16-Bit Language Tools Libraries Reference Manual

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MICROCHIP

16-BIT LANGUAGE TOOLS LIBRARIES REFERENCE MANUAL

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Preface

NOTICE TO CUSTOMERS

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

Documents are identified with a "DS" number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is "DSXXXXXXXXA", where "XXXXXXXX" 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 online help. Select the Help menu, and then Topics to open a list of available online 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 is organized in the following order:

- **Chapter 1: Library Overview** – gives an overview of libraries. Some are described further in this document, while others are described in other documents or online 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

CONVENTIONS USED IN THIS GUIDE

The following conventions may appear in this documentation:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic	Referenced books	*MPLAB® IDE User's Guide*
	Emphasized text	...is the *only* 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	*File>Save*
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	*`file`*`.o`, where *`file`* can be any valid filename
Square brackets [ ]	Optional arguments	`mpasmwin [options]` *`file`* `[options]`
Curly brackets and pipe character: { | }	Choice of mutually exclusive arguments; an OR selection	`errorlevel {0|1}`
Ellipses...	Replaces repeated text	`var_name [, var_name...]`
	Represents code supplied by user	`void main (void) { ... }`

RECOMMENDED READING

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.

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.

To register, access the Microchip web site at www.microchip.com, click on Customer Change Notification and follow the registration instructions.

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.This includes the MPLAB REAL ICE™ and MPLAB ICE™ 2000 in-circuit emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB® ICD 3 in-circuit debuggers and PICkit™ 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 production programmers such as MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger and MPLAB PM3 device programmers. Also included are nonproduction development programmers such as PICSTART® Plus and PICkit 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://www.microchip.com/support.

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 XC16 Assembler, Linker and Utilities User's Guide"* (DS50002106) for more information about making and using libraries.

1.1.1 Compiler Installation Locations

The majority of the libraries discussed in this manual come with the MPLAB® XC16 C Compiler, which is installed by default in the following locations:

- Windows OS 32-bit - `C:\Program Files\Microchip\xc16\`*`x.xx`*
- Windows OS 64-bit - `C:\Program Files (x86)\Microchip\xc16\`*`x.xx`*
- Mac OS - `Applications/microchip/xc16/`*`x.xx`*
- Linux OS - `/opt/microchip/xc16/`*`x.xx`*

(where *`x.xx`* is the version number).

1.1.2 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 XC16 C Compiler.

1.1.3 C Code Applications

The 16-bit language tool libraries are included in the `lib` subdirectory of the MPLAB XC16 C Compiler install directory (Section 1.1.1 "Compiler Installation Locations").

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

1.1.4 Chapter Organization

This chapter is organized in the following order:

- 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

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 `XC16_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® XC16 Assembler, Linker and Utilities User's Guide"* (DS52106) and, for C applications, the *"MPLAB® XC16 C Compiler User's Guide"* (DS00052071).

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 provided. By default, the documentation is found in the `docs\dsp_lib` subdirectory of the MPLAB XC16 C Compiler install directory (see Section 1.1.1 "Compiler Installation Locations").

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 `libp`*`Device`*`-`*`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 the `docs\periph_lib` subdirectory of the MPLAB XC16 C Compiler install directory (see Section 1.1.1 "Compiler Installation Locations").

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 XC16 C Compiler contains built-in functions that, to the developer, work like library functions. These functions are listed in the *“MPLAB XC16 C Compiler Users’ Guide”* (DS50002071).

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 XC16 C Compiler install directory (Section 1.1.1 “Compiler Installation Locations”) 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® XC16 Assembler, Linker and Utilities User's Guide"* (DS52106) and *"MPLAB® XC16 C Compiler User's Guide"* (DS00052071) 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:	`<ctype.h>`
Prototype:	`int isalnum(int c);`
Argument:	`c` 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:

```
#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");
}
```

Output:

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

isalpha

Description:	Test for an alphabetic character.
Include:	<ctype.h>
Prototype:	`int isalpha(int c);`
Argument:	`c` 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
```

iscntrl

Description: Test for a control character.

Include: `<ctype.h>`

Prototype: `int iscntrl(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 iscntrl */
#include <stdio.h> /* for printf */

int main(void)
{
  char ch;

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

  ch = '\t';
  if (iscntrl(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:

```
#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");
}
```

Output:

```
3 is a digit
# is NOT a digit
```

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:

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

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

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 lowercase 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 lowercase alphabetic character; otherwise, returns zero.
Remarks:	A character is considered to be a lowercase alphabetic character if it is in the range of ‘a’-‘z’.

Example:

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

int main(void)
{
  int ch;

  ch = 'B';
  if (islower(ch))
    printf("B is lowercase\n");
  else
    printf("B is NOT lowercase\n");

  ch = 'b';
  if (islower(ch))
    printf("b is lowercase\n");
  else
    printf("b is NOT lowercase\n");
}
```

islower (Continued)

Output:

```
B is NOT lowercase
b is lowercase
```

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:

```
#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");
}
```

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 uppercase 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 uppercase alphabetic character; otherwise, returns zero.

Remarks: A character is considered to be an uppercase 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 uppercase\n");
  else
    printf("B is NOT uppercase\n");

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

Output:

```
B is uppercase
b is NOT uppercase
```

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 lowercase alphabetical character.

Include: `<ctype.h>`

Prototype: `int tolower (int c);`

Argument: *c* The character to convert to lowercase.

Return Value: Returns the corresponding lowercase alphabetical character if the argument was originally uppercase; otherwise, returns the original character.

Remarks: Only uppercase 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 lowercase %c\n",
          tolower(ch));

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

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

tolower (Continued)

Output:

```
B changes to lowercase b
b remains lowercase b
@ has no lowercase, so @ is returned
```

toupper

Description:	Convert a character to an uppercase alphabetical character.
Include:	`<ctype.h>`
Prototype:	`int toupper (int c);`
Argument:	*c* The character to convert to uppercase.
Return Value:	Returns the corresponding uppercase alphabetical character if the argument was originally lowercase; otherwise, returns the original character.
Remarks:	Only lowercase alphabetical characters may be converted to uppercase.

Example:

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

int main(void)
{

  int ch;

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

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

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

Output:

```
b changes to uppercase B
B remains uppercase B
@ has no uppercase, 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:	`<errno.h>`
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:	`<errno.h>`
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:	`<errno.h>`
Remarks:	The variable `errno` is set to a non-zero integer value by a library function when an error occurs. At program start-up, `errno` is set to zero. `Errno` should be reset to zero prior to calling a function that sets it.

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:	`<float.h>`
Value:	6 by default, 15 if the switch `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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:	`<float.h>`
Value:	1.192093e-07 by default, 2.220446e-16 if the switch `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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:	`<float.h>`
Value:	24 by default, 53 if the switch `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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:	`<float.h>`
Value:	3.402823e+38 by default, 1.797693e+308 if the switch `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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 `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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 `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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 `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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 `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` switch allows the IEEE 64-bit representation to be used for a double precision floating-point value.

DBL_MIN_EXP

Description:	Minimum negative integer value for a double precision floating-point exponent in base `FLT_RADIX`.
Include:	`<float.h>`
Value:	-125 by default, -1021 if the switch `-fno-short-double` is used
Remarks:	By default, a double type is the same size as a float type (32-bit representation). The `-fno-short-double` 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:	`<float.h>`
Value:	6

FLT_EPSILON

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

FLT_MANT_DIG

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

FLT_MAX

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

FLT_MAX_10_EXP

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

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

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

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 accesses 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:	`<signal.h>`
Prototype:	`typedef int sig_atomic_t;`

SIG_DFL

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

SIG_ERR

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

SIG_IGN

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

SIGABRT

Description: Name for the abnormal termination signal.

Include: `<signal.h>`

Prototype: `#define SIGABRT`

Remarks: `SIGABRT` represents an abnormal termination signal and is used in conjunction with `raise` or `signal`. The default `raise` behavior (action identified by `SIG_DFL`) is to output to the standard error stream:

```
abort - terminating
```

See the example accompanying `signal` to see general usage of signal names and signal handling.

Example:

```
#include <signal.h> /* for raise, SIGABRT */
#include <stdio.h> /* for printf */

int main(void)
{
  raise(SIGABRT);
  printf("Program never reaches here.");
}
```

Output:

```
ABRT
```

Explanation:
ABRT stands for “abort”.

SIGFPE

Description: Signals floating-point errors such as for division by zero or result out of range.

Include: `<signal.h>`

Prototype: `#define SIGFPE`

Remarks: `SIGFPE` is used as an argument for `raise` and/or `signal`. 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 `signal` for an example of a user-defined function.

Example:

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

int main(void)
{
  raise(SIGFPE);
  printf("Program never reaches here");
}
```

Output:

```
FPE
```

Explanation:
FPE stands for “floating-point error”.

SIGILL

Description: Signals illegal instruction.

Include: `<signal.h>`

Prototype: `#define SIGILL`

Remarks: `SIGILL` is used as an argument for `raise` and/or `signal`. 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 `signal` for an example of a user-defined function.

Example:

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

int main(void)
{
  raise(SIGILL);
  printf("Program never reaches here");
}
```

Output:

```
ILL
```

Explanation:
ILL stands for “illegal instruction”.

SIGINT

Description: Interrupt signal.

Include: `<signal.h>`

Prototype: `#define SIGINT`

Remarks: `SIGINT` is used as an argument for `raise` and/or `signal`. 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 `signal` for an example of a user-defined function.

Example:

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

int main(void)
{
  raise(SIGINT);
  printf("Program never reaches here.");
}
```

Output:

```
INT
```

Explanation:
INT stands for “interruption”.

SIGSEGV

Description: Signals invalid access to storage.

Include: `<signal.h>`

Prototype: `#define SIGSEGV`

Remarks: `SIGSEGV` is used as an argument for `raise` and/or `signal`. 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 `signal` for an example of a user-defined function.

Example:

```
#include <signal.h> /* for raise, SIGSEGV */
#include <stdio.h> /* for printf */

int main(void)
{
  raise(SIGSEGV);
  printf("Program never reaches here.");
}
```

Output:

```
SEGV
```

Explanation:
SEGV stands for “invalid storage access”.

SIGTERM

Description: Signals a termination request.

Include: `<signal.h>`

Prototype: `#define SIGTERM`

Remarks: `SIGTERM` is used as an argument for `raise` and/or `signal`. 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 `signal` for an example of a user-defined function.

Example:

```
#include <signal.h> /* for raise, SIGTERM */
#include <stdio.h> /* for printf */

int main(void)
{
  raise(SIGTERM);
  printf("Program never reaches here.");
}
```

Output:

```
TERM
```

Explanation:
TERM stands for “termination request”.

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

va_start

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

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 `sizeof` 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:	`<stddef.h>`
Prototype:	`#define offsetof(`*`T`*`, `*`mbr`*`)`
Arguments:	*`T`* name of structure *`mbr`* name of member in structure T
Return Value:	Returns the offset in bytes of the specified member (*`mbr`*) from the beginning of the structure.
Remarks:	The macro `offsetof` 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.

It is recommended that these customized functions be allocated in a named section that begins with `.lib`. This will cause the linker to allocate them near to the rest of the library functions, which is where they ought to be.

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:

```
int __attribute__((__section__(".libc.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>`

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.
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`.

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("sampclearerr.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. This function requires a heap.

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
```

fdopen

Description:	Associate a stream with a file descriptor.
Include:	`<stdio.h>`
Prototype:	`FILE *fdopen(int` *`fildes`*`, const char *`*`mode`*`);`
Arguments:	*`fildes`* file descriptor
	`mode` type of access permitted
Return Value:	Returns a pointer to the open stream. If the function fails, a null pointer is returned.
Remarks:	The following are types of file access:

`r` -	opens an existing text file for reading
`w` -	opens an empty text file for writing.
`a` -	opens a text file for appending.
`rb` -	opens an existing binary file for reading.
`wb` -	opens an empty binary file for writing.
`ab` -	opens a binary file for appending.
`r+` -	opens an existing text file for reading and writing.
`w+` -	opens an empty text file for reading and writing.
`a+` -	opens a text file for reading and appending.
`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.
`a+b` or `ab+` -	opens a binary file for reading and appending.

This function requires a heap.

Example:

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

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

fdopen (Continued)

```
    if ((myfile1 = fdopen("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 = fdopen("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 = fdopen("afile2", "a+")) == 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
Cannot open afile2
```

Explanation:

`afile1` must exist before it can be opened for reading (`r`) or the `fdopen` function will fail.

If the `fdopen` function opens a file for writing (`w+`) that doesn't exist, it will be created and then opened. If the file does exist, it cannot be overwritten and will be appended.

If the `fdopen` function attempts to append a file (`a+`) that doesn't exist, it will NOT be created and `fdopen` will fail. If the file does exist, it will be opened for appending.

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.
```

ferror

Description: Tests if error indicator is set.

Include: `<stdio.h>`

Prototype: `int ferror(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 ferror 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 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("sampclearerr.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
```

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:	*stream* target stream
	pos 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:

```
/* 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
```

fgets

Description:	Get a string from a stream.
Include:	`<stdio.h>`
Prototype:	`char *fgets(char *s, int n, FILE *stream);`
Arguments:	*s* — pointer to the storage string
	n — maximum number of characters to read
	stream — pointer to the open stream.
Return Value:	Returns a pointer to the string *s* 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 *s* until it has read n-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 `fgets` sets the error indicator, the array contents are indeterminate.

Example:

```
#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);
  }
}
```

Input:
Contents of `afile.txt` (used as input):

```
Short
Longer string
```

Output:

```
Short
|Longer string
|
```

fopen

Description:	Opens a file.
Include:	`<stdio.h>`
Prototype:	`FILE *fopen(const char *filename, const char *mode);`
Arguments:	*filename* name of the file
	mode type of access permitted
Return Value:	Returns a pointer to the open stream. If the function fails a null pointer is returned.
Remarks:	The following are 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).
	This function requires a heap.

Example:

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

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

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:

stream	pointer to the stream in which to output data
format	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 `print`.

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 c, FILE *stream);`
Arguments:	*`c`* character to be written
	`stream` 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:

```
#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);
  }
}
```

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 *s, FILE *stream);`
Arguments:	*`s`* string to be written
	`stream` 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:

```
#include <stdio.h> /* for fputs, stdout */

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

  fputs(buf,stdout);
  fputs("|",stdout);
}
```

Output:

```
This is text
|
```

fread

Description:	Reads data from the stream.
Include:	`<stdio.h>`
Prototype:	`size_t fread(void *ptr, size_t size, size_t nelem, FILE *stream);`
Arguments:	*ptr* pointer to the storage buffer
	size size of item
	nelem maximum number of items to be read
	stream pointer to the stream
Return Value:	Returns the number of complete elements read up to *nelem* whose size is specified by size.
Remarks:	The function reads characters from a given stream into the buffer pointed to by *ptr* until the function stores *size * nelem* characters or sets the end-of-file or error indicator. `fread` returns n/size where n is the number of characters it read. If n is not a multiple of size, the value of the last element is indeterminate. If the function sets the error indicator, the file-position indicator is indeterminate.

Example:

```
#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");
```

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.

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:

filename	name of the new file
mode	type of access permitted
stream	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.
This function requires a heap.

Example:

```
#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);
    }
  }
}
```

Output:

```
afile1 was opened
afile2 was opened
```

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.

fscanf

Description: Scans formatted text from a stream.

fscanf (Continued)

Include: `<stdio.h>`

Prototype: `int fscanf(FILE *stream, const char *format, ...);`

Arguments:

stream	pointer to the open stream from which to read data
format	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 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 `scanf`.

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
```

fscanf (Continued)

Output:

```
Print
this
string
100
times
```

fseek

Description:	Moves file pointer to a specific location.
Include:	`<stdio.h>`
Prototype:	`int fseek(FILE *stream, long offset, int mode);`
Arguments:	*stream* stream in which to move the file pointer.
	offset value to add to the current position
	mode 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:

```
#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("\"%s\"\n\n", s);
    }
```

fseek (Continued)

```
    y = fseek(myfile, 2L, SEEK_CUR);
    if (y)
      perror("Fseek failed");
    else
    {
      fgets(s, 70, myfile);
      printf("\"%s\"\n\n", s);
    }

    y = fseek(myfile, -16L, SEEK_END);
    if (y)
      perror("Fseek failed");
    else
    {
      fgets(s, 70, myfile);
      printf("\"%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:	`<stdio.h>`
Prototype:	`int fsetpos(FILE *`*`stream`*`, const fpos_t *`*`pos`*`);`
Arguments:	*`stream`* target stream
	`pos` position-indicator storage as returned by an earlier call to `fgetpos`
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 `*`*`pos`* if successful; otherwise, `fsetpos` sets *`errno`*.

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:	`size_t fwrite(const void *ptr, size_t size, size_t nelem, FILE *stream);`
Arguments:	*ptr* pointer to the storage buffer
	size size of item
	nelem maximum number of items to be read
	stream pointer to the open stream
Return Value:	Returns the number of complete elements successfully written, which will be less than *nelem* only if a write error is encountered.
Remarks:	The function writes characters to a given stream from a buffer pointed to by *ptr* up to *nelem* elements whose size is specified by *size*. 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:

```
#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");
```

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 `stdin`.
Include:	`<stdio.h>`
Prototype:	`int getchar(void);`
Return Value:	Returns the character read or EOF if a read error occurs or end-of-file is reached.
Remarks:	Same effect as `fgetc` with the argument `stdin`.

Example:

```
#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);
}
```

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 `stdin`.
Include:	`<stdio.h>`
Prototype:	`char *gets(char *s);`
Argument:	*`s`* pointer to the storage string
Return Value:	Returns a pointer to the string *`s`* if successful; otherwise, returns a null pointer.
Remarks:	The function reads characters from the stream `stdin` and stores them into the string pointed to by *`s`* 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 `gets` 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 `stdout`.
Include:	`<stdio.h>`
Prototype:	`int printf(const char *format, ...);`
Arguments:	*format* format control string `...` optional arguments
Return Value:	Returns number of characters generated or a negative number if an error occurs.

Remarks: There must be exactly the same number of arguments as there are format specifiers. If the 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:

```
%[flags][width][.precision][size]type
```

`flags`

-	left justify the value within a given field width
0	Use 0 for the pad character instead of space (which is the default)
+	generate a plus sign for positive signed values
space	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

`width`

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 `int`) 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.

`precision`

The field width can be followed with dot (.) and a decimal integer representing the precision that specifies one of the following:
- 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

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 int) will be used for the precision.

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, 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

This function requires a heap.

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; otherwise, returns -1.
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; otherwise, returns a non-zero value.
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 `stdin`.
Include:	`<stdio.h>`
Prototype:	`int scanf(const char *format, ...);`
Argument:	*`format`* 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:

```
%[*][width][modifier]type
```

`*`
indicates assignment suppression. This will cause the input field to be skipped and no assignment made.

`width`
specify the maximum number of input characters to match for the conversion, not including white space that can be skipped.

`modifier`

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, 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`

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`. This function requires a heap.

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:	`int setvbuf(FILE *stream, char *buf, int mode, size_t size);`

Arguments:

stream	pointer to the open stream
buf	user allocated buffer
mode	type of buffering
size	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
This function requires a heap.

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 *`*`s`*`, const char *`*`format`*`, ...);`
Arguments:	*`s`* storage string for output
	`format` format control string
	... optional arguments
Return Value:	Returns the number of characters stored in *`s`* 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 *`*`s`*`, const char *`*`format`*`, ...);`
Arguments:	*`s`* storage string for input
	`format` 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
```

tmpfileprintf

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. This function requires a heap.

Example:

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

int main(void)
{
  FILE *mytempfile;

  if ((mytempfile = 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:

```
#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);
}
```

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
```

vasprintf

Description:	Prints formatted text to a string using a variable length argument list.
Include:	`<stdio.h>` `<stdarg.h>`
Prototype:	`int vasprintf(char **s, const char *format, va_list ap);`
Arguments:	*s* storage string for output; *format* format control string; *ap* pointer to a list of arguments
Return Value:	Returns number of characters stored in *s* 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 `vasprintf` function is called. Invoke `va_end` after the function returns. For more details, see `stdarg.h` This function requires a heap.

Example:

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

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

  va_start(ap, fmt);
  vasprintf(bufptr, 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.
```

vfprintf

Description:	Prints formatted data to a stream using a variable length argument list.
Include:	`<stdio.h>` `<stdarg.h>`
Prototype:	`int vfprintf(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 `vfprintf` function is called. Invoke `va_end` after the function returns. For more details, see `stdarg.h`.
This function requires a heap.

Example:

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

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

FILE *myfile;

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

  va_start(ap, fmt);
  vfprintf(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
  {
    errmsg("Error: The letter '%c' is not %s\n", 'a',
          "an integer value.");
    errmsg("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 `stdout` using a variable length argument list.

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

Prototype: `int vprintf(const char *format, va_list ap);`

Arguments:

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 `vprintf` function is called. Invoke `va_end` after the function returns. For more details, see `stdarg.h`

Example:

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

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

  va_start(ap, fmt);
  printf("Error: ");
  vprintf(fmt, ap);
  va_end(ap);
}

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.
```

vsprintf

Description:	Prints formatted text to a string using a variable length argument list.

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

Prototype:	`int vsprintf(char *s, const char *format, va_list ap);`
Arguments:	*s* storage string for output *format* format control string *ap* pointer to a list of arguments
Return Value:	Returns number of characters stored in *s* 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` This function requires a heap.

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.
```

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 `int`.
Include:	`<stdlib.h>`
Prototype:	`typedef struct { int quot, rem; } div_t;`
Remarks:	This is the structure type returned by the function, `div`.

ldiv_t

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

size_t

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

wchar_t

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

EXIT_FAILURE

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

EXIT_SUCCESS

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

key	object to search for
base	pointer to the start of the search data
nelem	number of elements
size	size of elements
cmp	pointer to the comparison function
ck	pointer to the key for the search
ce	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. This function requires a heap.

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 status);`

Argument: *status* 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:

```
#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
```

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. This function requires a heap.

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:	`ldiv_t ldiv(long` *`numer`*`, long` *`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). 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.
The default implementation of `malloc` will require an additional 4 bytes of heap memory per allocation.
The legacy library's `malloc` will use an additional 2 bytes of heap memory per allocation.

Include: `<stdlib.h>`

Prototype: `void *malloc(size_t` *`size`*`);`

Argument:

`size`	number of characters to allocate

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

Remarks: `malloc` does not initialize memory it returns.
This function requires a heap.

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
```

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:

s1	first buffer
s2	second buffer
n	number of characters to compare

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:

```
#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");
```

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:	*dst* buffer to copy characters to *src* buffer to copy characters from *n* number of characters to copy
Return Value:	Returns *dst*.
Remarks:	`memcpy` copies *n* characters from the source buffer *src* to the destination buffer *dst*. If the buffers overlap, the behavior is undefined. For `memcpy_eds`, `memcpy_packed`, `memcpy_p2d16` or `memcpy_p2d1624`, see Section 4.8 "Functions for Specialized Copying and Initialization".

Example:

```
#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);
}
```

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:

s1	buffer to copy characters to (destination)
s2	buffer to copy characters from (source)
n	number of characters to copy from *s2* to *s1*

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:	*s* buffer
	c character to put in buffer
	n 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:	*s1* first string
	s2 second string
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 successive characters from *s1* and *s2* until they are not equal or the null terminator is reached.

Example:

```
#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");
}
```

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. For `strcpy_eds` or `strcpy_packed`, see Section 4.8 "Functions for Specialized Copying and Initialization".

Example:

```
#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 (Continued)

```
  strcpy(buf1, buf2);
  printf("buf1 after strcpy of buf2: \n\t%s\n\n",
         buf1);

  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);
}
```

strcspn (Continued)

Output:

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

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\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)
```

strncmp

Description:	Compare two strings, up to a specified number of characters.
Include:	`<string.h>`
Prototype:	`int strncmp(const char *s1, const char *s2, size_t n);`
Arguments:	*s1* first string
	s2 second string
	n number of characters to compare
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:	`strncmp` returns a value based on the first character that differs between *s1* and *s2*. Characters that follow a null character are not compared.
Example:	

```
#include <string.h> /* for strncmp */
#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 = strncmp(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 = strncmp(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");
```

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.
For `strncpy_eds`, `strncpy_packed`, `strncpy_p2d16` or `strncpy_p2d24`, see Section 4.8 “Functions for Specialized Copying and Initialization”.

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?";
```

strncpy (Continued)

```
  printf("buf1 : %s\n", buf1);
  printf("buf2 : %s\n", buf2);
  printf("buf3 : %s\n", buf3);
  printf("buf4 : %s\n", buf4);

  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:

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

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:

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

int main(void)
{
  char str1[20] = "animal";
  char str2[20] = "aeiounm";
  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);
}
```

strspn (Continued)

Output:

```
strspn("animal", "aeiounm") = 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("\"%s\" found at position %d\n",
          str2, res);
  }
  else
    printf("\"%s\" not found\n", str2);
```

strstr (Continued)

```
  printf("\n");

  ptr = strstr(str1, str3);
if (ptr != NULL)
  {
    res = ptr - str1 + 1;
    printf("\"%s\" found at position %d\n",
           str3, res);
  }
  else
    printf("\"%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:

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 *n* is zero, the string is not transformed (*s1* may be a point null in this case) and the length of *s2* is returned.

Remarks: If the return value is greater than or equal to *n*, the content of *s1* is indeterminate. Since the 16-bit compiler does not support alternate locales, the transformation is equivalent to `strcpy`, except that the length of the destination string is bounded by *n*-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:	*`t1`* ending time
	`t0` beginning time
Return Value:	Returns the number of seconds between *`t1`* and *`t0`*.
Remarks:	By default, the 16-bit compiler returns the time as instruction cycles so `difftime` returns the number of ticks between *`t1`* and *`t0`*.

Example:

```
#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);
}
```

Output:

```
start = 0
stop = 317
Elapsed time = 317
```

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:	*`tod`* pointer to stored time
Return Value:	Returns the address of the time structure.
Remarks:	This function breaks down the *`tod`* 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.
```

time

Description:	Calculates the current calendar time.
Include:	`<time.h>`
Prototype:	`time_t time(time_t *tod);`
Argument:	*tod* 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:

```
#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);
}
```

Output:

```
Time = 256
```

NOTES:

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 XC16 C Compiler install directory (Section 1.1.1 “Compiler Installation Locations”) 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® XC16 Assembler, Linker and Utilities User’s Guide”* (DS50002106) and *“MPLAB® XC16 C Compiler User’s Guide”* (DS50002071) 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:	`HUGE_VAL` 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:	`<math.h>`
Remarks:	`-HUGE_VAL` 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 `+/- HUGE_VAL`, it will be represented by `+/- inf`.

acos

Description:	Calculates the trigonometric arc cosine function of a double precision floating-point value.
Include:	`<math.h>`
Prototype:	`double acos (double x);`
Argument:	*x* 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 *x* is less than -1 or greater than 1.

Example:

```
#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);
```

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 pi 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 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:

```
#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);
  }
}
```

Output:

```
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
```

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:

```
#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);
  }
}
```

Output:

```
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
```

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:

```
#include <math.h>  /* for cos            */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno          */

int main(void)
{
  double x,y;
```

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:

```
#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);
  }
}
```

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
```

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:

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 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);
}
```

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 sinhf (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 sinhf          */
#include <stdio.h> /* for printf, perror */
#include <errno.h> /* for errno          */

int main(void)
{
  float x, y;

  errno = 0;
  x = -1.0F;
  y = sinhf (x);
  if (errno)
    perror("Error");
  printf("The hyperbolic sine of %f is %f\n\n",
          x, y);

  errno = 0;
  x = 0.0F;
  y = sinhf (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:

```
#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);
}
```

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 XC16 C Compiler install directory (Section 1.1.1 "Compiler Installation Locations") 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:

4.2 USING THE SUPPORT FUNCTIONS

Building an application which utilizes the support functions requires two types of files: header files and library files.

- Header Files
- 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® XC16 Assembler, Linker and Utilities User's Guide"* (DS50002106) and *"MPLAB® XC16 C Compiler User's Guide"* (DS50002071) 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.

_dump_heap_info

Description:	Displays the current use/free state of the heap.
Include:	None
Prototype:	`void _dump_heap_info();`
Argument:	None
Remarks:	This helper function can be used to profile memory allocation in the heap. It is useful for memory allocation functions.
Default Behavior:	This function prints information about the heap to `stderr`. Information includes the memory region where heap is located, the different sections of the heap, whether a section is currently busy or free, and a summary of how much heap is free. For example, below, a heap of 1000 has been allocated. The heap begins and ends at d0c and 10f4, respectively. The `malloc` function has been executed 3 different times, resulting in 3 different sections of BUSY memory and 1 FREE memory section of heap that has not been used. If the free function were to be used on any of these 3 allocated sections, the status would turn from BUSY to FREE as well.
File:	`_dump_heap_info.c`

```
*** Unused Heap status:
***   start: 0x00000d0c   end: 0x000010f4
***   0d0c     8 BUSY
***   0d14    16 BUSY
***   0d24    20 BUSY
***   0d38   956 FREE
***   44 used, 956 free, 010f0 end
```

_exit

Description:	Terminate program execution.
Include:	None
Prototype:	`void _exit (int` *`status`*`);`
Argument:	*`status`* exit status
Remarks:	This is a helper function called by the `exit()` Standard C Library function.
Default Behavior:	As distributed, this function flushes stdout and terminates. The parameter status is the same as that passed to the `exit()` standard C library function.
File:	`_exit.c`

brk

Description: Set the end of the process's data space.

Include: None

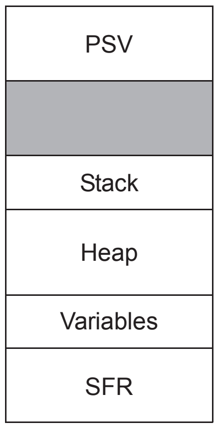
Prototype: `int brk(void *endds);`

Argument: *`endds`* pointer to the end of the data segment

Return Value: Returns '0' if successful; otherwise, returns '-1'.

Remarks: `brk()` 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 `malloc()`.

Default Behavior: If the argument *`endds`* is zero, the function sets the global variable `____curbrk` to the address of the start of the heap and returns zero.
If the argument *`endds`* 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 *`endds`* and returns zero.
Otherwise, the global variable `____curbrk` is unchanged and the function returns -1.
The argument *`endds`* 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`

lseek

Description:	Move a file pointer to a specified location.
Include:	None
Prototype:	`long lseek(int handle, long offset, int origin);`
Argument:	*`handle`* refers to an opened file *`offset`* the number of characters from the origin *`origin`* the position from which to start the seek. *`origin`* may be one of the following values (as defined in `stdio.h`): 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 `fgetpos()`, `ftell()`, `fseek()`, `fsetpos` and `rewind()`.
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:	`lseek.c`

open

Description:	Open a file.
Include:	None
Prototype:	`int open(const char *name, int access, int mode);`
Argument:	*`name`* name of the file to be opened *`access`* access method to open file *`mode`* 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.

open (Continued)

Remarks:	The access flag is a union of one of the following access methods and zero or more access qualifiers: 0 – Open a file for reading. 1 – Open a file for writing. 2 – Open a file for both reading and writing. The following access qualifiers must be supported: 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. The mode parameter may be one of the following: 0x0100 – Reading only permitted. 0x0080 – Writing permitted (implies reading permitted). This helper function is called by the Standard C Library functions `fopen()` and `freopen()`.
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 `errno` is set to the value of the symbolic constant, `EFOPEN`, defined in `<errno.h>`.
File:	`open.c`

read

Description:	Read data from a file.	
Include:	None	
Prototype:	`int read(int handle, void *buffer, unsigned int len);`	
Argument:	*handle*	handle referring to an opened file
	buffer	points to the storage location for read data
	len	the maximum number of characters to read
Return Value:	Returns the number of characters read, which may be less than *len* if there are fewer than *len* 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 `fgetc()`, `fgets()`, `fread()` and `gets()`.	
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:	`read.c`	

sbrk

Description:	Extend the process' data space by a given increment.	
Include:	None	
Prototype:	`void * sbrk(int incr);`	
Argument:	*incr*	number of characters to increment/decrement

sbrk (Continued)

Return Value:	Return the start of the new space allocated or '-1' for errors.
Remarks:	`sbrk()` adds *`incr`* characters to the break value and changes the allocated space accordingly. *`incr`* can be negative, in which case the amount of allocated space is decreased. `sbrk()` 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. This is a helper function called by the Standard C Library function `malloc()`.
Default Behavior:	If the global variable `__curbrk` is zero, the function calls `brk()` to initialize the break value. If `brk()` returns -1, so does this function. If the *`incr`* is zero, the current value of the global variable `__curbrk` is returned. If the *`incr`* is non-zero, the function checks that the address (`__curbrk` + *`incr`*) is less than the end address of the heap. If it is less, the global variable `__curbrk` is updated to that value and the function returns the unsigned value of `__curbrk`. Otherwise, the function returns -1. See the description of `brk()`.
File:	`sbrk.c`

write

Description:	Write data to a file.
Include:	None
Prototype:	`int __attribute__((__section__(".libc.write")))` `write(int` *`handle`*`, void *`*`buffer`*`, unsigned int` *`count`*`);`
Argument:	*`handle`* refers to an opened file; *`buffer`* points to the storage location of data to be written; *`count`* 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:	If the actual space remaining on the disk is less than the size of the buffer, the function 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. This is a helper function called by the Standard C Library function `fflush()`.
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:	`write.c`

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:	`<stdlib.h>`
Prototype:	`char *getenv(const char *s);`
Argument:	*s* 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:	`getenv.c`

remove

Description:	Remove a file.
Include:	`<stdio.h>`
Prototype:	`int remove(const char *filename);`
Argument:	*filename* 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:	`remove.c`

rename

Description:	Rename a file or directory.
Include:	`<stdio.h>`
Prototype:	`int rename(const char *oldname, const char *newname);`
Argument:	*oldname* pointer to the old name *newname* 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:	`rename.c`

system

Description:	Execute a command.
Include:	`<stdlib.h>`
Prototype:	`int system(const char *s);`
Argument:	*s* command to be executed

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 or MPLAB X 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 cycles);`
Argument:	*`cycles`* 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 or equal to 12 will result in 12 cycles). The delay includes the `call` and `return` 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 time);`
Argument:	*`time`* number of ms to delay
Remarks:	This function is implemented as a macro.
Default Behavior:	This function relies on a user-supplied definition of `FCY` to represent the instruction clock frequency. `FCY` must be defined before header file `libpic30.h` is included. The specified delay is converted to the equivalent number of instruction cycles and passed to `__delay32()`. If `FCY` is not defined, then `__delay_ms()` 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 time);`
Argument:	*`time`* 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 `FCY` to represent the instruction clock frequency. `FCY` must be defined before header file, `libpic30.h`, is included. The specified delay is converted to the equivalent number of instruction cycles and passed to `__delay32()`. If `FCY` is not defined, then `__delay_us()` 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;`
Argument:	N/A

__C30_UART (Continued)

Return Value:	N/A
Remarks:	Defines the default UART that `read()` and `write()` will use for `stdin` (unless a file has been attached) and `stdout`.
Default Behavior:	By default, or with a value of 1, UART 1 will be used. Otherwise, UART 2 will be used. `read()` and `write()` 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 defintions */
#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
                              defintions */
#include <stdio.h>

#ifndef __dsPIC33F__
#error this is a 33F demo for the explorer 16(tm) board
#endif
#inlcude <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 dst, int len);`
Argument:	*dst* destination memory address *len* 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`

_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:	*dst* destination memory address *dat* 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:	*dst* destination memory address **src* 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 */

  _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 `_FLASH_PAGE` words (1 word = 3 bytes = 2 PC address units).
Include:	`<libpic30.h>`
Prototype:	`void _erase_flash(_prog_addressT` *`dst`*`);`
Argument:	*`dst`* destination memory address
Return Value:	None.
Remarks:	None.
Default Behavior:	Erase a page of Flash memory.
File:	`flash_helper.s`

_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` *`dst`*`, int` *`len`*`);`
Argument:	*`dst`* destination memory address *`len`* 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_helper2.s`

_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` *`dst`*`, int` *`*src`*`);`
Argument:	*`dst`* destination memory address *`*src`* 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.s`

_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 dst, long *src);`
Argument:	*dst* destination memory address **src* 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.s`

_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:	*dst* destination memory address *dat* 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.s`

_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, long dat);`
Argument:	*dst* destination memory address *dat* 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.s`

_write_flash_word32

Description:	Write two words of FLASH memory with 16 bits of data per word. The 16 bits are written to the low 16 bits of the word. Word writes are supported dsPIC33E and PIC24E devices. The row address is specified with type `_prog_addressT`. Note that the location must be erased before any write can be successful. This function is currently disabled for devices subject to the Device ID errata as described in DS-80444, DS-80446, or DS-80447 (#32).
Include:	`<libpic30.h>`
Prototype:	`void _write_flash_word32(_prog_addressT dst, int dat1, int dat2);`
Argument:	*dst* destination memory address *dat1*, *dat2* integer data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write two words of Flash memory with 16-bit data for most dsPIC33E/PIC24E devices.
File:	`flash_helper.s`

_write_flash_word48

Description:	Write two words of FLASH memory with 24 bits of data per word. Word writes are supported 33E and 24E devices. The row address is specified with type `_prog_addressT`. Note that the location must be erased before any write can be successful. This function is currently disabled for devices subject to the Device ID errata as described in DS-80444, DS-80446, or DS-80447 (#32).
Include:	`<libpic30.h>`
Prototype:	`void _write_flash_word48(_prog_addressT dst, int dat1, int dat2);`
Argument:	*dst* destination memory address *dat1*, *dat2* integer data to be written
Return Value:	None.
Remarks:	None.
Default Behavior:	Write two words of Flash memory with 48-bit data for most dsPIC33E/PIC24E devices.
File:	`flash_helper.s`

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 */

#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_eds

Description:	Copies bytes from one `__eds__` buffer to another `__eds__` buffer.
Include:	`<libpic30.h>`
Prototype:	`__eds__ void* _memcpy_eds(__eds__ void *dest, __eds__ void *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 memory block pointed to by *`dest`*.
Remarks:	`__eds__` pointers are superset of unqualified data pointers; therefore these functions can be used to copy between `__eds__` and unqualified data memory.
Default Behavior:	Copy *`len`* bytes of data from each address pointed to by the *`src`* pointer to the destination pointed to by the *`dest`* pointer.
File:	`memcpy_helper.s`

_memcpy_packed

Description:	Copies bytes from one `__pack_upper_byte` Flash buffer to another buffer in RAM.
Include:	`<libpic30.h>`
Prototype:	`void* _memcpy_packed(void *dest, __pack_upper_byte void *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 memory block pointed to by *`dest`*.
Remarks:	None.
Default Behavior:	Copy *`len`* bytes of data from each address pointed to by the *`src`* pointer to the destination pointed to by the *`dest`* pointer.
File:	`memcpy_helper.s`

_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:	`_prog_addressT _memcpy_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 of the *`len`* bytes of addresses of *`src`* to the destination pointed to by the *`dest`* pointer.
File:	`memcpy_helper.s`

_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 of the *len* bytes of addresses of *src* to the destination pointed to by the *dest* pointer.
File:	`memcpy_helper.s`

_strcpy_eds

Description:	Copies a string from one `__eds__` buffer to another `__eds__` buffer.
Include:	`<libpic30.h>`
Prototype:	`__eds__ char* _strcpy_eds(__eds__ char *dest, __eds__ char *src);`
Argument:	**dest* pointer to destination memory address *src* address of data to be written
Return Value:	The string pointed to by *dest*.
Remarks:	`__eds__` pointers are superset of unqualified data pointers; therefore these functions can be used to copy between `__eds__` and unqualified data memory.
Default Behavior:	Copy the string *src* pointer to the destination pointed to by the *dest* pointer.
File:	`memcpy_helper.s`

_strncpy_eds

Description:	Copies at most *len* bytes from one `__eds__` string to another `__eds__` string.
Include:	`<libpic30.h>`
Prototype:	`__eds__ char* _strncpy_eds(__eds__ char *dest, __eds__ char *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 string pointed to by *dest*.
Remarks:	`__eds__` pointers are superset of unqualified data pointers; therefore these functions can be used to copy between `__eds__` and unqualified data memory.
Default Behavior:	Copy *len* bytes of the string pointed to by the *src* pointer to the destination pointed to by the *dest* pointer. Unlike the standard `strncpy` function, this function does not zero fill the remaining space in the destination string.
File:	`memcpy_helper.s`

_strcpy_packed

Description:	Copies a string from one `__pack_upper_byte` Flash buffer to another buffer in RAM.
Include:	`<libpic30.h>`
Prototype:	`void* _strcpy_packed( void *dest, __pack_upper_byte void *src);`
Argument:	*`*dest`* pointer to destination memory address *`src`* address of data to be written
Return Value:	The string pointed to by *`dest`*.
Remarks:	None.
Default Behavior:	Copy the string pointed to by *`src`* to the RAM buffer pointed to by *`dest`*. Unlike the standard `strncpy` function, this function does not zero fill the remaining space in the destination string.
File:	`memcpy_helper.s`

_strncpy_packed

Description:	Copies a string from one `__pack_upper_byte` Flash buffer to another buffer in RAM.
Include:	`<libpic30.h>`
Prototype:	`void* _strncpy_packed(void *dest, __pack_upper_byte void *src, int len);`
Argument:	*`*dest`* pointer to destination memory address *`src`* address of data to be written *`len`* length of program memory
Return Value:	The string pointed to by *`dest`*.
Remarks:	None.
Default Behavior:	Copy at most *`len`* bytes of the string pointed to by *`src`* to the RAM buffer pointed to by *`dest`*. Unlike the standard `strncpy` function, this function does not zero fill the remaining space in the destination string.
File:	`memcpy_helper.s`

_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 of the *`len`* bytes of addresses of *`src`* to the destination pointed to by the *`dest`* pointer.
File:	`memcpy_helper.s`

_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.
Default Behavior:	Copy 24 bits of data from each of the *`len`* bytes of addresses of *`src`* to the destination pointed to by the *`dest`* pointer.
File:	`memcpy_helper.s`

_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 XC16 C Compiler install directory (Section 1.1.1 "Compiler Installation Locations") 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 compliment to accommodate both positive and negative numbers in binary format. The two's compliment 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.

The binary representation of an N-bit (m+n+1 bits) number in Qn.m is shown in Figure 5-1. The value is given by the equation shown in Figure 5-2.

FIGURE 5-1: BINARY REPRESENTATION

$$b_{\underbrace{m+n}_{N-1}} b_{m+n-1} \ldots b_m . b_{m-1} \ldots b_1 b_o$$

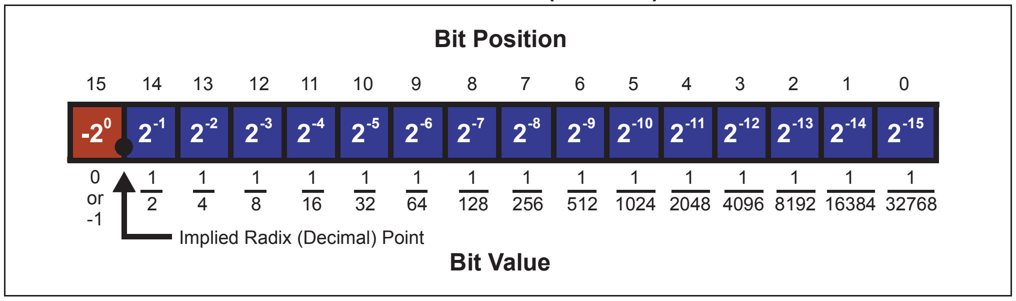
FIGURE 5-2: EQUATION VALUE

$$Value = -b_{N-1}2^n + \sum_{l=0}^{N-2} b_l 2^{l-m}$$

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 5-3: FRACTIONAL FORMAT (16 BITS)


Bit Position
15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
-2^0 2^{-1} 2^{-2} 2^{-3} 2^{-4} 2^{-5} 2^{-6} 2^{-7} 2^{-8} 2^{-9} 2^{-10} 2^{-11} 2^{-12} 2^{-13} 2^{-14} 2^{-15}
0 or -1
$\frac{1}{2}$ $\frac{1}{4}$ $\frac{1}{8}$ $\frac{1}{16}$ $\frac{1}{32}$ $\frac{1}{64}$ $\frac{1}{128}$ $\frac{1}{256}$ $\frac{1}{512}$ $\frac{1}{1024}$ $\frac{1}{2048}$ $\frac{1}{4096}$ $\frac{1}{8192}$ $\frac{1}{16384}$ $\frac{1}{32768}$
Implied Radix (Decimal) Point
Bit Value

The following table shows the conversion of a two's complement 16-bit integer +24576 to Q15 value +0.75.

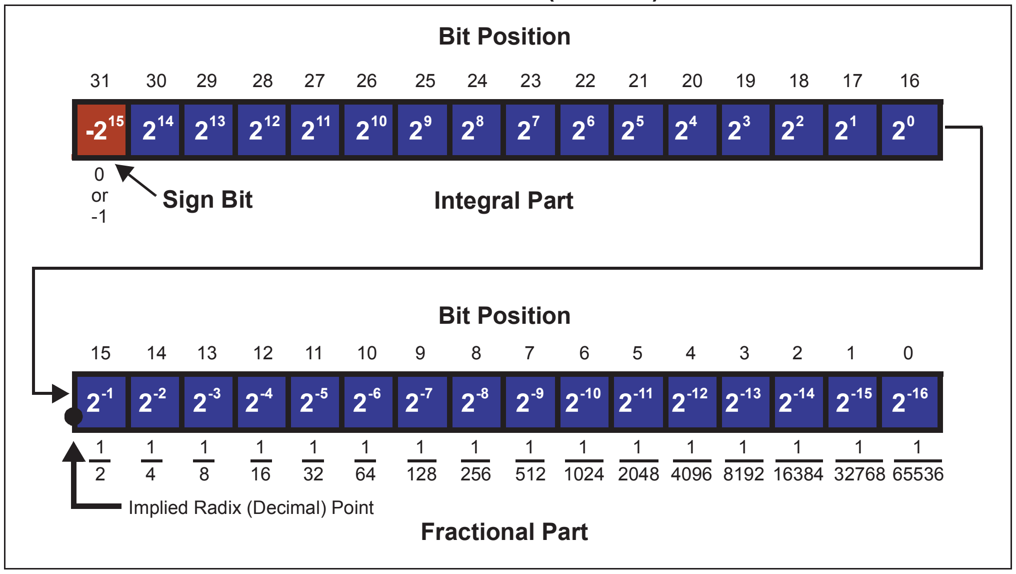
TABLE 5-1: CONVERSION OF A TWO'S COMPLEMENT 16-BIT INTEGER TO Q15

Binary		**Dec**		**Q15**
0	0 x (-2^{15})	0	0 x (-2^{0})	0
			●	●
1	1 x 2^{14}	16384	1 x 2^{-1}	0.5
1	1 x 2^{13}	8192	1 x 2^{-2}	0.25
0	0 x 2^{12}	0	0 x 2^{-3}	0
0	0 x 2^{11}	0	0 x 2^{-4}	0
0	0 x 2^{10}	0	0 x 2^{-5}	0
0	0 x 2^{9}	0	0 x 2^{-6}	0
0	0 x 2^{8}	0	0 x 2^{-7}	0
0	0 x 2^{7}	0	0 x 2^{-8}	0
0	0 x 2^{6}	0	0 x 2^{-9}	0
0	0 x 2^{5}	0	0 x 2^{-10}	0
0	0 x 2^{4}	0	0 x 2^{-11}	0
0	0 x 2^{3}	0	0 x 2^{-12}	0
0	0 x 2^{2}	0	0 x 2^{-13}	0
0	0 x 2^{1}	0	0 x 2^{-14}	0
0	0 x 2^{0}	0	0 x 2^{-15}	0
	SUM	**+24576**	**SUM**	**+0.75**
● - Radix Point				

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 5-4: FRACTIONAL FORMAT (32 BITS)



The following table shows the conversion of a two's complement 32-bit integer, -715827882 to Q15.16 value -10922.6666564941.

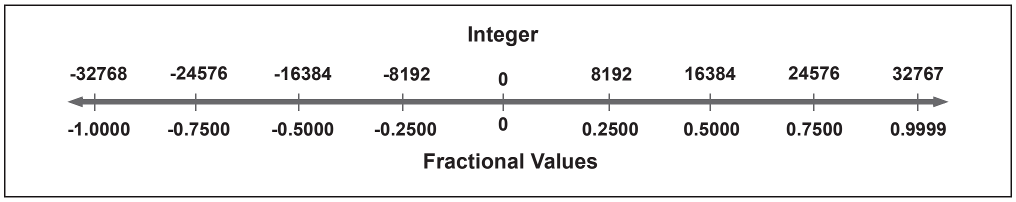
TABLE 5-2: CONVERSION OF A TWO'S COMPLEMENT 32-BIT INTEGER TO Q15.16

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}	3.01576E-05
0	0×2^{0}	0	0×2^{-16}	0
	SUM	**-715827882**	**SUM**	**-10922.6666564941**
● - Radix Point				

5.2.3 Integer - Fractional Format Mapping

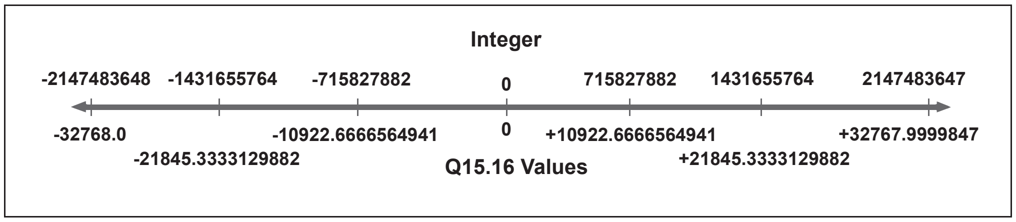
The same twos complement N-bit word may represent an integer format value or a fractional format value. For example., the 16-bit integer range [-32768, +32767] format maps to Q15 range of [-1.0, +0.999969482]. Figure 5-5 shows the mapping between these formats.

FIGURE 5-5: 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 5-6: 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:

Q*n_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:	`<libq.h>`
Prototype:	`_Q15 _Q15abs(_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 absolute value of *x* in Q15 format. The value ranges from 0 to 32767. Note `_Q15abs(-32768)` = `32767`. Also abs (smallest negative number) = largest positive number.

_Q15acos

Description:	This function finds the arc cosine of a Q15 value.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15acos(_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 17705 to 32767.
Return Value:	This function returns the arc cosine of *x* 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:	`<libq.h>`
Prototype:	`_Q15 _Q15acosByPI(_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 arc cosine of *x*, 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:	`<libq.h>`
Prototype:	`_Q15 _Q15add(_Q15 x, _Q15 y);`
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:	`<libq.h>`
Prototype:	`_Q15 _Q15asin(_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 -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:	`<libq.h>`
Prototype:	`_Q15 _Q15asinByPI(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15atan(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15atanByPI(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15atanYByX(_Q15 x, _Q15 y);`
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:	`<libq.h>`
Prototype:	`_Q15 _Q15atanYByXByPI(_Q15 x, _Q15 y);`
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:	`<libq.h>`
Prototype:	`_Q15 _Q15atoi(const char *s);`
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:	`<libq.h>`
Prototype:	`void _itoaQ15(_Q15 x, char *s);`
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:	`<libq.h>`
Prototype:	`float _itofQ15(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15log(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15log10(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15neg(_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 -*x* in Q15 format. The value ranges from -32768 to 32767.

_Q15norm

Description:	This function finds the normalized value of a Q15 value.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15norm(_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 square root of *x* 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:	`<libq.h>`
Prototype:	`_Q15 _Q15power(_Q15 x, _Q15 y);`
Argument:	*x* 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. *y* 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 `_Q15randomSeed` variable as a random seed value.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15random(void);`
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 *num* bits, to the left if *num* is positive or to the right if *num* is negative. The function takes care of saturating the result, in case of underflow or overflow.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15shl(_Q15 x, short num);`
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. *num* an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of *x* in Q15 format. The value ranges from -32768 to 32767.

_Q15shlNoSat

Description:	This function shifts a Q15 value by *num* bits, to the left if *num* is positive or to the right if *num* is negative. The function sets the `_Q15shlSatFlag` variable in case of underflow or overflow but does not take care of saturation.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15shlNoSat(_Q15 x, short num);`
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. *num* an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of *x* in Q15 format. The value ranges from -32768 to 32767.

_Q15shr

Description:	This function shifts a Q15 value by *num* bits, to the right if *num* is positive or to the left if *num* is negative. The function takes care of saturating the result, in case of underflow or overflow.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15shr(_Q15 x, short num);`
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. *num* an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of *x* in Q15 format. The value ranges from -32768 to 32767.

_Q15shrNoSat

Description:	This function shifts a Q15 value by *num* bits, to the right if *num* is positive or to the left if *num* is negative. The function sets the `_Q15shrSatFlag` variable in case of underflow or overflow but does not take care of saturation.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15shrNoSat(_Q15 x, short num);`
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. *num* an integer number, which ranges from -15 to 15.
Return Value:	This function returns the shifted value of *x* 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:	`_Q15 _Q15sin(_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 sine of *x* 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:	`_Q15 _Q15sinPI(_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 sine of PI times *x* in Q15 format. The value ranges from -32768 to 32767.

_Q15sinSeries

Description:	Generates the sine series with the given normalizing frequency, *f*, and the given number of samples, *num*, starting from *start*. Stores the result in buffer, *buf*.
Include:	`<libq.h>`
Prototype:	`short _Q15sinSeries(_Q15 f, short start, short num, _Q15 *buf);`
Argument:	*f* 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. *start* 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. *num* 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:** *num* should not be more than 16383 for dsPIC and 32767 for PIC devices. *buf* a pointer to the buffer where the generated sine samples would get copied into.
Return Value:	This function returns *num*, the number of generated sine samples.

_Q15sqrt

Description:	This function finds the square root of a Q15 value.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15sqrt(_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 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:	`<libq.h>`
Prototype:	`_Q15 _Q15sub(_Q15 x,_Q15 y);`
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:	`<libq.h>`
Prototype:	`_Q15 _Q15tan(_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 -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 PI (π) times a Q15 value.
Include:	`<libq.h>`
Prototype:	`_Q15 _Q15tanPI(_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 tangent of PI 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:	`<libq.h>`
Prototype:	`_Q16 _Q16acos(_Q16 x);`
Argument:	*x* 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 *x* 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:	`<libq.h>`
Prototype:	`_Q16 _Q16acosByPI(_Q16 x);`
Argument:	*x* 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 *x*, 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:	`<libq.h>`
Prototype:	`_Q16 _Q16asin(_Q16 x);`
Argument:	*x* 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 *x* 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:	`<libq.h>`
Prototype:	`_Q16 _Q16asinByPI(_Q16 x);`
Argument:	*x* 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 *x*, 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:	`<libq.h>`
Prototype:	`_Q16 _Q16atan(_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 arc tangent of *x* 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:	`<libq.h>`
Prototype:	`_Q16 _Q16atanByPI(_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 arc tangent of *x*, divided by PI, in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16atanYByX

Description:	This function finds the arc tangent of *y* divided by *x*.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16atanYByX(_Q16 x, _Q16 y);`
Argument:	*x* a fixed-point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. This forms the x input. *y* 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 *y*, divided by *x*, in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16atanYByXByPI

Description:	This function finds the arc tangent of the 32-bit input, *y*, divided by *x*, and then divides by PI (π).
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16atanYByXByPI(_Q16 x, _Q16 y);`
Argument:	*x* a fixed-point number in Q16 format. The value of this argument ranges from -2147483648 to 2147483647. This forms the x input. *y* 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 *y* divided by *x*, divided by PI, in Q16 format. The value ranges from -2147483648 to 2147483647.

_Q16cos

Description:	This function finds the cosine of a Q16 value.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16cos(_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 cosine of *x* 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:	`_Q16 _Q16cosPI(_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 cosine of PI times *x* in Q16 format. The value ranges from -65536 to 65536.

_Q16div

Description:	This function returns the quotient of its arguments.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16mpy(_Q16 dividend, _Q16 divisor);`
Argument:	*dividend* a fixed-point number in Q16 format. The value of this argument ranges from 0 to 2147483647. *divisor* a fixed-point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
Return Value:	This function returns the quotient of its arguments. The value ranges from 0 to 2147483647..

_Q16divmod

Description:	This function returns the quotient and remainder of its arguments.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16mpy(_Q16 dividend, _Q16 divisor, _Q16 *remainder);`
Argument:	*dividend* a fixed-point number in Q16 format. The value of this argument ranges from 0 to 2147483647. *divisor* a fixed-point number in Q16 format. The value of this argument ranges from 0 to 2147483647. *remainder* a pointer to an object large enough to hold the remainder. This must be provided by the caller.
Return Value:	This function returns the quotient and remainder of its arguments. The values range from 0 to 2147483647.

_Q16exp

Description:	This function finds the exponential value of a Q16 value.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16exp(_Q16 x);`
Argument:	*x* 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 *x* 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:	`_Q16 _Q16log(_Q16 x);`
Argument:	*x* 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 *x* 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:	`_Q16 _Q16log10(_Q16 x);`
Argument:	*x* 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 *x* 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(_Q16x, _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.

_Q16mpy

Description:	This function returns the product of its arguments.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16mpy(_Q16 a,_Q16 b);`
Argument:	*a* a fixed-point number in Q16 format. The value of this argument ranges from 0 to 2147483647. *b* a fixed-point number in Q16 format. The value of this argument ranges from 0 to 2147483647.
Return Value:	This function returns the product of its arguments. 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.

_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 normalized 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:	RndNum(n) = (RndNum(n-1) * RAN_MULT) + 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:	`<libq.h>`
Prototype:	`_Q16 _Q16shr(_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.

_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 `_Q16shrSatFlag` variable in case of underflow or overflow, but does not take care of saturation.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16shrNoSat(_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.

_Q16sin

Description:	This function finds the sine of a Q16 value.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16sin(_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 sine of *x* in Q16 format. The value ranges from -65566 to 65536.

_Q16sinPI

Description:	This function finds the sine of PI (π) times a Q16 value.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16sinPI(_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 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, *f*, and the given number of samples, *num*, starting from *start*. Stores the result in buffer, *buf*.
Include:	`<libq.h>`
Prototype:	`short _Q16sinSeries(_Q16 f, short start, short num, _Q16 *buf);`

_Q16sinSeries (Continued)

Argument:	`f` 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. `start` 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. `num` 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:** `num` should not be more than 16383 for dsPIC and 32767 for PIC devices. `buf` a pointer to the buffer where the generated sine samples would get copied into.
Return Value:	This function returns `num`, the number of generated sine samples.

_Q16tan

Description:	This function finds the tangent of a Q16 value.
Include:	`<libq.h>`
Prototype:	`_Q16 _Q16tan(_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 tangent of `x` 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:	`_Q16 _Q16tanPI(_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 tangent of PI times `x` in Q16 format. The value ranges from -2147483648 to 2147483647.

_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 _itofQ16(_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.

NOTES:

Appendix A. ASCII Character Set

This table shows the ASCII character set in nibbles.

	Most Significant Nibbles								
	Hex	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Least Significant Nibbles	**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

NOTES:

Appendix B. Document Revision History

Revision A (May 2004)

- Initial release of this document.

Revision B (September 2004)

- Added **"NOTICE TO CUSTOMERS"**
- Divided Chapter 4. "Standard C Libraries - Support Functions" into Chapter 5. "Fixed-Point Math Functions"
- Added Section 1.2 "OMF-Specific Libraries/Start-up Modules"
- Minor typographical changes

Revision C (2005)

- Updated Section 2.8 "<locale.h> Localization" and the following function descriptions:
  - `PIDInit`
  - `PIDCoeffCalc`
  - `PID`
- Updated Section 2.9 "<setjmp.h> Non-Local Jumps" and the following function descriptions:
  - `Fract2Float`
  - `Float2Fract`
- Updated Section 3.2 "Using the Standard C Libraries"
- Section 3.3 "<math.h> Mathematical Functions" - the following function descriptions have been updated:
  - `OpenXLCD`
  - `putsXLCD`
  - `SetDDRamAddr`
  - `WriteDataXLCDWriteCmdXLCD`
- Divided Section 3.3 "<math.h> Mathematical Functions" into **Section 3.4 "CAN Functions"**. The following function descriptions have been updated:
  - `CAN1AbortAll`
  - `CAN1GetRXErrorCount`
  - `CAN1GetTXErrorCount`
  - `CAN1IsBusOff`
  - `CAN1IsRXReady`
  - `CAN1IsRXPassive`
  - `CAN1IsTXPassive`

- Section 5.2 "Overview of Fixed-Point Data Formats" - the following function descriptions have been updated:
  - `_builtin_addab`
  - `_builtin_add`
  - `_builtin_btg`
  - `_builtin_clr`
  - `_builtin_clr_prefetch`
  - `_builtin_dmaoffset`
  - `_builtin_ed`
  - `_builtin_edac`
  - `_builtin_fbcl`
  - `_builtin_mac`
  - `_builtin_movsac`
  - `_builtin_mpy`
  - `_builtin_mpyn`
  - `_builtin_msc`
  - `_builtin_mulss`
  - `_builtin_mulsu`
  - `_builtin_mulus`
  - `_builtin_muluu`
  - `_builtin_nop`
  - `_builtin_psvpage`
- Minor typographical changes

Revision D (December 2006)

- **Section 3.7 "<limits.h> implementation-defined limits"** - the following function descriptions have been updated:
  - `LLONG_MIN`
  - `LONG_MAX`
  - `LONG_MIN`
  - `MB_LEN_MAX`
  - `SCHAR_MAX`
  - `SCHAR_MIN`
  - `SHRT_MAX`
  - `SHRT_MIN`
  - `UCHAR_MAX`
- **Section 3.9 "<setjmp.h> non-local jumps"** - the following function descriptions have been updated:
  - `jmp_buf`
  - `setjmp`
  - `longjmp`
- **Section 3.10 "<signal.h> signal handling"** - the following function descriptions have been updated:
  - `SIGFPE`
  - `SIGILL`
  - `SIGINT`
  - `raise`

- **Section 3.13 "<stdio.h> input and output"**- the following function descriptions have been updated:
  - `FILE`
  - `fpos_t`
  - `_IOFBF`
  - `_IOLBF`
  - `_IONBF`
  - `BUFSIZ`
  - `FOPEN_MAX`
  - `L_tmpnam`
  - `SEEK_CUR`
  - `stderr`
  - `stdout`
  - `TMP_MAX`
  - `clearerr`
  - `feof`
  - `fgetpos`
  - `fopen`
  - `fprintf`
  - `fread`
- Minor typographical changes

Revision E (2008)

- Section 2.4 "<ctype.h> Character Handling" - the following function descriptions have been updated:
  - `islower`
  - `isxdigit`
  - `tolower`
  - `toupper`
- Section 2.6 "<float.h> Floating-Point Characteristics"- the following function descriptions have been updated:
  - `FLT_MAX_EXP`
  - `FLT_MIN`
  - `FLT_MIN_EXP`
  - `LDBL_MIN`
  - `LDBL_MIN_EXP`
  - `UCHAR_MAX`
  - `UINT_MAX`
  - `ULLONG_MAX`
  - `ULONG_MAX`
  - `USHRT_MAX`

- Section 2.9 “<setjmp.h> Non-Local Jumps” - the following function descriptions have been updated:
  - jmp_buf
  - longjmp
  - SIGILL
  - SIGSEGV
  - raise
  - signal
- Divided Chapter 3. “Standard C Libraries - Math Functions” into Chapter 4. “Standard C Libraries - Support Functions” and Chapter 5. “Fixed-Point Math Functions”
- Minor typographical changes.

Revision F (March 2009)

- Section 4.5 “Functions/Constants to Support A Simulated UART” - the following function descriptions have been updated:
  - _delay_ms
  - _delay_us
  - _C30UART
- Section 4.6 “Functions for Erasing and Writing EEDATA Memory”- updated `_write_eedata_row` function.
- Section 4.7 “Functions for Erasing and Writing Flash Memory” - updated descriptions for `_erase_flash` and `_write_flash_word24`.
- Section 5.3 “Using the Fixed-Point Libraries” - updated descriptions for `Q16ftoi` and `itofQ16`.
- Minor typographical changes.

Revision G (October 2010)

- Section 2.13 “<stdio.h> Input and Output” - updated `scanf` function
- Section 2.15 “<string.h> String Functions” - updated `memchr` function
- Inserted Section 5.2 “Overview of Fixed-Point Data Formats”
- Minor typographical changes.

Revision H (September 2013)

- Section 1.1 “Introduction” - added Compiler Installation Locations
- Section 2.10 “<signal.h> Signal Handling” - updated `signal` function.
- Section 2.13 “<stdio.h> Input and Output” - updated Customizing STDIO handles and descriptions for `fdopen` and `vasprintf`.
- Section 4.3 “Standard C Library Helper Functions” - updated `_dump_heap_info` function.
- Section 4.7 “Functions for Erasing and Writing Flash Memory” - updated descriptions for `_write_flash_word32` and `_write_flash_word48`.
- Section 5.2 “Overview of Fixed-Point Data Formats” - inserted Table 5-1 and Table 5-2.
- Section 5.4 “<libq.h> Mathematical Functions” - the following function descriptions have been updated:
  - _Q16div
  - _Q16divmod
  - _Q16mpy
- Minor typographical changes.

Revision J (December 2014)

- Section 2.14 “<stdlib.h> Utility Functions” - updated `malloc` function.
- Section 4.7 “Functions for Erasing and Writing Flash Memory” - updated descriptions for `_erase_flash` (PIC24FXXKA Only) and `_write_flash_word24()`.
- Section 4.8 “Functions for Specialized Copying and Initialization” - the following function descriptions have been updated:
  - `_memcpy_p2d24`
  - `_memcpy_p2d16`
  - `_strncpy_p2d24`
  - `_strncpy_p2d16`

Revision K (February 2018)

- Section 4.8 “Functions for Specialized Copying and Initialization” - added `_memcpy_eds`, `_strcpy_eds`, `_strncpy_eds`, `_memcpy_packed`, `_strcpy_packed`, `_strncpy_packed`. Also referenced in Section 2.15 “<string.h> String Functions” under `_memcpy`, `_strcpy`, `_strncpy`.
- Section 5.4.1 “Q15 Functions” - updated `_Q15abs` return value.
- Section 5.4.2 “Q16 Functions” - updated `_Q16norm` return value.

NOTES:

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