strncpy_p2d24

Description: Copy 24 bits of data from each address in program memory to data memory. The operation terminates early if a NULL char is copied. The next unused source address is returned.

Include: <libpic30.h>

Prototype: `_prog_addressT _strncpy_p2d24(char *dest, _prog_addressT src, unsigned int len);`

Argument: **dest* pointer to destination memory address
src address of data to be written
len length of program memory

Return Value: The next unused source address.

Remarks: None.

_strncpy_p2d24 (Continued)

Default Behavior: Copy 24 bits of data from each address in program memory to data memory.

File: memcpy_helper.c

_init_prog_address

Description: A macro that is used to initialize variables of type, `_prog_addressT`. These variables are not equivalent to C pointers.

Include: `<libpic30.h>`

Prototype: `_init_prog_address(a,b);`

Argument: `a` variable of type `_prog_addressT`
`b` initialization value for variable `a`

Return Value: N/A

Remarks: None.

Default Behavior: Initialize variable to specified value.

File: `libpic30.c`

Example of Use

```
#include "stdio.h"
#include "libpic30.h"

void display_mem(char *p, unsigned int len) {
    int i;
    for (i = 0; i < len; i++) {
        printf("  %d", *p++);
    }
    printf("\n");
}

char __attribute__((space(prog))) dat[] =
{ 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 };

char buf[10];

int main() {
    int i;
    _prog_addressT p;

    /* method 1 */
    _init_prog_address(p, dat);
    (void) _memcpy_p2d16(buf, p, 10);

    display_mem(buf,10);

    /* method 2 */
    _init_prog_address(p, dat);
    p = _memcpy_p2d16(buf, p, 4);
    p = _memcpy_p2d16(&buf[4], p, 6);

    display_mem(buf,10);
}
```

Chapter 5. Fixed Point Math Functions

5.1 INTRODUCTION

Fixed point library math functions are contained in the files, `libq-omf.a` (standard), and `libq-dsp-omf.a` (DSP), where *omf* will be *coff* or *elf* depending upon the selected object module format. The header file is named `libq.h` and is the same for standard or DSP versions of the library. Linker options, `-lq` (standard and DSP) and `-lq-dsp` (DSP only), must be used when linking the respective libraries.

5.1.1 Assembly Code Applications

A free version of the math functions library and header file is available from the Microchip web site.

5.1.2 C Code Applications

The MPLAB C Compiler for PIC24 MCUs and dsPIC DSCs (formerly MPLAB C30) install directory (`c:\Program Files\Microchip\MPLAB C30`) contains the following subdirectories with library-related files:

- `lib` – standard C library files
- `support\h` – header files for libraries

In addition, there is a file, `ResourceGraphs.pdf`, which contains diagrams of resources used by each function, located in `lib`.

5.1.3 Chapter Organization

This chapter is organized as follows:

- Overview of Fixed Point Data Formats
- Using the Fixed Point Libraries
- `<libq.h>` mathematical functions

5.2 OVERVIEW OF FIXED POINT DATA FORMATS

The integer data is encoded as its two's complement to accommodate both positive and negative numbers in binary format. The two's complement can be represented using integer format or the fractional format.

5.2.1 Integer Format

The integer format data is represented as a signed two's complement value, where the Most Significant bit is defined as a sign bit. The range of an N-bit two's complement integer is -2^{N-1} to $2^{N-1}-1$ with a resolution of 1. For a 16-bit integer, the data range is -32768 (0x8000) to +32767 (0x7FFF) with a resolution of 1. For a 32-bit integer, the data range is -2,147,483,648 (0x8000 0000) to +2,147,483,647 (0x7FFF FFFF) with a resolution of 1.

5.2.2 Fractional Format

The fractional data format (Qn.m) has integral part (n) and fractional part (m) and the Most Significant bit represents the sign, thus consisting of (m+n+1) bits. It represents a signed two's complement value. Qn.m format data has a range of $[-2^n, (2^n-2^{-m})]$ with 2^{-m} resolution.

For the binary representation of an N-bit (m+n+1 bits) number in Qn.m:

$$b_{\underbrace{m+n}_{N-1}} b_{m+n-1} \dots b_m . b_{m-1} \dots b_1 b_0$$

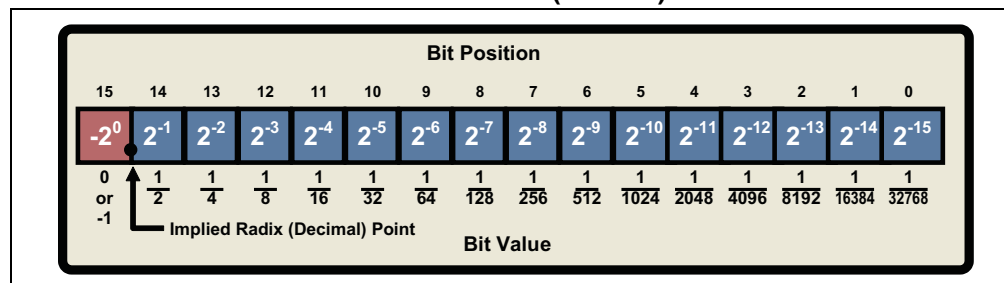
the value is give by the equation:

$$Value = -b_{N-1}2^n + \sum_{l=0}^{N-2} b_l 2^{l-m}$$

5.2.2.1 Q15 (1.15) FORMAT

In Q15 format, the Most Significant bit is defined as a sign bit and the radix point is implied to lie just after the sign bit followed by the fractional value. This format is commonly referred to as 1.15 or Q15 format, where 1 is the number of bits used to represent the integer portion of the number, and 15 is the number of bits used to represent the fractional portion. The range of an N-bit two's complement fraction with this implied radix point is -1.0 to $(1 - 2^{1-N})$. For a 16-bit fraction, the 1.15 data range is -1.0 (0x8000) to +0.999969482 (0x7FFF) with a precision of 3.05176×10^{-5} .

FIGURE 5-1: FRACTIONAL FORMAT (16 BITS)



Fixed Point Math Functions

The following example shows the conversion of a two's complement 16-bit integer +24576 to Q15 value +0.75.

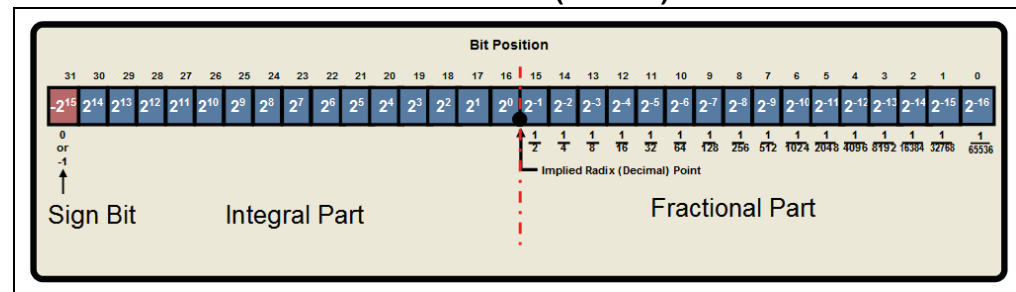
EXAMPLE 5-1: CONVERSION OF A TWO'S COMPLEMENT 16-BIT INTEGER TO Q15

Binary		Dec		Q15
0	$0 \times (-2^{15})$	0	$0 \times (-2^0)$	0
			●	● ← Radix point
1	1×2^{14}	16384	1×2^{-1}	0.5
1	1×2^{13}	8192	1×2^{-2}	0.25
0	0×2^{12}	0	0×2^{-3}	0
0	0×2^{11}	0	0×2^{-4}	0
0	0×2^{10}	0	0×2^{-5}	0
0	0×2^9	0	0×2^{-6}	0
0	0×2^8	0	0×2^{-7}	0
0	0×2^7	0	0×2^{-8}	0
0	0×2^6	0	0×2^{-9}	0
0	0×2^5	0	0×2^{-10}	0
0	0×2^4	0	0×2^{-11}	0
0	0×2^3	0	0×2^{-12}	0
0	0×2^2	0	0×2^{-13}	0
0	0×2^1	0	0×2^{-14}	0
0	0×2^0	0	0×2^{-15}	0
	Sum	+24576	Sum	+0.75

5.2.2.2 Q15.16 FORMAT

In the Q15.16 format, the Most Significant bit is defined as a sign bit, followed by 16 bits of the integral part. The radix point is implied to lie just after the integral part, followed by 16 bits of the fractional value. This format is commonly referred to as Q15.16 format. The range of Q15.16 numbers is from -32768.0 (0x8000 0000) to +32767.9999847412109375 (0x7FFF FFFF) and has a precision of 2^{-16} .

FIGURE 5-2: FRACTIONAL FORMAT (32 BITS)



16-Bit Language Tools Libraries

The following example shows the conversion of a two's complement 32-bit integer, -715827882 to Q15.16 value -10922.6666564941.

EXAMPLE 5-2: CONVERSION OF A TWO'S COMPLEMENT 32-BIT INTEGER TO Q15.16

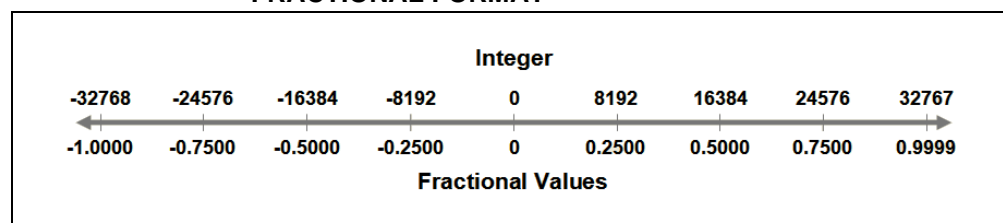
Binary		Dec		Q15.16
1	$1 \times (-2^{31})$	-2147483648	$1 \times (-2^{15})$	-32768
1	1×2^{30}	1073741824	1×2^{14}	16384
0	0×2^{29}	0	0×2^{13}	0
1	1×2^{28}	268435456	1×2^{12}	4096
0	0×2^{27}	0	0×2^{11}	0
1	1×2^{26}	67108864	1×2^{10}	1024
0	0×2^{25}	0	0×2^9	0
1	1×2^{24}	16777216	1×2^8	256
0	0×2^{23}	0	0×2^7	0
1	1×2^{22}	4194304	1×2^6	64
0	0×2^{21}	0	0×2^5	0
1	1×2^{20}	1048576	1×2^4	16
0	0×2^{19}	0	0×2^3	0
1	1×2^{18}	262144	1×2^2	4
0	0×2^{17}	0	0×2^1	0
1	1×2^{16}	65536	1×2^0	1
			●	●
0	0×2^{15}	0	0×2^{-1}	0
1	1×2^{14}	16384	1×2^{-2}	0.25
0	0×2^{13}	0	0×2^{-3}	0
1	1×2^{12}	4096	1×2^{-4}	0.0625
0	0×2^{11}	0	0×2^{-5}	0
1	1×2^{10}	1024	1×2^{-6}	0.015625
0	0×2^9	0	0×2^{-7}	0
1	1×2^8	256	1×2^{-8}	0.00390625
0	0×2^7	0	0×2^{-9}	0
1	1×2^6	64	1×2^{-10}	0.000976563
0	0×2^5	0	0×2^{-11}	0
1	1×2^4	16	1×2^{-12}	0.000244141
0	0×2^3	0	0×2^{-13}	0
1	1×2^2	4	1×2^{-14}	6.10352E-05
1	1×2^1	2	1×2^{-15}	3.05176E-05
0	0×2^0	0	0×2^{-16}	0
	Sum	-715827882	Sum	-10922.6666564941

Radix point

5.2.3 Integer - Fractional Format Mapping

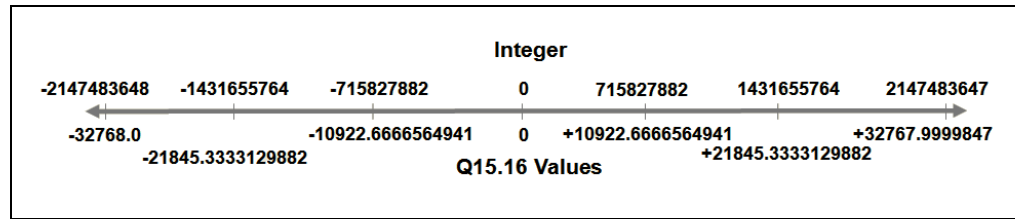
The same twos complement N-bit word may represent an integer format value or a fractional format value. For eg., the 16-bit integer range [-32768, +32767] format maps to Q15 range of [-1.0, +0.999969482]. Figure 5-3 shows the mapping between these formats.

FIGURE 5-3: MAPPING BETWEEN 16-BIT INTEGER FORMAT AND Q15 FRACTIONAL FORMAT



A similar relationship exists between the 32-bit integer format and the Q15.16 format, where the integer range [-2147483648, +2147483647] is mapped to the Q15.16 range [-32768.0, +32767.9999847412109375].

FIGURE 5-4: MAPPING BETWEEN 32-BIT INTEGER FORMAT AND Q15.16 FORMAT



5.2.4 libq Library and Fixed Point Data Format

The functions in the `libq` library use the fixed point data format. The parameters passed and the results generated by the functions are fractional in nature. There are two similar sets of math functions which perform the same math operations. One set supports Q15 operands and the other supports Q15.16 operands. Q15.16 operand functions, naturally, have better precision and range compared to Q15 operand functions.

5.3 USING THE FIXED POINT LIBRARIES

Building an application which utilizes the fixed point libraries requires two types of files: header files and library files.

5.3.1 Header Files

All standard C library entities are declared or defined in one or more standard headers. (See list in **Section 5.1.3 “Chapter Organization”**.) To make use of a library entity in a program, write an include directive that names the relevant standard header.

The contents of a standard header are included by naming them in an include directive, as in:

```
#include <libq.h> /* include fixed point library */
```

The standard headers can be included in any order. Do not include a standard header within a declaration. Do not define macros that have the same names as keywords before including a standard header.

A standard header never includes another standard header.

5.3.2 Library Files

The archived library files contain all the individual object files for each library function.

When linking an application, the library file (`libq-omf.a` or `libq-dsp-omf.a`) must be provided as an input to the linker (using the `--library` or `-l` linker option), such that the functions used by the application may be linked into the application. Also, linker options, `-lq` and `-lq-dsp`, must be used when linking the respective libraries.

A typical C application will require three library files: `libc-omf.a`, `libm-omf.a` and `libpic30-omf.a`. (See **Section 1.2 “OMF-Specific Libraries/Start-up Modules”** for more on OMF-specific libraries.) These libraries will be included automatically if linking is performed using the compiler.

5.3.3 Function Naming Conventions

Signed fixed point types are defined as follows:

Qn_m

where:

- n is the number of data bits to the left of the radix point
- m is the number of data bits to the right of the radix point

Note: A sign bit is implied.

For convenience, short names are also defined:

Exact Name	# Bits Required	Short Name
_Q0_15	16	_Q15
_Q15_16	32	_Q16

In this document the terms Q15.16 and Q16 are used interchangeably; however, both imply Q15.16 format. Functions in the library are prefixed with the type of the return value. For example, _Q15acos returns a Q15 value equal to the arc cosine of its argument.

Argument types do not always match the return type. Refer to the function prototype for a specification of its arguments.

In cases where the return value is not a fixed point type, the argument type is appended to the function name. For example, function _itoaQ15 accepts a type Q15 argument.

In cases where two versions of a function are provided, with the same return type but different argument types, the argument type is appended to the function name. For example:

Function Name	Return Type	Argument Type
_Q16reciprocalQ15	_Q16	_Q15
_Q16reciprocalQ16	_Q16	_Q16

5.4 <LIBQ.H> MATHEMATICAL FUNCTIONS

The header file, `libq.h`, consists of macro definitions and various functions that calculate fixed point mathematical operations.

5.4.1 Q15 Functions

Many functions in this section use fixed point Q15 (1.15) format. For each function, the entire range may not be used.

`_Q15abs`

Description:	The function finds the absolute value of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15abs(_Q15 x);</code>
Argument:	<code>x</code> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the absolute value of <code>x</code> in Q15 format. The value ranges from 0 to 32767.

`_Q15acos`

Description:	This function finds the arc cosine of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15acos(_Q15 x);</code>
Argument:	<code>x</code> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from 17705 to 32767.
Return Value:	This function returns the arc cosine of <code>x</code> in Q15 format. The value ranges from 256 to 32767.

`_Q15acosByPI`

Description:	This function finds the arc cosine of a Q15 value and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15acosByPI(_Q15 x);</code>
Argument:	<code>x</code> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the arc cosine of <code>x</code> , divided by PI, in Q15 format. The value ranges from 82 to 32767.

_Q15add

Description:	This function finds the sum value of two Q15 values. The function takes care of saturation during overflow and underflow occurrences.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15add(_Q15 x, _Q15 y);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. y a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the sum of x and y in Q15 format. The value ranges from -32768 to 32767.

_Q15asin

Description:	This function finds the arc sine of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15asin(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -27573 to 27573.
Return Value:	This function returns the arc sine of x in Q15 format. The value ranges from -32768 to 32767.

_Q15asinByPI

Description:	This function finds the arc sine of a Q15 value and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15asinByPI(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the arc sine of x , divided by PI, in Q15 format. The value ranges from -16384 to 16303.

_Q15atan

Description:	This function finds the arc tangent of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15atan(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the arc tangent of x in Q15 format. The value ranges from -25736 to 25735.

_Q15atanByPI

Description:	This function finds the arc tangent of a Q15 value and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15atanByPI(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the arc tangent of x , divided by PI, in Q15 format. The value ranges from -8192 to 8192.

_Q15atanYByX

Description:	This function finds the arc tangent of a Q15 value divided by a second Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15atanYByX(_Q15 x, _Q15 y);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. y a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the arc tangent of y divided by x in Q15 format. The value ranges from -25736 to 25735.

_Q15atanYByXByPI

Description:	This function finds the arc tangent of a Q15 value divided by a second Q15 value and then divides the result by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15atanYByXByPI(_Q15 x, _Q15 y);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. y a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the arc tangent of y divided by x , divided by PI, in Q15 format. The value ranges from -8192 to 8192.

_Q15atoi

Description:	This function takes a string which holds the ASCII representation of decimal digits and converts it into a single Q15 number. Note: The decimal digit should not be beyond the range: -32768 to 32767.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15atoi(const char *s);</code>
Argument:	s a buffer holding the ASCII values of each decimal digit.
Return Value:	This function returns the integer equivalent of s in Q15 format, which range is from -32768 to 32767.

_Q15cos

Description: This function finds the cosine of a Q15 value.

Include: `<libq.h>`

Prototype: `_Q15 _Q15cos(_Q15 x);`

Argument: `x` a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.

Return Value: This function returns the cosine of `x` in Q15 format. The value ranges from 17705 to 32767.

_Q15cosPI

Description: This function finds the cosine of PI (π) times a Q15 value.

Include: `<libq.h>`

Prototype: `_Q15 _Q15cosPI(_Q15 x);`

Argument: `x` a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.

Return Value: This function returns the cosine of PI times `x` in Q15 format. The value ranges from -32768 to 32767.

_Q15exp

Description: This function finds the exponential value of a Q15 value.

Include: `<libq.h>`

Prototype: `_Q15 _Q15exp(_Q15 x);`

Argument: `x` a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 0.

Return Value: This function returns the exponent value of `x` in Q15 format. The value ranges from 12055 to 32767.

_Q15ftoi

Description: This function converts a single precision floating-point value into its corresponding Q15 value.

Include: `<libq.h>`

Prototype: `_Q15 _Q15ftoi(float x);`

Argument: `x` a floating-point equivalent number. The corresponding floating-point range is -1 to 0.99996.

Return Value: This function returns a fixed point number in Q15 format. The value ranges from -32768 to 32767.

_itoaQ15

Description:	This function converts each decimal digit of a Q15 value to its representation in ASCII. For example, 1 is converted to 0x31, which is the ASCII representation of 1.
Include:	<code><libq.h></code>
Prototype:	<code>void _itoaQ15(_Q15 x, char *s);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. s a buffer holding values in ASCII, at least 8 characters long.
Return Value:	None.

_itofQ15

Description:	This function converts a Q15 value into its corresponding floating-point value.
Include:	<code><libq.h></code>
Prototype:	<code>float _itofQ15(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns a floating-point equivalent number. The corresponding floating-point range is -1 to 0.99996.

_Q15log

Description:	This function finds the natural log of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15log(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from 12055 to 32767.
Return Value:	This function returns the natural log of x in Q15 format. The value ranges from -32768 to -1.

_Q15log10

Description:	This function finds the log (base 10) of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15log10(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from 3277 to 32767.
Return Value:	This function returns the log of x in Q15 format. The value ranges from -32768 to 0.

_Q15neg

Description:	This function negates a Q15 value with saturation. The value is saturated in the case where the input is -32768.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15neg(_Q15 x);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns $-x$ in Q15 format. The value ranges from -32768 to 32767.

_Q15norm

Description:	This function finds the normalized value of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15norm(_Q15 x);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the square root of <i>x</i> in Q15 format. The value ranges from 16384 to -32767 for a positive number and -32768 to -16384 for a negative number.

_Q15power

Description:	This function finds the power result given the base value and the power value in Q15 format.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15power(_Q15 x, _Q15 y);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from 1 to $2^{15}-1$. The value of this argument ranges from 1 to 32767. <i>y</i> a fixed point number in Q15 format, which ranges from 1 to $2^{15}-1$. The value of this argument ranges from 1 to 32767.
Return Value:	This function returns x to the power of y in Q15 format. The value ranges from 1 to 32767.

_Q15random

Description:	This function generates a random number in the range from -32768 to 32767. The random number generation is periodic with period 65536. The function uses the <code>_Q15randomSeed</code> variable as a random seed value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15random(void);</code>
Argument:	None.
Return Value:	This function returns a random number in Q15 format. The value ranges from -32768 to 32767.

_Q15shl

Description:	This function shifts a Q15 value by <i>num</i> bits, to the left if <i>num</i> is positive or to the right if <i>num</i> is negative. The function takes care of saturating the result, in case of underflow or overflow.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15shl(_Q15 x, short num);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. <i>num</i> an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of <i>x</i> in Q15 format. The value ranges from -32768 to 32767.

_Q15shlNoSat

Description:	This function shifts a Q15 value by <i>num</i> bits, to the left if <i>num</i> is positive or to the right if <i>num</i> is negative. The function sets the <code>_Q15shlSatFlag</code> variable in case of underflow or overflow but does not take care of saturation.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15shlNoSat(_Q15 x, short num);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. <i>num</i> an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of <i>x</i> in Q15 format. The value ranges from -32768 to 32767.

_Q15shr

Description:	This function shifts a Q15 value by <i>num</i> bits, to the right if <i>num</i> is positive or to the left if <i>num</i> is negative. The function takes care of saturating the result, in case of underflow or overflow.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15shr(_Q15 x, short num);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. <i>num</i> an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of <i>x</i> in Q15 format. The value ranges from -32768 to 32767.

_Q15shrNoSat

Description:	This function shifts a Q15 value by <i>num</i> bits, to the right if <i>num</i> is positive or to the left if <i>num</i> is negative. The function sets the <code>_Q15shrSatFlag</code> variable in case of underflow or overflow but does not take care of saturation.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15shrNoSat(_Q15 x, short num);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. <i>num</i> an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of <i>x</i> in Q15 format. The value ranges from -32768 to 32767.

_Q15sin

Description:	This function finds the sine of a Q15 value.
Include:	<libq.h>
Prototype:	<code>_Q15 _Q15sin(_Q15 x);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the sine of <i>x</i> in Q15 format. The value ranges from -27573 to 27573.

_Q15sinPI

Description:	This function finds the sine of PI (π) times a Q15 value.
Include:	<libq.h>
Prototype:	<code>_Q15 _Q15sinPI(_Q15 x);</code>
Argument:	<i>x</i> a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the sine of PI times <i>x</i> in Q15 format. The value ranges from -32768 to 32767.

_Q15sinSeries

Description:	Generates the sine series with the given normalizing frequency, <i>f</i> , and the given number of samples, <i>num</i> , starting from <i>start</i> . Stores the result in buffer, <i>buf</i> .
Include:	<libq.h>
Prototype:	<code>short _Q15sinSeries(_Q15 f, short start, short num, _Q15 *buf);</code>
Argument:	<i>f</i> a fixed point number in Q15 format, which ranges from 0 to $(2^{31}-1)$. The valid range of values for this argument is from -16384 to 16384. The argument represents the Normalizing frequency. <i>start</i> a fixed point number in Q16 format, which ranges from 0 to $(2^{31}-1)$. The valid range of values for this argument is from 1 to 32767. This argument represents the Starting Sample number in the Sine Series. <i>num</i> a fixed point number in Q16 format, which ranges from 0 to $(2^{31}-1)$. The valid range of values for this argument is from 1 to 32767. This argument represents the Number of Sine Samples the function is called to generate. Note: <i>num</i> should not be more than 16383 for dsPIC and 32767 for PIC devices. <i>buf</i> a pointer to the buffer where the generated sine samples would get copied into.
Return Value:	This function returns <i>num</i> , the number of generated sine samples.

_Q15sqrt

Description:	This function finds the square root of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15sqrt(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from 1 to 32767.
Return Value:	This function returns the square root of x in Q15 format. The value ranges from 1 to 32767.

_Q15sub

Description:	This function finds the difference of two Q15 values. The function takes care of saturation during overflow and underflow occurrences.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15sub(_Q15 x, _Q15 y);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767. y a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns x minus y in Q15 format. The value ranges from -32768 to 32767.

_Q15tan

Description:	This function finds the tangent of a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15tan(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -25736 to 25735.
Return Value:	This function returns the tangent of x in Q15 format. The value ranges from -32768 to 32767.

_Q15tanPI

Description:	This function finds the tangent of π times a Q15 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q15 _Q15tanPI(_Q15 x);</code>
Argument:	x a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.
Return Value:	This function returns the tangent of π times x in Q15 format. The value ranges from -32768 to 32767.

5.4.2 Q16 Functions

Many functions in this section use fixed point Q16 (15.16) format. For each function, the entire range may not be used.

_Q16acos

Description:	This function finds the arc cosine of a Q16 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16acos(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -65566 to 65536.
Return Value:	This function returns the arc cosine of <code>x</code> in Q16 format. The value ranges from -205887 to 205887.

_Q16acosByPI

Description:	This function finds the arc cosine of a Q16 value and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16acosByPI(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -65536 to 65536.
Return Value:	This function returns the arc cosine of <code>x</code> , divided by PI, in Q16 format. The value ranges from -65536 to 65536.

_Q16asin

Description:	This function finds the arc sine of a Q16 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16asin(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -65566 to 65536.
Return Value:	This function returns the arc sine of <code>x</code> in Q16 format. The value ranges from -102944 to 102944.

_Q16asinByPI

Description:	This function finds the arc sine of a Q16 value and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16asinByPI(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -65536 to 65536.
Return Value:	This function returns the arc sine of <code>x</code> , divided by PI, in Q16 format. The value ranges from -65536 to 65536.

_Q16atan

Description:	This function finds the arc tangent of a Q16 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16atan(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the arc tangent of <code>x</code> in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16atanByPI

Description:	This function finds the arc tangent of a Q16 value and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16atanByPI(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the arc tangent of <code>x</code> , divided by PI, in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16atanYByX

Description:	This function finds the arc tangent of <code>y</code> divided by <code>x</code> .
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16atanYByX(_Q16 x, _Q16 y);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. This forms the x input. <code>y</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. This forms the y input.
Return Value:	This function returns the arc tangent of <code>y</code> , divided by <code>x</code> , in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16atanYByXByPI

Description:	This function finds the arc tangent of the 32-bit input, <code>y</code> , divided by <code>x</code> , and then divides by PI (π).
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16atanYByXByPI(_Q16 x, _Q16 y);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. This forms the x input. <code>y</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. This forms the y input.
Return Value:	This function returns the arc tangent <code>y</code> divided by <code>x</code> , divided by PI, in Q16 format. The value ranges from -2147483648 to 2147483647.

16-Bit Language Tools Libraries

_Q16cos

Description:	This function finds the cosine of a Q16 value.
Include:	<libq.h>
Prototype:	<code>_Q16 _Q16cos(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the cosine of <code>x</code> in Q16 format. The value ranges from -65566 to 65536.

_Q16cosPI

Description:	This function finds the cosine of PI (π) times a Q16 value.
Include:	<libq.h>
Prototype:	<code>_Q16 _Q16cosPI(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the cosine of PI times <code>x</code> in Q16 format. The value ranges from -65536 to 65536.

_Q16exp

Description:	This function finds the exponential value of a Q16 value.
Include:	<libq.h>
Prototype:	<code>_Q16 _Q16exp(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from -772244 to 681391.
Return Value:	This function returns the exponent value of <code>x</code> in Q16 format. The value ranges from 0 to 2147483647.

_Q16log

Description:	This function finds the natural log of a Q16 value.
Include:	<libq.h>
Prototype:	<code>_Q16 _Q16log(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from 1 to 2147483647.
Return Value:	This function returns the natural log of <code>x</code> in Q16 format. The value ranges from -726817 to 681391.

_Q16log10

Description:	This function finds the log (base 10) of a Q16 value.
Include:	<libq.h>
Prototype:	<code>_Q16 _Q16log10(_Q16 x);</code>
Argument:	<code>x</code> a fixed point number in Q16 format. The value of this argument ranges from 1 to 2147483647.
Return Value:	This function returns the log of <code>x</code> in Q16 format. The value ranges from -315653 to 295925.

_Q16mac

Description: This function multiplies the two 32-bit inputs, *x* and *y*, and accumulates the product with *prod*. The function takes care of saturating the result in case of underflow or overflow.

Include: `<libq.h>`

Prototype: `_Q16 _Q16mac(_Q16 x, _Q16 y, _Q16 prod);`

Argument: *x* a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
y a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
prod a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.

Return Value: This function returns the multiplied and accumulated value *prod* in Q16 format. The value ranges from 0 to 2147483647.

_Q16macNoSat

Description: This function multiplies the two 32 bit inputs, *x* and *y* and accumulates the product with *prod*. This function only sets the `_Q16macSatFlag` variable in case of an overflow or underflow and does not take care of saturation.

Include: `<libq.h>`

Prototype: `_Q16 _Q16macNoSat(_Q16 x, _Q16 y, _Q16 prod);`

Argument: *x* a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
y a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
prod a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.

Return Value: This function returns the multiplied and accumulated value *prod* in Q16 format. The value ranges from 0 to 2147483647.

_Q16neg

Description: This function negates *x* with saturation. The value is saturated in the case where the input is -2147483648.

Include: `<libq.h>`

Prototype: `_Q16 _Q16neg(_Q16 x);`

Argument: *x* a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.

Return Value: This function returns the negated value of *x* in Q16 format. The value ranges from -2147483648 to 2147483647.

16-Bit Language Tools Libraries

_Q16norm

Description: This function finds the normalized value of a Q16 value.

Include: `<libq.h>`

Prototype: `_Q16 _Q16norm(_Q16 x);`

Argument: *x* a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.

Return Value: This function returns the square root value of *x* in Q16 format. The value ranges from 1073741824 to 2147483647 for a positive number and -2147483648 to -1073741824 for a negative number.

_Q16power

Description: This function finds the power result, given the base value, *x*, and the power value, *y*.

Include: `<libq.h>`

Prototype: `_Q16 _Q16power(_Q16 x, _Q16 y);`

Argument: *x* a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
y a fixed point number in Q16 format. The value of this argument ranges from 0 to 2147483647.

Return Value: This function returns the value of *x* to the power of *y* in Q16 format. The value ranges from 0 to 2147483647.

_Q16random

Description: This function generates a pseudo random number with a period of 2147483648. The function uses the `_Q16randomSeed` variable as a random seed value.

Include: `<libq.h>`

Prototype: `_Q16 _Q16random(void);`

Argument: None.

Return Value: This function returns the generated random number in Q16 format. The value of this output ranges from -2147483648 to 2147483647.

Remarks: $\text{RndNum}(n) = (\text{RndNum}(n-1) * \text{RAN_MULT}) + \text{RAN_INC}$
SEED VALUE = 21845, RAN_MULT = 1664525 and
RAN_INC = 1013904223.

_Q16reciprocal

Description: This function returns the reciprocal of a Q16 value.

Include: `<libq.h>`

Prototype: `_Q16 _Q16reciprocal(_Q16 x);`

Argument: *x* a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.

Return Value: This function returns the reciprocal of *x* in Q16 format. The value of this output ranges from -2147483648 to 2147483647.

_Q16reciprocalQ15

Description: This function returns the reciprocal of a Q15 value. Since the input range lies in the -1 to +1 region, the output is always greater than the -1 or +1 region. So, Q16 format is used to represent the output.

Include: `<libq.h>`

Prototype: `_Q16 _Q16reciprocalQ15(_Q15 x);`

Argument: `x` a fixed point number in Q15 format, which ranges from -2^{15} to $2^{15}-1$. The value of this argument ranges from -32768 to 32767.

Return Value: This function returns the reciprocal of `x` in Q16 format. The value ranges from -2147483648 to 2147418112.

_Q16reciprocalQ16

Description: This function returns the reciprocal value of the input.

Include: `<libq.h>`

Prototype: `_Q16 _Q16reciprocalQ16(_Q16 x);`

Argument: `x` a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.

Return Value: This function returns the reciprocal of `x` in Q16 format. The value of this output ranges from -2147483648 to 2147483647.

_Q16shl

Description: This function shifts the input argument, `x`, by `y` number of bits, to the left if `y` is positive or to the right if `y` is negative. The function takes care of saturating the result, in case of underflow or overflow.

Include: `<libq.h>`

Prototype: `_Q16 _Q16shl(_Q16 x, short y);`

Argument: `x` a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
`y` an integer number, which ranges from -32 to +32.

Return Value: This function returns the shifted value of `x` in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16shlNoSat

Description: This function shifts the input argument, `x`, by `y` number of bits, to the left if `y` is positive or to the right if `y` is negative. The function sets the `_Q16shlSatFlag` variable in case of underflow or overflow, but does not take care of saturation.

Include: `<libq.h>`

Prototype: `_Q16 _Q16shlNoSat(_Q16 x, short y);`

Argument: `x` a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
`y` an integer number, which ranges from -32 to +32.

Return Value: This function returns the shifted value of `x` in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16shr

Description:	This function shifts the input argument, x , by y number of bits, to the right if y is positive or to the left if y is negative. The function takes care of saturating the result, in case of underflow or overflow.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16shr(_Q16 x, short y);</code>
Argument:	x a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. y an integer number, which ranges from -32 to +32.
Return Value:	This function returns the shifted value of x in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16shrNoSat

Description:	This function shifts the input argument, x , by y number of bits, to the right if y is positive or to the left if y is negative. The function sets the <code>_Q16shrSatFlag</code> variable in case of underflow or overflow, but does not take care of saturation.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16shrNoSat(_Q16 x, short y);</code>
Argument:	x a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. y an integer number, which ranges from -32 to +32.
Return Value:	This function returns the shifted value of x in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16sin

Description:	This function finds the sine of a Q16 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16sin(_Q16 x);</code>
Argument:	x a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the sine of x in Q16 format. The value ranges from -65536 to 65536.

_Q16sinPI

Description:	This function finds the sine of $\text{PI} (\pi)$ times a Q16 value.
Include:	<code><libq.h></code>
Prototype:	<code>_Q16 _Q16sinPI(_Q16 x);</code>
Argument:	x a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the sine of PI times x in Q16 format. The value ranges from -65536 to 65536.

_Q16sinSeries

Description:	Generates the sine series with the given normalizing frequency, <i>f</i> , and the given number of samples, <i>num</i> , starting from <i>start</i> . Stores the result in buffer, <i>buf</i> .
Include:	<libq.h>
Prototype:	<pre>short _Q16sinSeries(_Q16 f, short start, short num, _Q16 *buf);</pre>
Argument:	<p><i>f</i> a fixed point number in Q16 format, which ranges from 0 to $(2^{31}-1)$. The valid range of values for this argument is from -32768 to 32768. This argument represents the Normalizing frequency.</p> <p><i>start</i> a fixed point number in Q16 format, which ranges from 0 to $(2^{31}-1)$. The valid range of values for this argument is from 1 to 32767. This argument represents the Starting Sample number in the Sine Series.</p> <p><i>num</i> a fixed point number in Q16 format, which ranges from 0 to $(2^{31}-1)$. The valid range of values for this argument is from 1 to 32767. This argument represents the Number of Sine Samples the function is called to generate.</p> <p>Note: <i>num</i> should not be more than 16383 for dsPIC and 32767 for PIC devices.</p> <p><i>buf</i> a pointer to the buffer where the generated sine samples would get copied into.</p>
Return Value:	This function returns <i>num</i> , the number of generated sine samples.

_Q16tan

Description:	This function finds the tangent of a Q16 value.
Include:	<libq.h>
Prototype:	<pre>_Q16 _Q16tan(_Q16 x);</pre>
Argument:	<i>x</i> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the tangent of <i>x</i> in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16tanPI

Description:	This function finds the tangent of PI (π) times a Q16 value.
Include:	<libq.h>
Prototype:	<pre>_Q16 _Q16tanPI(_Q16 x);</pre>
Argument:	<i>x</i> a fixed point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647.
Return Value:	This function returns the tangent of PI times <i>x</i> in Q16 format. The value ranges from -2147483648 to 2147483647.

16-Bit Language Tools Libraries

_Q16ftoi

Description: This function converts a `float` value to a Q16 fixed point fractional value.

Include: `<libq.h>`

Prototype: `_Q16 _Q16ftoi(float f);`

Argument: `f` a floating-point number. The value of this argument ranges from -32768 to 32768.

Return Value: This function returns a Q16 fixed point fractional value. The value ranges from -2147483648 to 2147483647.

_itofQ16

Description: This function converts a Q16 fixed point fractional value to a `float` value.

Include: `<libq.h>`

Prototype: `float _Q16ftoi(_Q16 q);`

Argument: `q` a fixed point number. The value of this argument ranges from -2147483648 to 2147483647.

Return Value: This function returns a floating-point value. The value ranges from -32768 to 32768.

Appendix A. ASCII Character Set

TABLE A-1: ASCII CHARACTER SET

		Most Significant Character						
Hex	0	1	2	3	4	5	6	7
0	NUL	DLE	Space	0	@	P	'	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	\$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	Bell	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

Least
Significant
Character

16-Bit Language Tools Libraries

NOTES:

Index

Symbols

^, Caret.....	84	_Q15sinPI	226
_attach_input_file	201	_Q15sinSeries.....	226
_C30_UART	202	_Q15sqrt	227
_close_input_file	201	_Q15sub.....	227
_delay_ms.....	202	_Q15tan	227
_delay_us.....	202	_Q15tanPI	227
_delay32	202	_Q16acos.....	228
_FILE	17	_Q16acosByPI	228
_LINE	17	_Q16asin.....	228
_erase_eedata	204	_Q16asinByPI	228
_erase_eedata_all	204	_Q16atan	229
_erase_flash	206, 207	_Q16atanByPI.....	229
_exit	195	_Q16atanYByX	229
_init_prog_address	211	_Q16atanYByXByPI.....	229
_IOFBF	50, 85, 86	_Q16cos.....	230
_IOLBF.....	50, 86	_Q16cosPI	230
_IONBF	50, 85, 86	_Q16exp.....	230
_itoaQ15	223	_Q16ftoi.....	236
_itofQ15	223	_Q16log.....	230
_itofQ16	236	_Q16log10.....	230
_MathError	41	_Q16mac (Continued).....	231
_memcpy_p2d16	209	_Q16macNoSat.....	231
_memcpy_p2d24	210	_Q16neg	231
_NSETJMP	36	_Q16norm	232
_Q15abs	219	_Q16power.....	232
_Q15acos.....	219	_Q16random	232
_Q15acosByPI	219	_Q16reciprocal	232
_Q15add	220	_Q16reciprocalQ15.....	233
_Q15asin.....	220	_Q16reciprocalQ16.....	233
_Q15asinByPI	220	_Q16shl.....	233
_Q15atan	220	_Q16shlNoSat.....	233
_Q15atanByPI.....	221	_Q16shr	234
_Q15atanYByX	221	_Q16shrNoSat	234
_Q15atanYByXByPI.....	221	_Q16sin	234
_Q15atoi	221	_Q16sinPI	234
_Q15cos.....	222	_Q16sinSeries.....	235
_Q15cosPI	222	_Q16tan	235
_Q15exp	222	_Q16tanPI	235
_Q15ftoi	222	_strncpy_p2d16.....	210
_Q15log	223	_strncpy_p2d24.....	210
_Q15log10	223	_VERBOSE_DEBUGGING.....	17
_Q15neg	224	_wait_eedata.....	205
_Q15norm	224	_write_eedata_row.....	205
_Q15power	224	_write_eedata_word.....	205
_Q15random	224	_write_flash_word16.....	208
_Q15shl.....	225	_write_flash_word24	208
_Q15shlNoSat.....	225	_write_flash16.....	207
_Q15shr	225	_write_flash24.....	207
_Q15shrNoSat	225	-, Dash.....	84
_Q15sin.....	226	\f, Form Feed.....	23
		\n, Newline	23, 47, 59, 64, 75, 76, 80

16-Bit Language Tools Libraries

\r, Carriage Return.....	23
\t, Horizontal Tab.....	23
\v, Vertical Tab.....	23
#if.....	33
#include.....	16, 149, 194, 217
%, Percent.....	78, 83, 84, 147

Numerics

0x.....	24, 77, 115, 116
---------	------------------

A

Abnormal Termination Signal.....	38
abort.....	17, 95
abs.....	96
Absolute Value	
Double Floating-Point.....	165
Integer.....	96
Long Integer.....	106
Single Floating-Point.....	165
Absolute Value Function	
abs.....	96
fabs.....	165
fabsf.....	165
labs.....	106
Access Mode	
Binary.....	60
Text.....	60
acos.....	151
acosh.....	152
Allocate Memory.....	108
calloc.....	102
Free.....	105
realloc.....	111
Alphabetic Character	
Defined.....	18
Test for.....	18
Alphanumeric Character	
Defined.....	18
Test for.....	18
AM/PM.....	147
Append.....	124, 130
arccosine	
Double Floating-Point.....	151
Single Floating-Point.....	152
arcsine	
Double Floating-Point.....	153
Single Floating-Point.....	153
arctangent	
Double Floating-Point.....	154
Single Floating-Point.....	155
arctangent of y/x	
Double Floating-Point.....	155
Single Floating-Point.....	157
Argument List.....	43, 91, 92, 93
Arithmetic Error Message.....	38
ASCII Character Set.....	237
asctime.....	142
asin.....	153
asinh.....	153
assert.....	17
assert.h.....	17

Assignment Suppression.....	83
Asterisk.....	77, 83
atan.....	154
atan2.....	155
atan2f.....	157
atanf.....	155
atexit.....	96, 104
atof.....	98
atoi.....	99
atol.....	99
attach_input_file.....	201

B

Base.....	115, 116
10.....	29, 30, 31, 32, 177, 178
2.....	31
e.....	176, 179
FLT_RADIX.....	28, 29, 30, 31, 32, 33
Binary	
Base.....	31
Mode.....	60, 88
Search.....	100
Streams.....	47
Bitfields.....	46
brk.....	195, 198
bsearch.....	100
Buffer Size.....	50, 86
Buffering Modes.....	86
Buffering, See File Buffering	
BUFSIZ.....	50, 85
Built-in Functions.....	13

C

C Locale.....	18, 35
C30_UART.....	202
Calendar Time.....	141, 143, 144, 146, 148
calloc.....	102, 105
Caret (^).....	84
Carriage Return.....	23
ceil.....	158
ceilf.....	159
ceiling	
Double Floating-Point.....	158
Single Floating-Point.....	159
char	
Maximum Value.....	33
Minimum Value.....	33
Number of Bits.....	33
CHAR_BIT.....	33
CHAR_MAX.....	33
CHAR_MIN.....	33
Character Array.....	84
Character Case Mapping	
Lower Case Alphabetic Character.....	25
Upper Case Alphabetic Character.....	26
Character Case Mapping Functions	
tolower.....	25
toupper.....	26
Character Handling, See ctype.h	
Character Input/Output Functions	
fgetc.....	57

fgets	59	memcmp	119
fputc	63	strcmp	126
fputs	63	strcoll	127
getc	74	strncmp	132
getchar	75	strxfrm	140
gets	75	Compiler Options	
putc	79	-fno-short-double	48
putchar	80	-msmart-io	47
puts	80	Concatenation Functions	
ungetc	89	strcat	124
Character Testing		strncat	130
Alphabetic Character	18	Control Character	
Alphanumeric Character	18	Defined	19
Control Character	19	Test for	19
Decimal Digit	20	Control Transfers	36
Graphical Character	20	Conversion	77, 83, 87
Hexadecimal Digit	24	Convert	
Lower Case Alphabetic Character	21	Character to Multibyte Character	117
Printable Character	22	Multibyte Character to Wide Character	109
Punctuation Character	22	Multibyte String to Wide Character String	109
Upper Case Alphabetic Character	24	String to Double Floating-Point	98, 113
White-Space Character	23	String to Integer	99
Character Testing Functions		String to Long Integer	99, 115
isalnum	18	String to Unsigned Long Integer	116
isalpha	18	To Lower Case Alphabetic Character	25
iscntrl	19	To Upper Case Alphabetic Character	26
isdigit	20	Wide Character String to Multibyte String	117
isgraph	20	Copying Functions	
islower	21	memcpy	121
isprint	22	memmove	122
ispunct	22	memset	123
isspace	23	strcpy	127
isupper	24	strncpy	133
isxdigit	24	cos	159
Characters		cosf	160
Alphabetic	18	cosh	161
Alphanumeric	18	coshf	162
Control	19	cosine	
Convert to Lower Case Alphabetic	25	Double Floating-Point	159
Convert to Upper Case Alphabetic	26	Single Floating-Point	160
Decimal Digit	20	crt0, crt1	12
Graphical	20	ctime	143
Hexadecimal Digit	24	ctype.h	18
Lower Case Alphabetic	21	isalnum	18
Printable	22	iscntrl	19
Punctuation	22	isdigit	20
Upper Case Alphabetic	24	isgraph	20
White-Space	23	islapha	18
Classifying Characters	18	islower	21
clearerr	53	ispring	22
Clearing Error Indicator	53	ispunct	22
clock	142	isspace	23
clock_t	141, 142	isupper	24
CLOCKS_PER_SEC	141	isxdigit	24
close	196	tolower	25
close_input_file	201	toupper	26
COFF	12	Current Argument	43
Common Definitions, See stddef.h		Customer Notification Service	8
Compare Strings	126	Customer Support	9
Comparison Function	100, 110	Customized Function	105
Comparison Functions			

16-Bit Language Tools Libraries

D

Dash (-)	84
Date and Time	146
Date and Time Functions, See time.h	
Day of the Month	141, 142, 146
Day of the Week	141, 142, 146
Day of the Year	141, 147
Daylight Savings Time	141, 144, 145
DBL_DIG	28
DBL_EPSILON	28
DBL_MANT_DIG	28
DBL_MAX	28
DBL_MAX_10_EXP	29
DBL_MAX_EXP	29
DBL_MIN	29
DBL_MIN_10_EXP	29
DBL_MIN_EXP	30
Deallocate Memory	105, 111
Debugging Logic Errors	17
Decimal	78, 84, 115, 116
Decimal Digit	
Defined	20
Number Of	28, 30, 31
Test for	20
Decimal Point	77
Default Handler	37
delay_ms	202
delay_us	202
delay32	202
Diagnostics, See assert.h	
difftime	144
Digit, Decimal, See Decimal Digit	
Digit, Hexadecimal, See Hexadecimal Digit	
Direct Input/Output Functions	
fread	64
fwrite	72
div	94, 102
div_t	94
Divide	
Integer	102
Long Integer	107
Divide by Zero	38, 41, 102
Documentation	
Conventions	6
Layout	5
Domain Error	27, 151, 152, 153, 155, 157, 159, 160, 167, 169, 176, 177, 178, 179, 184, 185, 188, 189, 190
dot	77
Double Precision Floating-Point	
Machine Epsilon	28
Maximum Exponent (base 10)	29
Maximum Exponent (base 2)	29
Maximum Value	28
Minimum Exponent (base 10)	29
Minimum Exponent (base 2)	30
Minimum Value	29
Number of Binary Digits	28
Number of Decimal Digits	28
double Type	48
Dream Function	77

DWARF	12
E	
EDOM	27
edom	151
ELF	12
Ellipses (...)	43, 84
Empty Binary File	60
Empty Text File	60
End Of File	50
Indicator	47
Seek	68
Test For	55
Environment Function	
getenv	105
Environment Variable	200
EOF	50
ERANGE	27
erange	151
erase_eedata	204
erase_eedata_all	204
erase_flash	206, 207
errno	27, 151
errno.h	27, 151, 197
EDOM	27
ERANGE	27
errno	27
Error Codes	27, 129
Error Conditions	151
Error Handler	102
Error Handling Functions	
clearerr	53
feof	55
ferror	56
perror	76
Error Indicator	47
Error Indicators	
Clearing	53, 82
End Of File	53, 59
Error	53, 59
Test For	56
Error Signal	37
Errors, See errno.h	
Errors, Testing For	27
Exception Error	102
exit	88, 94, 96, 104, 195
EXIT_FAILURE	94
EXIT_SUCCESS	94
exp	163
expf	164
Exponential and Logarithmic Functions	
exp	163
expf	164
frexp	171
frexpf	172
ldexp	173
ldexpf	174
log	176
log10	177
log10f	178
logf	179

modf	180	FLT_MIN_10_EXP	31
modff	181	FLT_MIN_EXP	31
Exponential Function		FLT_RADIX	31
Double Floating-Point	163	FLT_ROUNDS	31
Single Floating-Point	164	LDBL_DIG	31
F		LDBL_EPSILON	32
fabs	165	LDBL_MANT_DIG	32
fabsf	165	LDBL_MAX	32
fclose	54, 196	LDBL_MAX_10_EXP	32
feof	53, 55	LDBL_MAX_EXP	32
ferror	53, 56	LDBL_MIN	32
fflush	57, 199	LDBL_MIN_10_EXP	32
fgetc	57, 198	LDBL_MIN_EXP	33
fgetpos	58, 197	Floating-Point	
fgets	59, 198	Limits	28
Field Width	77	No Conversion	47
FILE	17, 47, 49	Types, Properties Of	28
File Access Functions		Floating-Point, See float.h	
fclose	54	Floating-Point Error Signal	38
fflush	57	floor	166
fopen	60	Double Floating-Point	166
freopen	66	Single Floating-Point	166
setbuf	85	floorf	166
setvbuf	86	FLT_DIG	30
File Access Modes	47, 60	FLT_EPSILON	30
File Buffering		FLT_MANT_DIG	30
Fully Buffered	47, 50	FLT_MAX	30
Line Buffered	47, 50	FLT_MAX_10_EXP	30
Unbuffered	47, 50	FLT_MAX_EXP	31
File Operations		FLT_MIN	31
Remove	81	FLT_MIN_10_EXP	31
Rename	81	FLT_MIN_EXP	31
File Positioning Functions		FLT_RADIX	31
fgetpos	58	FLT_RADIX Digit	
fseek	68	Number Of	28, 30, 32
fsetpos	69	FLT_ROUNDS	31
ftell	71	Flush	57, 104
rewind	82	fmod	167
FILENAME_MAX	50	fmodf	169
File-Position Indicator	47, 49, 57, 58, 63, 64, 69, 72	-fno-short-double	28, 29, 30, 48
Files, Maximum Number Open	50	fopen	47, 60, 86, 197
Fixed Point Math Library	213	FOPEN_MAX	50
flags	77	Form Feed	23
float.h	28	Format Specifiers	77, 83
DBL_DIG	28	Formatted I/O Routines	47
DBL_EPSILON	28	Formatted Input/Output Functions	
DBL_MANT_DIG	28	fprintf	62
DBL_MAX	28	fscanf	66
DBL_MAX_10_EXP	29	printf	77
DBL_MAX_EXP	29	scanf	83
DBL_MIN	29	sprintf	87
DBL_MIN_10_EXP	29	sscanf	87
DBL_MIN_EXP	30	vfprintf	91
FLT_DIG	30	vprintf	92
FLT_EPSILON	30	vsprintf	93
FLT_MANT_DIG	30	Formatted Text	
FLT_MAX	30	Printing	87
FLT_MAX_10_EXP	30	Scanning	87
FLT_MAX_EXP	31	fpos_t	49
FLT_MIN	31	fprintf	47, 62

16-Bit Language Tools Libraries

fputc	63	Hexadecimal.....	78, 84, 115, 116
fputs	63	Hexadecimal Conversion	77
fraction and exponent function		Hexadecimal Digit	
Double Floating-Point	171	Defined.....	24
Single Floating-Point.....	172	Test for	24
Fraction Digits	77	Horizontal Tab.....	23
fread	64, 198	Hour.....	141, 142, 146
free	105	HUGE_VAL	151
Free Memory.....	105	Hyperbolic Cosine	
freopen	47, 66, 197	Double Floating-Point.....	161
frexp	171	Single Floating-Point	162
frexpf	172	Hyperbolic Functions	
fscanf.....	47, 66	cosh.....	161
fseek.....	68, 89, 197	coshf.....	162
fsetpos.....	69, 89, 197	sinh.....	186
ftell.....	71, 197	sinhf.....	187
Full Buffering	85, 86	tanh	191
Fully Buffered	47, 50	tanhf	192
fwrite.....	72	Hyperbolic Sine	
G		Double Floating-Point.....	186
getc	74	Single Floating-Point	187
getchar	75	Hyperbolic Tangent	
getenv	105, 200	Double Floating-Point.....	191
gets	75, 198	hyperbolic tangent	
GMT	144	Single Floating-Point	192
gmtime	144, 145	I	
Graphical Character		Ignore Signal	37
Defined.....	20	Illegal Instruction Signal	39
Test for.....	20	Implementation-Defined Limits, See limits.h	
Greenwich Mean Time	144	Indicator	
H		End Of File	47, 50
h modifier	78, 83	Error	47, 56
Handler		File Position.....	47, 57, 58, 63, 64, 69, 72
Default.....	37	Infinity	151
Error	102	init_prog_address.....	211
Interrupt.....	41	Input and Output, See stdio.h	
Nested.....	36	Input Formats	47
Signal	37, 42	Instruction Cycles	144, 145, 148
Signal Type	37	int	
Handling		Maximum Value	33
Interrupt Signal.....	42	Minimum Value	33
Header Files		INT_MAX.....	33
assert.h	17	INT_MIN	33
ctype.h	18	Integer Limits.....	33
errno.h.....	27, 151, 197	Internal Error Message	129
float.h	28	Internet Address, Microchip.....	8
libq.h	219	Interrupt Handler	41
limits.h	33	Interrupt Signal	39
locale.h.....	35	Interrupt Signal Handling.....	42
math.h	151	Interruption Message.....	39
setjmp.h	36	Invalid Executable Code Message	39
signal.h.....	37	Invalid Storage Request Message	40
stdarg.h	43	Inverse Cosine, See arccosine	
stddef.h	45	Inverse Sine, See arcsine	
stdio.h	47, 200	Inverse Tangent, See arctangent	
stdlib.h.....	94, 200	IOBF	50, 85, 86
string.h	118	IOLBF	50, 86
time.h	141, 201	IONBF	50, 85, 86
Heap.....	196	isalnum	18
		isctrl.....	19

isdigit	20
isgraph	20
isalpha	18
islower	21
isprint	22
ispunct	22
isspace	23
isupper	24
isxdigit	24

J

jmp_buf	36
Justify	77

L

L modifier	78, 83
l modifier	78, 83
L_tmpnam	51, 89
labs	106
LC_ALL	35
LC_COLLATE	35
LC_CTYPE	35
LC_MONETARY	35
LC_NUMERIC	35
LC_TIME	35
lconv, struct	35
LDBL_DIG	31
LDBL_EPSILON	32
LDBL_MANT_DIG	32
LDBL_MAX	32
LDBL_MAX_10_EXP	32
LDBL_MAX_EXP	32
LDBL_MIN	32
LDBL_MIN_10_EXP	32
LDBL_MIN_EXP	33
ldexp	173
ldexpf	174
ldiv	94, 107
ldiv_t	94
Leap Second	141, 147
Left Justify	77
libc	13
libdsp	12
libm	13
libp	12
libpic30	13
libpic30, Rebuilding	194
libq.h	219
Libraries	
Fixed Point Math	213
Math	149
Standard C	15
Standard C Math	151
Support	193
Limits	
Floating-Point	28
Integer	33
limits.h	33
CHAR_BITS	33
CHAR_MAX	33
CHAR_MIN	33

INT_MAX	33
INT_MIN	33
LLONG_MAX	33
LLONG_MIN	34
LONG_MAX	34
LONG_MIN	34
MB_LEN_MAX	34
SCHAR_MAX	34
SCHAR_MIN	34
SHRT_MAX	34
SHRT_MIN	34
UCHAR_MAX	35
UINT_MAX	35
ULLONG_MAX	35
ULONG_MAX	35
USHRT_MAX	35
LINE	17
Line Buffered	47, 50
Line Buffering	86
ll modifier	78, 83
LLONG_MAX	33
LLONG_MIN	34
Load Exponent Function	
Double Floating-Point	173
Single Floating-Point	174
Local Time	143, 145, 146
Locale, C	18, 35
Locale, Other	35
locale.h	35
localeconv	35
Localization, See locale.h	
localtime	143, 144, 145
Locate Character	125
log	176
log10	177
log10f	178
Logarithm Function	
Double Floating-Point	177
Single Floating-Point	178
Logarithm Function, Natural	
Double Floating-Point	176
Single Floating-Point	179
logf	179
Logic Errors, Debugging	17
Long Double Precision Floating-Point	
Machine Epsilon	32
Maximum Exponent (base 10)	32
Maximum Exponent (base 2)	32
Maximum Value	32
Minimum Exponent (base 10)	32
Minimum Exponent (base 2)	33
Minimum Value	32
Number of Binary Digits	32
Number of Decimal Digits	31
long double Type	48
long int	
Maximum Value	34
Minimum Value	34
long long int	
Maximum Value	33

16-Bit Language Tools Libraries

Minimum Value	34
long long unsigned int	
Maximum Value	35
long unsigned int	
Maximum Value	35
LONG_MAX	34
LONG_MIN	34
longjmp	36
Lower Case Alphabetic Character	
Convert To	25
Defined	21
Test for	21
lseek	197

M

Machine Epsilon	
Double Floating-Point	28
Long Double Floating-Point	32
Single Floating-Point	30
Magnitude	151, 163, 164, 167, 169, 186, 187
malloc	105, 108, 195, 198
Mapping Characters	18
Math Exception Error	102
Math Library	149
math.h	151
acos.	151
acosf.	152
asin.	153
asinf	153
atan.	154
atan2.	155
atan2f.	157
atanf.	155
ceil	158
ceilf	159
cos	159
cosf	160
cosh	161
coshf	162
exp	163
expf	164
fabs	165
fabsf	165
floor	166
floorf	166
fmod	167
fmodf	169
frexp	171
frexpf	172
HUGE_VAL	151
ldexp	173
ldexpf	174
log	176
log10	177
log10f	178
logf	179
modf	180
modff	181
pow	182
powf	183
sin	184

sinf	185
sinh	186
sinhf	187
sqrt	188
sqrtf	189
tan	190
tanf	190
tanh	191
tanhf	192
Mathematical Functions, See libq.h	
Mathematical Functions, See math.h	
MathError	41
Maximum	
Multibyte Character	95
Maximum Value	
Double Floating-Point Exponent (base 10)	29
Double Floating-Point Exponent (base 2)	29
Long Double Floating-Point Exponent (base 10) ..	32
Long Double Floating-Point Exponent (base 2) ..	32
Multibyte Character	34
rand	95
Single Floating-Point Exponent (base 10)	30
Single Floating-Point Exponent (base 2)	31
Type char	33
Type Double	28
Type int	33
Type Long Double	32
Type long int	34
Type long long int	33
Type long long unsigned int	35
Type long unsigned int	35
Type short int	34
Type signed char	34
Type Single	30
Type unsigned char	35
Type unsigned int	35
Type unsigned short int	35
MB_CUR_MAX	95
MB_LEN_MAX	34
mblen	109
mbstowcs	109
mbtowc	109
memchr	118
memcmp	119
memcpy	121
memcpy_p2d16	209
memcpy_p2d24	210
memmove	122
Memory	
Allocate	102, 108
Deallocate	105
Free	105
Reallocate	111
memset	123
Message	
Arithmetic Error	38
Interrupt	39
Invalid Executable Code	39
Invalid Storage Request	40

Termination Request	40
Minimum Value	
Double Floating-Point Exponent (base 10)	29
Double Floating-Point Exponent (base 2)	30
Long Double Floating-Point Exponent (base 10) ..	32
Long Double Floating-Point Exponent (base 2) ..	33
Single Floating-Point Exponent (base 10)	31
Single Floating-Point Exponent (base 2)	31
Type char	33
Type Double	29
Type int	33
Type Long Double	32
Type long int	34
Type long long int	34
Type short int	34
Type signed char	34
Type Single	31
Minute	141, 142, 147
mkttime	146
modf	180
modff	181
modulus function	
Double Floating-Point	180
Single Floating-Point	181
Month	141, 142, 146, 147
-msmart-io	47
Multibyte Character	95, 109, 117
Maximum Number of Bytes	34
Multibyte String	109, 117
N	
NaN	151
Natural Logarithm	
Double Floating-Point	176
Single Floating-Point	179
NDEBUG	17
Nearest Integer Functions	
ceil	158
ceilf	159
floor	166
floorf	166
Nested Signal Handler	36
Newline	23, 47, 59, 64, 75, 76, 80
No Buffering	47, 50, 85, 86
Non-Local Jumps, See setjmp.h	
NSETJMP	36
NULL	35, 45, 51, 95, 118, 142
O	
Object Module Format	12
Octal	78, 84, 115, 116
Octal Conversion	77
offsetof	46
OMF	12
open	197
Output Formats	47
Overflow Errors ..	27, 151, 163, 164, 173, 174, 182, 183
Overlap	121, 122, 124, 127, 130, 133

P

Pad Characters	77
Percent	78, 83, 84, 147
Peripheral Libraries	12
perror	76
pic30-libs	
__attach_input_file	201
__C30_UART	202
__close_input_file	201
__delay_ms	202
__delay_us	202
__delay32	202
__erase_eedata	204
__erase_eedata_all	204
__erase_flash	206, 207
__exit	195
__init_prog_address	211
__memcpy_p2d16	209
__memcpy_p2d24	210
__strncpy_p2d16	210
__strncpy_p2d24	210
__wait_eedata	205
__write_eedata_row	205
__write_eedata_word	205
__write_flash_word16	208
__write_flash_word24	208
__write_flash16	207
__write_flash24	207
brk	195
close	196
getenv	200
lseek	197
open	197
read	198
remove	200
rename	200
sbrk	198
system	200
time	201
write	199
Plus Sign	77
Pointer, Temporary	111
pow	182
Power Function	
Double Floating-Point	182
Single Floating-Point	183
Power Functions	
pow	182
powf	183
powf	183
precision	77
Prefix	24, 77
Print Formats	47
Printable Character	
Defined	22
Test for	22
printf	47, 77
Processor Clocks per Second	141
Processor Time	141, 142
Pseudo-Random Number	111, 113

16-Bit Language Tools Libraries

ptrdiff_t	45	From Current Position	68
Punctuation Character		From End Of File	68
Defined.....	22	SEEK_CUR	51, 68
Test for.....	22	SEEK_END	52, 68
Pushed Back	89	SEEK_SET	52, 68
putc	79	setbuf.....	47, 50, 85
putchar	80	setjmp	36
puts	80	setjmp.h	36
Q		jmp_buf	36
Q15 Functions	219	longjmp.....	36
Q16 Functions	228	setjmp.....	36
qsort	100, 110	setlocale	35
Quick Sort	110	setvbuf.....	47, 50, 86
R		short int	
Radix	31	Maximum Value	34
raise	37, 38, 39, 40, 41, 42	Minimum Value	34
rand	111, 113	SHRT_MAX.....	34
RAND_MAX	95, 111	SHRT_MIN	34
Range.....	84	sig_atomic_t	37
Range Error27, 115, 116, 161, 162, 163, 164, 173, 174,		SIG_DFL	37
.....	182, 183, 186, 187	SIG_ERR	37
read	198	SIG_IGN.....	37
Reading, Recommended.....	7	SIGABRT.....	38
realloc	105, 111	SIGFPE	38
Reallocate Memory	111	SIGILL	39
Rebuilding the libpic30 library	194	SIGINT	39
Registered Functions	96, 104	Signal	
Remainder		Abnormal Termination.....	38
Double Floating-Point	167	Error	37
Single Floating-Point.....	169	Floating-Point Error.....	38
Remainder Functions		Ignore	37
fmod	167	Illegal Instruction	39
fmodf	169	Interrupt.....	39
remove	81, 200	Reporting.....	41
rename	81, 200	Termination Request.....	40
Reset.....	95, 117	signal.....	38, 39, 40, 42
Reset File Pointer.....	82	Signal Handler.....	37, 42
rewind.....	82, 89, 197	Signal Handler Type.....	37
Rounding Mode.....	31	Signal Handling, See signal.h	
S		signal.h	37
sbrk	196, 198	raise	41
Scan Formats	47	sig_atomic_t.....	37
scanf.....	47, 83	SIG_DFL	37
SCHAR_MAX	34	SIG_ERR	37
SCHAR_MIN	34	SIG_IGN.....	37
Search Functions		SIGABRT	38
memchr	118	SIGFPE	38
strchr	125	SIGILL	39
strcspn	128	SIGINT	39
strpbrk	135	signal.....	42
strrchr	136	SIGSEGV	40
strspn	137	SIGTERM.....	40
strstr	138	signed char	
strtok	139	Maximum Value	34
Second	141, 142, 144, 147	Minimum Value	34
Seed	111, 113	SIGSEGV	40
Seek		SIGTERM	40
From Beginning of File.....	68	sim30 simulator	194
		sin	184
		sine	

Double Floating-Point	184	_IOFBF	50
Single Floating-Point	185	_IOLBF	50
sinf	185	_IONBF	50
Single Precision Floating-Point		BUFSIZ	50
Machine Epsilon	30	clearerr	53
Maximum Exponent (base 10)	30	EOF	50
Maximum Exponent (base 2)	31	fclose	54
Maximum Value	30	feof	55
Minimum Exponent (base 10)	31	ferror	56
Minimum Exponent (base 2)	31	fflush	57
Minimum Value	31	fgetc	57
Number of Binary Digits	30	fgetpos	58
Number of Decimal Digits	30	fgets	59
sinh	186	FILE	49
sinhf	187	FILENAME_MAX	50
size	78	fopen	60
size_t	45, 50, 94, 118, 141	FOPEN_MAX	50
sizeof	45, 50, 94, 118, 141	fpos_t	49
Sort, Quick	110	fprintf	62
Source File Name	17	fputc	63
Source Line Number	17	fputs	63
Space	77	fread	64
Space Character		freopen	66
Defined	23	fscanf	66
Test for	23	fseek	68
Specifiers	77, 83	fsetpos	69
sprintf	47, 87	ftell	71
sqrt	188	fwrite	72
sqrtf	189	getc	74
Square Root Function		getchar	75
Double Floating-Point	188	gets	75
Single Floating-Point	189	L_tmpnam	51
Square Root Functions		NULL	51
sqrt	188	perror	76
sqrtf	189	printf	77
srand	113	putc	79
sscanf	47, 87	putchar	80
Stack	196	puts	80
Standard C Libraries	15	remove	81
Standard C Locale	18	rename	81
Standard Error	47, 52	rewind	82
Standard Input	47, 52	scanf	83
Standard Output	47, 52	SEEK_CUR	51
Start-up	47	SEEK_END	52
Module, Alternate	12	SEEK_SET	52
Module, Primary	12	setbuf	85
stdarg.h	43	setvbuf	86
va_arg	43	size_t	50
va_end	45	sprintf	87
va_list	43	sscanf	87
va_start	45	stderr	52
stddef.h	45	stdin	52
NULL	45	stdout	52
offsetof	46	TMP_MAX	52
ptrdiff_t	45	tmpfile	88
size_t	45	tmpnam	89
wchar_t	45	ungetc	89
stderr	17, 47, 51, 52, 76	vfprintf	91
stdin	47, 51, 52, 75, 83	vprintf	92
stdio.h	47, 200	vsprintf	93

16-Bit Language Tools Libraries

stdlib.h	94, 200	string.h	118
abort	95	memchr	118
abs	96	memcmp	119
atexit	96	memcpy	121
atof	98	memmove	122
atoi	99	memset	123
atol	99	NULL	118
bsearch	100	size_t	118
calloc	102	strcat	124
div	102	strchr	125
div_t	94	strcmp	126
exit	104	strcoll	127
EXIT_FAILURE	94	strcpy	127
EXIT_SUCCESS	94	strcspn	128
free	105	strerror	129
getenv	105	strlen	129
labs	106	strncat	130
ldiv	107	strncmp	132
ldiv_t	94	strncpy	133
malloc	108	strpbrk	135
MB_CUR_MAX	95	strchr	136
mblen	109	strspn	137
mbstowcs	109	strstr	138
mbtowc	109	strtok	139
NULL	95	strxfrm	140
qsort	110	strlen	129
rand	111	strncat	130
RAND_MAX	95	strncmp	132
realloc	111	strncpy	133
size_t	94	strncpy_p2d16	210
srand	113	strncpy_p2d24	210
strtod	113	strpbrk	135
strtol	115	strchr	136
strtoul	116	strspn	137
system	117	strstr	138
wchar_t	94	strtod	98, 113
wctomb	117	strtok	139
wxstombs	117	strtol	99, 115
stdout	47, 51, 52, 77, 80	strtoul	116
strcat	124	struct lconv	35
strchr	125	struct tm	141
strcmp	126	strxfrm	140
strcoll	127	Substrings	139
strcpy	127	Subtracting Pointers	45
strcspn	128	Successful Termination	94
Streams	47	Support Library	193
Binary	47	system	117, 200
Buffering	86	T	
Closing	54, 104	Tab	23
Opening	60	tan	190
Reading From	74	tanf	190
Text	47	tangent	
Writing To	72, 79	Double Floating-Point	190
strerror	129	Single Floating-Point	190
strftime	146	tanh	191
String		tanhf	192
Length	129	Temporary	
Search	138	File	88, 104
Transform	140	Filename	51, 89
String Functions, See string.h		Pointer	111

Termination		
Request Message	40	
Request Signal	40	
Successful	94	
Unsuccessful	94	
Text Mode	60	
Text Streams	47	
Ticks	141, 142, 144	
time	148, 201	
Time Difference	144	
Time Structure	141, 146	
Time Zone	147	
time_t	141, 146, 148	
time.h	141, 201	
asctime	142	
clock	142	
clock_t	141	
CLOCKS_PER_SEC	141	
ctime	143	
difftime	144	
gmtime	144	
localtime	145	
mktime	146	
NULL	142	
size_t	141	
strftime	146	
struct tm	141	
time	148	
time_t	141	
TMP_MAX	52	
tmpfile	88	
tmpnam	89	
Tokens	139	
tolower	25	
toupper	26	
Transferring Control	36	
Transform String	140	
Trigonometric Functions		
acos	151	
acosf	152	
asin	153	
asinf	153	
atan	154	
atan2	155	
atan2f	157	
atanf	155	
cos	159	
cosf	160	
sin	184	
sinf	185	
tan	190	
tanf	190	
type	78, 84	
U		
UCHAR_MAX	35	
UINT_MAX	35	
ULLONG_MAX	35	
ULONG_MAX	35	
Underflow Errors 27, 151, 163, 164, 173, 174, 182, 183		
ungetc	89	
Universal Time Coordinated	144	
unsigned char		
Maximum Value	35	
unsigned int		
Maximum Value	35	
unsigned short int		
Maximum Value	35	
Unsuccessful Termination	94	
Upper Case Alphabetic Character		
Convert To	26	
Defined	24	
Test for	24	
USHRT_MAX	35	
UTC	144	
Utility Functions, See stdlib.h		
V		
va_arg	43, 45, 91, 92, 93	
va_end	45, 91, 92, 93	
va_list	43	
va_start	45, 91, 92, 93	
Variable Argument Lists, See stdarg.h		
Variable Length Argument List	43, 45, 91, 92, 93	
VERBOSE_DEBUGGING	17	
Vertical Tab	23	
vfprintf	47, 91	
vprintf	47, 92	
vsprintf	47, 93	
W		
wait_eeedata	205	
wchar_t	45, 94	
wcstombs	117	
wctomb	117	
Web Site, Microchip	8	
Week	147	
White Space	83, 98, 99, 113	
White-Space Character		
Defined	23	
Test for	23	
wide	94	
Wide Character	109, 117	
Wide Character String	109, 117	
Wide Character Value	45	
Width	77	
width	77, 83	
write	199	
write_eeedata_row	205	
write_eeedata_word	205	
write_flash_word16	208	
write_flash_word24	208	
write_flash16	207	
write_flash24	207	
Y		
Year	141, 142, 147	
Z		
Zero	151	
Zero, divide by	38, 41, 102	



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