

# **EK-LM4F232 Firmware Development Package**

## **USER'S GUIDE**



---

# Copyright

Copyright © 2011-2012 Texas Instruments Incorporated. All rights reserved. Stellaris and StellarisWare are registered trademarks of Texas Instruments. ARM and Thumb are registered trademarks and Cortex is a trademark of ARM Limited. Other names and brands may be claimed as the property of others.

 Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this document.

Texas Instruments  
108 Wild Basin, Suite 350  
Austin, TX 78746  
Main: +1-512-279-8800  
Fax: +1-512-279-8879  
<http://www.ti.com/stellaris>



## Revision Information

This is version 8555 of this document, last updated on January 28, 2012.

# Table of Contents

<b>Copyright</b>	<b>2</b>
<b>Revision Information</b>	<b>2</b>
<b>1 Introduction</b>	<b>5</b>
<b>2 Example Applications</b>	<b>7</b>
2.1 AES Pre-expanded Key (aes_expanded_key)	7
2.2 AES Normal Key (aes_set_key)	7
2.3 Bit-Banding (bitband)	7
2.4 Blinky (blinky)	8
2.5 Hello World (hello)	8
2.6 Hibernate Example (hibernate)	8
2.7 Interrupts (interrupts)	8
2.8 MPU (mpu_fault)	8
2.9 Data Logger (qs-logger)	8
2.10 SD card using FAT file system (sd_card)	10
2.11 Sine Demo (sine_demo)	10
2.12 Timer (timers)	10
2.13 UART Echo (uart_echo)	10
2.14 uDMA (udma_demo)	10
2.15 USB Generic Bulk Device (usb_dev_bulk)	11
2.16 USB HID Keyboard Device (usb_dev_keyboard)	11
2.17 USB Serial Device (usb_dev_serial)	11
2.18 USB Mass Storage Class Host Example (usb_host_msc)	12
2.19 Watchdog (watchdog)	12
<b>3 Development System Utilities</b>	<b>13</b>
<b>4 Buttons Driver</b>	<b>25</b>
4.1 Introduction	25
4.2 API Functions	25
4.3 Programming Example	26
<b>5 Display Driver</b>	<b>27</b>
5.1 Introduction	27
5.2 API Functions	27
5.3 Programming Example	28
<b>6 Command Line Processing Module</b>	<b>29</b>
6.1 Introduction	29
6.2 API Functions	29
6.3 Programming Example	31
<b>7 CPU Usage Module</b>	<b>33</b>
7.1 Introduction	33
7.2 API Functions	33
7.3 Programming Example	34
<b>8 CRC Module</b>	<b>37</b>
8.1 Introduction	37
8.2 API Functions	37
8.3 Programming Example	40
<b>9 Flash Parameter Block Module</b>	<b>41</b>
9.1 Introduction	41

9.2	API Functions	41
9.3	Programming Example	43
<b>10</b>	<b>Integer Square Root Module</b>	<b>45</b>
10.1	Introduction	45
10.2	API Functions	45
10.3	Programming Example	46
<b>11</b>	<b>Ring Buffer Module</b>	<b>47</b>
11.1	Introduction	47
11.2	API Functions	47
11.3	Programming Example	53
<b>12</b>	<b>Simple Task Scheduler Module</b>	<b>55</b>
12.1	Introduction	55
12.2	API Functions	55
12.3	Programming Example	60
<b>13</b>	<b>Sine Calculation Module</b>	<b>63</b>
13.1	Introduction	63
13.2	API Functions	63
13.3	Programming Example	64
<b>14</b>	<b>Micro Standard Library Module</b>	<b>65</b>
14.1	Introduction	65
14.2	API Functions	65
14.3	Programming Example	74
<b>15</b>	<b>UART Standard IO Module</b>	<b>77</b>
15.1	Introduction	77
15.2	API Functions	78
15.3	Programming Example	84
<b>IMPORTANT NOTICE</b>		<b>86</b>

# 1 Introduction

The Texas Instruments® Stellaris® EK-LM4F232 evaluation board is a platform that can be used for software development and prototyping a hardware design. It can also be used as a guide for custom board design using a Stellaris microcontroller.

The EK-LM4F232 includes a Stellaris ARM® Cortex™-M3-based microcontroller and the following features:

- Stellaris® LM4F232H5QD microcontroller
- Four 20V analog inputs
- 3-axis analog accelerometer
- On-board temperature sensor
- Bright 96 x 64 16-bit color OLED display
- 5 user buttons
- User LED
- Shunt for microcontroller current consumption measurement
- MicroSD card connector
- USB OTG connector
- On-board In-Circuit Debug Interface (ICDI)
- Coin cell backup battery for Hibernate feature
- Power supply option from USB ICDI connection, or OTG connection

This document describes the board-specific drivers and example applications that are provided for this development board.



## 2 Example Applications

The example applications show how to utilize features of the EK-LM4F232 evaluation board. Examples are included to show how to use many of the general features of the Stellaris microcontroller, as well as the features that are unique to this evaluation board.

A number of drivers are provided to make it easier to use the features of the EK-LM4F232. These drivers also contain low-level code that make use of the Stellaris peripheral driver library and utilities.

There is an IAR workspace file (`ek-lm4f232.eww`) that contains the peripheral driver library project, along with all of the board example projects, in a single, easy-to-use workspace for use with Embedded Workbench version 5.

There is a Keil multi-project workspace file (`ek-lm4f232.mpw`) that contains the peripheral driver library project, along with all of the board example projects, in a single, easy-to-use workspace for use with uVision.

All of these examples reside in the `boards/ek-lm4f232` subdirectory of the firmware development package source distribution.

### 2.1 AES Pre-expanded Key (`aes_expanded_key`)

This example shows how to use pre-expanded keys to encrypt some plaintext, and then decrypt it back to the original message. Using pre-expanded keys avoids the need to perform the expansion at run-time. This example also uses cipher block chaining (CBC) mode instead of the simpler ECB mode.

This example uses the AES tables present in the Stellaris ROM, which makes the overall program smaller.

### 2.2 AES Normal Key (`aes_set_key`)

This example shows how to set an encryption key and then use that key to encrypt some plaintext. It then sets the decryption key and decrypts the previously encrypted block back to plaintext.

This example uses the AES tables present in the Stellaris ROM, which makes the overall program smaller.

### 2.3 Bit-Banding (`bitband`)

This example application demonstrates the use of the bit-banding capabilities of the Cortex-M3 microprocessor. All of SRAM and all of the peripherals reside within bit-band regions, meaning that bit-banding operations can be applied to any of them. In this example, a variable in SRAM is set to a particular value one bit at a time using bit-banding operations (it would be more efficient to do a single non-bit-banded write; this simply demonstrates the operation of bit-banding).

## 2.4 Blinky (blinky)

A very simple example that blinks the on-board LED.

## 2.5 Hello World (hello)

A very simple “hello world” example. It simply displays “Hello World!” on the display and is a starting point for more complicated applications. This example uses calls to the Stellaris Graphics Library graphics primitives functions to update the display. For a similar example using widgets, please see “hello\_widget”.

## 2.6 Hibernate Example (hibernate)

An example to demonstrate the use of the Hibernation module. The user can put the microcontroller in hibernation by pressing the select button. The microcontroller will then wake on its own after 5 seconds, or immediately if the user presses the select button again. The program keeps a count of the number of times it has entered hibernation. The value of the counter is stored in the battery backed memory of the Hibernation module so that it can be retrieved when the microcontroller wakes.

## 2.7 Interrupts (interrupts)

This example application demonstrates the interrupt preemption and tail-chaining capabilities of Cortex-M4 microprocessor and NVIC. Nested interrupts are synthesized when the interrupts have the same priority, increasing priorities, and decreasing priorities. With increasing priorities, pre-emption will occur; in the other two cases tail-chaining will occur. The currently pending interrupts and the currently executing interrupt will be displayed on the display; GPIO pins D0, D1 and D2 will be asserted upon interrupt handler entry and de-asserted before interrupt handler exit so that the off-to-on time can be observed with a scope or logic analyzer to see the speed of tail-chaining (for the two cases where tail-chaining is occurring).

## 2.8 MPU (mpu\_fault)

This example application demonstrates the use of the MPU to protect a region of memory from access, and to generate a memory management fault when there is an access violation.

## 2.9 Data Logger (qs-logger)

This example application is a data logger. It can be configured to collect data from up to 10 data sources. The possible data sources are:



- 4 analog inputs, 0-20V
- 3-axis accelerometer
- internal and external temperature sensors
- processor current consumption

The data logger provides a menu navigation that is operated by the buttons on the EK-LM4F232 board (up, down, left, right, select). The data logger can be configured by using the menus. The following items can be configured:

- data sources to be logged
- sample rate
- storage location
- sleep modes
- clock

Using the data logger:

Use the CONFIG menu to configure the data logger. The following choices are provided:

- CHANNELS - enable specific channels of data that will be logged
- PERIOD - select the sample period
- STORAGE - select where the collected data will be stored:
  - FLASH - stored in the internal flash memory
  - USB - stored on a connected USB memory stick
  - HOST PC - transmitted to a host PC via USB OTG virtual serial port
  - NONE - the data will only be displayed and not stored
- SLEEP - select whether or not the board sleeps between samples. Sleep mode is allowed when storing to flash at with a period of 1 second or longer.
- CLOCK - allows setting of internal time-of-day clock that is used for time stamping of the sampled data

Use the START menu to start the data logger running. It will begin collecting and storing the data. It will continue to collect data until stopped by pressing the left button or select button.

While the data logger is collecting data and it is not configured to sleep, a simple strip chart showing the collected data will appear on the display. If the data logger is configured to sleep, then no strip chart will be shown.

If the data logger is storing to internal flash memory, it will overwrite the oldest data. If storing to a USB memory device it will store data until the device is full.

The VIEW menu allows viewing the values of the data sources in numerical format. When viewed this way the data is not stored.

The SAVE menu allows saving data that was stored in internal flash memory to a USB stick. The data will be saved in a text file in CSV format.

The ERASE menu is used to erase the internal memory so more data can be saved.

When the EK-LM4F232 board running qs-logger is connected to a host PC via the USB OTG connection for the first time, Windows will prompt for a device driver for the board. This can be found in C:/StellarisWare/windows\_drivers assuming you installed the software in the default folder.

A companion Windows application, logger, can be found in the StellarisWare/tools/bin directory. When the data logger's STORAGE option is set to "HOST PC" and the board is connected to a PC via the USB OTG connection, captured data will be transferred back to the PC using the virtual serial port that the EK board offers. When the logger application is run, it will search for the first connected EK-LM4F232 board and display any sample data received. The application also offers the option to log the data to a file on the PC.

## 2.10 SD card using FAT file system (sd\_card)

This example application demonstrates reading a file system from an SD card. It makes use of FatFs, a FAT file system driver. It provides a simple command console via a serial port for issuing commands to view and navigate the file system on the SD card.

The first UART, which is connected to the USB debug virtual serial port on the evaluation board, is configured for 115,200 bits per second, and 8-N-1 mode. When the program is started a message will be printed to the terminal. Type "help" for command help.

For additional details about FatFs, see the following site:  
[http://elm-chan.org/fsw/ff/00index\\_e.html](http://elm-chan.org/fsw/ff/00index_e.html)

## 2.11 Sine Demo (sine\_demo)

This example uses the floating point capabilities of the Stellaris Cortex-M4 processor to compute a sine wave and show it on the display.

## 2.12 Timer (timers)

This example application demonstrates the use of the timers to generate periodic interrupts. One timer is set up to interrupt once per second and the other to interrupt twice per second; each interrupt handler will toggle its own indicator on the display.

## 2.13 UART Echo (uart\_echo)

This example application utilizes the UART to echo text. The first UART (connected to the USB debug virtual serial port on the evaluation board) will be configured in 115,200 baud, 8-n-1 mode. All characters received on the UART are transmitted back to the UART.

## 2.14 uDMA (udma\_demo)

This example application demonstrates the use of the uDMA controller to transfer data between memory buffers, and to transfer data to and from a UART. The test runs for 10 seconds before exiting.

## 2.15 USB Generic Bulk Device (usb\_dev\_bulk)

This example provides a generic USB device offering simple bulk data transfer to and from the host. The device uses a vendor-specific class ID and supports a single bulk IN endpoint and a single bulk OUT endpoint. Data received from the host is assumed to be ASCII text and it is echoed back with the case of all alphabetic characters swapped.

A Windows INF file for the device is provided on the installation CD and in the C:/StellarisWare/windows\_drivers directory of StellarisWare releases. This INF contains information required to install the WinUSB subsystem on WindowsXP and Vista PCs. WinUSB is a Windows subsystem allowing user mode applications to access the USB device without the need for a vendor-specific kernel mode driver.

A sample Windows command-line application, usb\_bulk\_example, illustrating how to connect to and communicate with the bulk device is also provided. The application binary is installed as part of the “Windows-side examples for USB kits” package (SW-USB-win) on the installation CD or via download from <http://www.ti.com/stellarisware> . Project files are included to allow the examples to be built using Microsoft VisualStudio 2008. Source code for this application can be found in directory StellarisWare/tools/usb\_bulk\_example.

## 2.16 USB HID Keyboard Device (usb\_dev\_keyboard)

This example application turns the evaluation board into a USB keyboard supporting the Human Interface Device class. When the push button is pressed, a sequence of key presses is simulated to type a string. Care should be taken to ensure that the active window can safely receive the text; enter is not pressed at any point so no actions are attempted by the host if a terminal window is used (for example). The status LED is used to indicate the current Caps Lock state and is updated in response to any other keyboard attached to the same USB host system.

The device implemented by this application also supports USB remote wakeup allowing it to request the host to reactivate a suspended bus. If the bus is suspended (as indicated on the application display), pressing the push button will request a remote wakeup assuming the host has not specifically disabled such requests.

## 2.17 USB Serial Device (usb\_dev\_serial)

This example application turns the evaluation kit into a virtual serial port when connected to the USB host system. The application supports the USB Communication Device Class, Abstract Control Model to redirect UART0 traffic to and from the USB host system.

Assuming you installed StellarisWare in the default directory, a driver information (INF) file for use with Windows XP, Windows Vista and Windows7 can be found in C:/StellarisWare/windows\_drivers. For Windows 2000, the required INF file is in C:/StellarisWare/windows\_drivers/win2K.

## 2.18 USB Mass Storage Class Host Example (usb\_host\_msc)

This example application demonstrates reading a file system from a USB flash disk. It makes use of FatFs, a FAT file system driver. It provides a simple widget-based display for showing and navigating the file system on a USB stick.

For additional details about FatFs, see the following site:  
[http://elm-chan.org/fsw/ff/00index\\_e.html](http://elm-chan.org/fsw/ff/00index_e.html)

## 2.19 Watchdog (watchdog)

This example application demonstrates the use of the watchdog as a simple heartbeat for the system. If the watchdog is not periodically fed, it will reset the system. Each time the watchdog is fed, the LED is inverted so that it is easy to see that it is being fed, which occurs once every second. To stop the watchdog being fed and, hence, cause a system reset, press the select button.

## 3 Development System Utilities

These are tools that run on the development system, not on the embedded target. They are provided to assist in the development of firmware for Stellaris microcontrollers.

These tools reside in the `tools` subdirectory of the firmware development package source distribution.

### AES Key Expansion Utility

#### Usage:

```
aes_gen_key [OPTIONS] --keysize=[SIZE] --key=[KEYSTRING] [FILE]
```

#### Description:

Generates pre-expanded keys for AES encryption and decryption. It is designed to work in conjunction with the AES library code found in the StellarisWare directory `third_party/aes`. When using an AES key to perform encryption or decryption, the key must first be expanded into a larger table of values before the key can be used. This operation can be performed at run-time but takes time and uses space in RAM.

If the keys are fixed and known in advance, then it is possible to perform the expansion operation at build-time and the pre-expanded table can be built into the code. The advantages of doing this are that it saves time when the keys are used, and the expanded table is stored in non-volatile program memory (flash), which is usually less precious in a typical microcontroller application.

By default, the pre-expanded key is generated as a data array that can be used by reference in the application. It is also possible to generate the pre-expanded key as a code sequence. A function is generated that will copy the pre-expanded key to a caller supplied buffer. This does not save RAM space, but it makes the expanded key more secure. By making the key into pure code (versus data in flash), the Texas Instruments Stellaris OTP feature can be used to make the code execute only (no read). This means that the expanded key cannot be read from flash. It is only loaded into RAM during an encrypt or decrypt operation.

The length of a pre-set key is 44 words for 128-bit keys, 54 words for 192-bit keys, and 68 words for 256-bit keys; instruction-based versions are about two to four times as large in flash and require as much RAM as run-time expansion.

The source code for this utility is contained in `tools/aes_gen_key`, with a pre-built binary contained in `tools/bin`.

#### Arguments:

- a, **--data** generates expanded key as an array of data.
- x, **--code** generates expanded key as executable code.
- e, **--encrypt** generate expanded key for encryption.
- d, **--decrypt** generate expanded key for decryption.
- s, **--keysize** **KEYSIZE** size of the key in bits (128, 192, or 256).
- k, **--key** **KEY** key value in hexadecimal.
- v, **--version** show program version.
- h, **--help** display usage information.

The **--keysize** and **--key** arguments are mandatory. Only one each of **--data** or **--code**, and **--encrypt** or **--decrypt** should be used. If not specified otherwise then the default is **--data --encrypt**.

**FILE** is the name of the file that will be created containing the expanded key. This file will be in the form of a C header file and should be included in your application.

**Example:**

The following will generate an expanded 128-bit key for encryption, encoded as data and create a C header file named `enc_key.h`:

```
aes_gen_key --data --encrypt --keysize=128
--key=112233445566778899AABBCCDDEEFF00 enc_key.h
```

The following will generate an expanded 128-bit key for decryption, encoded as a code function and create a C header file named `dec_key.h`:

```
aes_gen_key --code --decrypt --keysize=128
--key=112233445566778899AABBCCDDEEFF00 dec_key.h
```

## USB DFU Programmer

**Usage:**

```
dfuprog [OPTION]...
```

**Description:**

Downloads images to a Texas Instruments Stellaris microcontroller running the USB Device Firmware Upgrade boot loader. Additionally, this utility may be used to read back the existing application image or a subsection of flash and store it either as raw binary data or as a DFU-downloadable image file.

The source code for this utility is contained in `tools/dfuprog`. The binary for this utility is installed as part of the “Windows-side examples for USB kits” package (SW-USB-win) shipped on the release CD and downloadable from [http://www.luminarymicro.com/products/software\\_updates.html](http://www.luminarymicro.com/products/software_updates.html). A Microsoft Visual Studio project file is provided to allow the application to be built.

**Arguments:**

- e** specifies the address of the binary.
- u** specifies that an image is to be uploaded from the board into the target file. If absent, the file will be downloaded to the board.
- c** specifies that a section of flash memory is to be cleared. The address and size of the block may be specified using the **-a** and **-l** parameters. If these are absent, the entire writable area of flash is erased.
- f FILE** specifies the name of the file to download or, if **-u** is given, to upload.
- b** specifies that an uploaded file is to be stored as raw binary data without the DFU file wrapper. This option is only valid if used alongside **-u**.
- d** specifies that the VID and PID in the DFU file wrapper should be ignored for a download operation.
- s** specifies that image verification should be skipped following a download operation.
- a ADDR** specifies the address at which the binary file will be downloaded or from which an uploaded file will be read. If a download operation is taking place and the source file provided is DFU-wrapped, this parameter will be ignored.

- l **SIZE** specifies the number of bytes to be uploaded when used in conjunction with -i or the number of bytes of flash to erase if used in conjunction with -c.
- i **NUM** specifies the zero-based index of the USB DFU device to access if more than one is currently attached to the system. If absent, the first device found is used.
- x specifies that destination file for an upload operation should be overwritten without prompting if it already exists.
- w specifies that the utility should wait for the user to press a key before it exits.
- v displays verbose output during the requested operation.
- h displays this help information.
- ? displays this help information.

**Example:**

The following example writes binary file program.bin to the device flash memory at address 0x1800:

```
dfuprog -f program.bin -a 0x1800
```

The following example writes DFU-wrapped file program.dfu to the flash memory of the second connected USB DFU device at the address found in the DFU file prefix:

```
dfuprog -i 1 -f program.dfu
```

The following example uploads (reads) the current application image into a DFU-formatted file appimage.dfu:

```
dfuprog -u -f appimage.dfu
```

## USB DFU Wrapper

**Usage:**

```
dfuwrap [OPTION]...
```

**Description:**

Prepares binary images for download to a particular position in device flash via the USB device firmware upgrade protocol. A Stellaris-specific prefix and a DFU standard suffix are added to the binary.

The source code for this utility is contained in `tools/dfuwrap`, with a pre-built binary contained in `tools/bin`.

**Arguments:**

- a **ADDR** specifies the address of the binary.
- c specifies that the validity of the DFU wrapper on the input file should be checked.
- d **ID** specifies the USB device ID to place into the DFU wrapper. If not specified, the default of 0x0000 will be used.
- e enables verbose output.
- f specifies that a DFU wrapper should be added to the file even if one already exists.
- h displays usage information.
- i **FILE** specifies the name of the input file.

- o **FILE** specifies the name of the output file. If not specified, the default of image.dfu will be used.
- p **ID** specifies the USB product ID to place into the DFU wrapper. If not specified, the default of 0x00ff will be used.
- q specifies that only error information should be output.
- r specifies that the DFU header should be removed from the input file.
- v **ID** specifies the USB vendor ID to place into the DFU wrapper. if not specified, the default of 0x1cbe will be used.
- x specifies that the output file should be overwritten without prompting.

**Example:**

The following example adds a DFU wrapper which will cause the image to be programmed to address 0x1800:

```
dfuwrap -i program.bin -o program.dfu -a 0x1800
```

## FreeType Rasterizer

**Usage:**

```
ftrasterize [OPTION]... [INPUT FILE]
```

**Description:**

Uses the FreeType font rendering package to convert a font into the format that is recognized by the graphics library. Any font that is recognized by FreeType can be used, which includes TrueType®, OpenType®, PostScript® Type 1, and Windows® FNT fonts. A complete list of supported font formats can be found on the FreeType web site at <http://www.freetype.org>.

FreeType is used to render the glyphs of a font at a specific size in monochrome, using the result as the bitmap images for the font. These bitmaps are compressed and the results are written as a C source file that provides a tFont structure describing the font.

The source code for this utility is contained in `tools/ftrasterize`, with a pre-built binary contained in `tools/bin`.

**Arguments:**

- a specifies the index of the font character map to use in the conversion. If absent, Unicode is assumed when “-r” or “-u” is present. Without either of these switches, the Adobe Custom character map is used if such a map exists in the font, otherwise Unicode is used. This ensures backwards compatibility. To determine which character maps a font supports, call ftrasterize with the “-d” option to show font information.
- b specifies that this is a bold font. This does not affect the rendering of the font, it only changes the name of the file and the name of the font structure that are produced.
- c **FILENAME** specifies the name of a file containing a list of character codes whose glyphs should be encoded into the output font. Each line of the file contains either a single decimal or hex character code in the chosen codepage (Unicode unless “-a” is provided), or two character codes separated by a comma and a space to indicate all characters in the inclusive range. Additionally, if the first non-comment line of the file is “REMAP”, the output font is generated to use a custom codepage with character codes starting at 1 and incrementing with every character in the character map file. This switch is only valid with “-r” and overrides “-p” and “-e” which are ignored if present.



- d** displays details about the first font whose name is supplied at the end of the command line. When “-d” is used, all other switches are ignored. When used without “-v”, font header information and properties are shown along with the total number of characters encoded by the font and the number of contiguous blocks these characters are found in. With “-v”, detailed information on the character blocks is also displayed.
- f FILENAME** specifies the base name for this font, which is used as a base for the output file names and the name of the font structure. The default value is “font” if not specified.
- h** shows command line help information.
- i** specifies that this is an italic font. This does not affect the rendering of the font, it only changes the name of the file and the name of the font structure that are produced.
- m** specifies that this is a monospaced font. This causes the glyphs to be horizontally centered in a box whose width is the width of the widest glyph. For best visual results, this option should only be used for font faces that are designed to be monospaced (such as Computer Modern TeleType).
- s SIZE** specifies the size of this font, in points. The default value is 20 if not specified. If the size provided starts with “F”, it is assumed that the following number is an index into the font’s fixed size table. For example “-s F3” would select the fourth fixed size offered by the font. To determine whether a given font supports a fixed size table, use frasterize with the “-d” switch.
- p NUM** specifies the index of the first character in the font that is to be encoded. If the value is not provided, it defaults to 32 which is typically the space character. This switch is ignored if “-c” is provided.
- e NUM** specifies the index of the last character in the font that is to be encoded. If the value is not provided, it defaults to 126 which, in ISO8859-1 is tilde. This switch is ignored if “-c” is provided.
- v** specifies that verbose output should be generated.
- w NUM** encodes the specified character index as a space regardless of the character which may be present in the font at that location. This is helpful in allowing a space to be included in a font which only encodes a subset of the characters which would not normally include the space character (for example, numeric digits only). If absent, this value defaults to 32, ensuring that character 32 is always the space. Ignored if “-r” is specified.
- n** overrides -w and causes no character to be encoded as a space unless the source font already contains a space.
- u** causes frasterize to use Unicode character mapping when extracting glyphs from the source font. If absent, the Adobe Custom character map is used if it exists or Unicode otherwise.
- r** specifies that the output should be a relocatable, wide character set font described using the tFontWide structure. Such fonts are suitable for encoding characters sets described using Unicode or when multiple contiguous blocks of characters are to be stored in a single font file. This switch may be used in conjunction with “-y” to create a binary font file suitable for use from a file system.
- y** writes the output in binary rather than text format. This switch is only valid if used in conjunction with “-r” and is ignored otherwise. Fonts generated in binary format may be accessed by the graphics library from a file system or other indirect storage assuming that simple wrapper software is provided.
- o NUM** specifies the codepoint for the first character in the source font which is to be translated to a new position in the output font. If this switch is not provided, no remapping takes place. If specified, this switch must be used in conjunction with -t which specifies where remapped characters are placed in the output font. Ignored if “-r” is specified.
- t NUM** specifies the output font character index for the first character remapped from a higher

codepoint in the source font. This should be used in conjunction with “-o”. The default value is 0. Ignored if “-r” is specified.

**-z NUM** specifies the codepage identifier for the output font. This switch is only valid if used with “-r” and is primarily intended for use when performing codepage remapping and custom string tables. The number provided when performing remapping must be in the region between CODEPAGE\_CUSTOM\_BASE (0x8000) and 0xFFFF.

**INPUT FILE** specifies the name of the input font file. When used with “-r”, up to four font filenames may be provided in order of priority. Characters missing from the first font are searched for in the remaining fonts. This allows the output font to contain characters from multiple different fonts and is helpful when generating multi-language string tables containing different alphabets which do not all exist in a single input font file.

### Examples:

The following example produces a 24-point font called test and containing ASCII characters in the range 0x20 to 0x7F from test.ttf:

```
ftrasterize -f test -s 24 test.ttf
```

The result will be written to fonttest24.c, and will contain a structure called g\_sFontTest24 that describes the font.

The following would render a Computer Modern small-caps font at 44 points and generate an output font containing only characters 47 through 58 (the numeric digits). Additionally, the first character in the encoded font (which is displayed if an attempt is made to render a character which is not included in the font) is forced to be a space:

```
ftrasterize -f cmscdigits -s 44 -w 47 -p 47 -e 58 cmcsc10.pfb
```

The output will be written to fontcmscdigits44.c and contain a definition for g\_sFontCmscdigits44 that describes the font.

To generate some ISO8859 variant fonts, a block of characters from a source Unicode font must be moved downwards into the [0-255] codepoint range of the output font. This can be achieved by making use of the -t and -o switches. For example, the following will generate a font containing characters 32 to 255 of the ISO8859-5 character mapping. This contains the basic western European alphanumerics and the Cyrillic alphabet. The Cyrillic characters are found starting at Unicode character 1024 (0x400) but these must be placed starting at ISO8859-5 character number 160 (0xA0) so we encode characters 160 and above in the output from the Unicode block starting at 1024 to translate the Cyrillic glyphs into the correct position in the output:

```
ftrasterize -f cyrillic -s 18 -p 32 -e 255 -t 160 -o 1024 -u unicode.ttf
```

When encoding wide character sets for multiple alphabets (Roman, Arabic, Cyrillic, Hebrew, etc.) or to deal with ideograph-based writing systems (Hangul, Traditional or Simplified Chinese, Hiragana, Katakana, etc.), a character block map file is required to define which sections of the source font’s codespace to encode into the destination font. The following example character map could be used to encode a font containing ASCII plus the Japanese Katakana alphabets:

```
#####  
#  
# katakana.txt - Unicode block definitions for ASCII and Katakana.  
#  
#####
```

```
# ASCII characters  
0x20, 0x7E
```

```
# Katakana alphabet  
0x30A0, 0x30FF  
0x31F0, 0x32FF  
0xFF00, 0xFFEF
```

Assuming the font “unicode.ttf” contains these glyphs and that it includes fixed size character renderings, the fifth of which uses an 8x12 character cell size, the following `ftrasterize` command line could then be used to generate a binary font file called `fontkatakana8x12.bin` containing this subset of characters:

```
ftrasterize -f katakana -s F4 -c katakana.txt -y -r -u unicode.ttf
```

In this case, the output file will be `fontkatakana8x12.bin` and it will contain a binary version of the font suitable for use from external memory (SDCard, a file system, serial flash memory, etc.) via a `tFontWrapper` and a suitable font wrapper module.

## USB DFU Library

### Description:

LMDFU is a Windows dynamic link library offering a high level interface to the USB Device Firmware Upgrade functionality provided by the Stellaris USB boot loader (`boot_usb`). This DLL is used by the `dfuprog` utility and also by the `LMFlash` application to allow download and upload of application images to or from a Stellaris-based board via USB.

The source code for this DLL is contained in `tools/lmdfu`. The DLL binary is installed as part of the “Stellaris embedded USB drivers” package (SW-USB-windrivers) shipped on the release CD and downloadable from [http://www.ti.com/software\\_updates.html](http://www.ti.com/software_updates.html). A Microsoft Visual Studio 2008 project file is provided to allow the application to be built.

## USB Dynamic Link Library

### Description:

LMUSB DLL is a simple Windows dynamic link library offering low level packet read and write functions for some USB-connected Stellaris example applications. The DLL is written above the Microsoft WinUSB interface and is intended solely to ensure that various Windows-side example applications can be built without having to use WinUSB header files. These header files are not included in the Visual Studio tools and are only shipped in the Windows Device Driver Kit (DDK). By providing this simple mapping DLL which links to WinUSB, the user avoids the need for a multi-gigabyte download to build the examples.

The source code for this DLL is contained in `tools/lmusbdll`. The DLL binary is installed as part of the “Stellaris embedded USB drivers” package (SW-USB-windrivers) shipped on the release CD and downloadable from [http://www.ti.com/software\\_updates.html](http://www.ti.com/software_updates.html). A Microsoft Visual Studio 2008 project file is provided to allow the DLL to be built on a PC which has the Windows Device Driver Kit installed.

## Data Logger

### Usage:

`logger`

### Description:

Provides a Windows front-end for the ek-lm4f232 data logger application (qs-logger) and allows captured data to be logged to file and displayed on the screen in several strip charts.

The qs-logger application provides a virtual COM port via USB and the logger application opens this and parses data received from the board as it is captured. All control, other than setting up the file and deciding which captured channels' data to display, is performed using the menus provided by the qs-logger application on the ek-lm4f232 board.

The device driver required to support the qs-logger application's virtual COM port on Windows can be found in `windows_drivers`.

The source code for this utility is contained in `tools/logger`, with a pre-built binary contained in `tools/bin`.

## String Table Generator

### Usage:

`mkstringtable [INPUT FILE] [OUTPUT FILE]`

### Description:

Converts a comma separated file (.csv) to a table of strings that can be used by the Stellaris Graphics Library. The source .csv file has a simple fixed format that supports multiple strings in multiple languages. A .c and .h file will be created that can be compiled in with an application and used with the graphics library's string table handling functions. If encoding purely ASCII strings, the strings will also be compressed in order to reduce the space required to store them. If the CSV file contains strings encoded in other codepages, for example UTF8, the "-s" command line option must be used to specify the encoding used for the string and "-u" must also be used to ensure that the strings are stored correctly.

The format of the input .csv file is simple and easily edited in any plain text editor or a spreadsheet editor capable of reading and editing a .csv file. The .csv file format has a header row where the first entry in the row can be any string as it is ignored. The remaining entries in the row must be one of the GrLang\* language definitions defined by the graphics library in `grlib.h` or they must have a `#define` definition that is valid for the application as this text is used directly in the C output file that is produced. Adding additional languages only requires that the value is unique in the table and that the name used is defined by the application.

The strings are specified one per line in the .csv file. The first entry in any line is the value that is used as the actual text for the definition for the given string. The remaining entries should be the strings for each language specified in the header. Single words with no special characters do not require quotations, however any strings with a "," character must be quoted as the "," character is the delimiter for each item in the line. If the string has a quote character "" it must be preceded by another quote character.

The following is an example .csv file containing string in English (US), German, Spanish (SP), and Italian:

```
LanguageIDs,GrLangEnUS,GrLangDE,GrLangEsSP,GrLangIt
STR_CONFIG,Configuration,Konfigurieren,Configuracion,Configurazione
STR_INTRO,Introduction,Einführung,Introduccion,Introduzione
STR_QUOTE,Introduction in "English","Einführung, in Deutsch",Prueba,Verifica
...
```

In this example, `STR_QUOTE` would result in the following strings in the various languages:

- `GrLangEnUs` – Introduction in "English"
- `GrLangDE` – Einführung, in Deutsch
- `GrLangEsSP` – Prueba
- `GrLangIt` – Verifica

The resulting `.c` file contains the string table that must be included with the application that is using the string table and two helper structure definitions, one a `tCodepointMap` array containing a single entry that is suitable for use with `GrCodepageMapTableSet()` and the other a `tGrLibDefaults` structure which can be used with `GrLibInit()` to initialize the graphics library to use the correct codepage for the string table.

While the contents of this `.c` file are readable, the string table itself may be unintelligible due to the compression or remapping used on the strings themselves. The `.h` file that is created has the definition for the string table as well as an enumerated type `enum SCOMP_STR_INDEX` that contains all of the string indexes that were present in the original `.csv` file and external definitions for the `tCodepointMap` and `tGrLibDefaults` structures defined in the `.c` file.

The code that uses the string table produced by this utility must refer to the strings by their identifier in the original `.csv` file. In the example above, this means that the value `STR_CONFIG` would refer to the “Configuration” string in English (`GrLangEnUS`) or “Konfigurieren” in German (`GrLangDE`).

This utility is contained in `tools/bin`.

#### Arguments:

- u** indicates that the input `.csv` file contains strings encoded with UTF8 or some other non-ASCII codepage. If absent, `mkstringtable` assumes ASCII text and uses this knowledge to apply higher compression to the string table.
- c NUM** specifies the custom codepage identifier to use when remapping the string table for use with a custom font. Applications using the string table must set this value as the text codepage in use via a call to `GrStringCodepageSet()` and must ensure that they include an entry in their codepage mapping table specifying this value as both the source and font codepage. A macro, `GRLIB_CUSTOM_MAP_xxx`, containing the required `tCodePointMap` structure is written to the output header file to make this easier. A structure, `g_GrLibDefaultxxxx`, is also exported and a pointer to this may be passed to `GrLibInit()` to allow widgets to make use of the string table’s custom codepage. Valid values to pass as `NUM` are in the `0x8000` to `0xFFFF` range set aside by the graphics library for application-specific or custom text codepages.
- r** indicates that the output string table should be constructed for use with a custom font and codepage. Character values in the string are remapped into a custom codepage intended to minimize the size of both the string table and the custom font used to display its strings. If “-r” is specified, an additional `.txt` output file is generated containing information that may be passed to the `ftrasterize` tool to create a compatible custom font containing only the characters required by the string table contents.
- s STR** specifies the codepage used in the input `.csv` file. If this switch is absent, ASCII is assumed. Valid values of `STR` are “ASCII”, “utf8” and “iso8859-n” where “n” indicates the ISO8859 variant in use and can have values from 1 to 11 or 13 to 16. Care must be taken

to ensure that the .csv file is correctly encoded and makes use of the encoding specified using “-s” since a mismatch will cause the output strings to be incorrect. Note, also, that support for UTF-8 and ISO8859 varies from text editor to text editor so it is important to ensure that your editor supports the desired codepage to prevent string corruption.

**-t** indicates that a character map file with a .txt extension should be generated in addition to the usual .c and .h output files. This output file may be passed to `ftrasterize` to generate a custom font containing only the glyphs required to display the strings in the table. Unlike the character map file generated when using “-r”, the version generated by “-t” will not remap the codepage of the strings in the table. This has the advantage of leaving them readable in a debugger (which typically understands ASCII and common codepages) but will generate a font that is rather larger than the font that would have been generated using a remapped codepage due to the additional overhead of encoding many small blocks of discontinuous characters.

**INPUT FILE** specifies the input .csv file to use to create a string table.

**OUTPUT FILE** specifies the root name of the output files as `<OUTPUT FILE>.c` and `<OUTPUT FILE>.h`. The value is also used in the naming of the string table variable.

**Example:**

The following will create a string table in `str.c`, with prototypes in `str.h`, based on the ASCII input file `str.csv`:

```
mkstringtable str.csv str
```

In the produced `str.c`, there will be a string table in `g_pucTablestr`.

The following will create a string table in `widestr.c`, with prototypes in `widestr.h`, based on the UTF8 input file `widestr.csv`. This form of the call should be used to encode string tables containing accented characters or non-Western character sets:

```
mkstringtable -u widestr.csv widestr
```

In the produced `widestr.c`, there will be a string table in `g_pucTablewidestr`.

## NetPNM Converter

**Usage:**

```
pnmtoC [OPTION]... [INPUT FILE]
```

**Description:**

Converts a NetPBM image file into the format that is recognized by the Stellaris Graphics Library. The input image must be in the raw PPM format (in other words, with the P4, P5 or P6 tags). The NetPBM image format can be produced using GIMP, NetPBM (<http://netpbm.sourceforge.net>), ImageMagick (<http://www.imagemagick.org>), or numerous other open source and proprietary image manipulation packages.

The resulting C image array definition is written to standard output; this follows the convention of the NetPBM toolkit after which the application was modeled (both in behavior and naming). The output should be redirected into a file so that it can then be used by the application.

To take a JPEG and convert it for use by the graphics library (using GIMP; a similar technique would be used in other graphics programs):

1. Load the file (File->Open).

2. Convert the image to indexed mode (Image->Mode->Indexed). Select “Generate optimum palette” and select either 2, 16, or 256 as the maximum number of colors (for a 1 BPP, 4 BPP, or 8 BPP image respectively). If the image is already in indexed mode, it can be converted to RGB mode (Image->Mode->RGB) and then back to indexed mode.
3. Save the file as a PNM image (File->Save As). Select raw format when prompted.
4. Use `pnmto c` to convert the PNM image into a C array.

This sequence will be the same for any source image type (GIF, BMP, TIFF, and so on); once loaded into GIMP, it will treat all image types equally. For some source images, such as a GIF which is naturally an indexed format with 256 colors, the second step could be skipped if an 8 BPP image is desired in the application.

The source code for this utility is contained in `tools/pnmto c`, with a pre-built binary contained in `tools/bin`.

**Arguments:**

- c specifies that the image should be compressed. Compression is bypassed if it would result in a larger C array.

**Example:**

The following will produce a compressed image in `foo.c` from `foo.ppm`:

```
pnmto c -c foo.ppm > foo.c
```

This will result in an array called `g_pucImage` that contains the image data from `foo.ppm`.

## Serial Flash Downloader

**Usage:**

```
sflash [OPTION]... [INPUT FILE]
```

**Description:**

Downloads a firmware image to a Stellaris board using a UART connection to the Stellaris Serial Flash Loader or the Stellaris Boot Loader. This has the same capabilities as the serial download portion of the Stellaris Flash Programmer.

The source code for this utility is contained in `tools/sflash`, with a pre-built binary contained in `tools/bin`.

**Arguments:**

- b **BAUD** specifies the baud rate. If not specified, the default of 115,200 will be used.
- c **PORT** specifies the COM port. If not specified, the default of COM1 will be used.
- d disables auto-baud.
- h displays usage information.
- l **FILENAME** specifies the name of the boot loader image file.
- p **ADDR** specifies the address at which to program the firmware. If not specified, the default of 0 will be used.
- r **ADDR** specifies the address at which to start processor execution after the firmware has been downloaded. If not specified, the processor will be reset after the firmware has been downloaded.

**-s SIZE** specifies the size of the data packets used to download the firmware data. This must be a multiple of four between 8 and 252, inclusive. If using the Serial Flash Loader, the maximum value that can be used is 76. If using the Boot Loader, the maximum value that can be used is dependent upon the configuration of the Boot Loader. If not specified, the default of 8 will be used.

**INPUT FILE** specifies the name of the firmware image file.

**Example:**

The following will download a firmware image to the board over COM2 without auto-baud support:

```
sflash -c 2 -d image.bin
```

## USB Bulk Data Transfer Example

**Description:**

usb\_bulk\_example is a Windows command line application which communicates with the StellarisWare usb\_dev\_bulk example. The application finds the Stellaris device on the USB bus then, if found, prompts the user to enter strings which are sent to the application running on the Stellaris board. This application then inverts the case of the alphabetic characters in the string and returns the data back to the USB host where it is displayed.

The source code for this application is contained in `tools/usb_bulk_example`. The binary is installed as part of the “Windows-side examples for USB kits” package (SW-USB-win) shipped on the release CD and downloadable from [http://www.luminarymicro.com/products/software\\_updates.html](http://www.luminarymicro.com/products/software_updates.html). A Microsoft Visual Studio project file is provided to allow the application to be built.



## 4 Buttons Driver

Introduction .....	25
API Functions .....	25
Programming Example .....	26

### 4.1 Introduction

The buttons driver provides functions to make it easy to use the push buttons on the EK-LM4F232 evaluation board. The driver provides a function to initialize all the hardware required for the buttons, and features for debouncing and querying the button state.

This driver is located in `boards/ek-lm4f232/drivers`, with `buttons.c` containing the source code and `buttons.h` containing the API definitions for use by applications.

### 4.2 API Functions

#### Functions

- void `ButtonsInit` (void)
- unsigned char `ButtonsPoll` (unsigned char \*pucDelta, unsigned char \*pucRawState)

#### 4.2.1 Function Documentation

##### 4.2.1.1 ButtonsInit

Initializes the GPIO pins used by the board pushbuttons.

**Prototype:**

```
void  
ButtonsInit(void)
```

**Description:**

This function must be called during application initialization to configure the GPIO pins to which the pushbuttons are attached. It enables the port used by the buttons and configures each button GPIO as an input with a weak pull-up.

**Returns:**

None.

##### 4.2.1.2 ButtonsPoll

Polls the current state of the buttons and determines which have changed.

**Prototype:**

```
unsigned char
ButtonsPoll(unsigned char *pucDelta,
            unsigned char *pucRawState)
```

**Parameters:**

***pucDelta*** points to a character that will be written to indicate which button states changed since the last time this function was called. This value is derived from the debounced state of the buttons.

***pucRawState*** points to a location where the raw button state will be stored.

**Description:**

This function should be called periodically by the application to poll the pushbuttons. It determines both the current debounced state of the buttons and also which buttons have changed state since the last time the function was called.

In order for button debouncing to work properly, this function should be called at a regular interval, even if the state of the buttons is not needed that often.

If button debouncing is not required, the caller can pass a pointer for the *pucRawState* parameter in order to get the raw state of the buttons. The value returned in *pucRawState* will be a bit mask where a 1 indicates the button is pressed.

**Returns:**

Returns the current debounced state of the buttons where a 1 in the button ID's position indicates that the button is pressed and a 0 indicates that it is released.

## 4.3 Programming Example

The following example shows how to use the buttons driver to initialize the buttons, debounce and read the buttons state.

```
//
// Initialize the buttons.
//
ButtonsInit();

//
// From timed processing loop (for example every 10 ms)
//
...
{
    //
    // Poll the buttons. When called periodically this function will
    // run the button debouncing algorithm.
    //
    ucState = ButtonsPoll(&ucDelta, 0);

    //
    // Test to see if the SELECT button was pressed and do something
    //
    if (BUTTON_PRESSED(SELECT_BUTTON, ucState, ucDelta))
    {
        ...
        // SELECT button action
    }
}
```

## 5 Display Driver

Introduction .....	27
API Functions .....	27
Programming Example .....	28

### 5.1 Introduction

The display driver offers a standard interface to access display functions on the CrystalFontz 96x64 16-bit color OLED display and is used by the Stellaris Graphics Library and widget manager. In addition to providing the `tDisplay` structure required by the graphics library, the display driver also provides an API for initializing the display.

This driver is located in `boards/ek-lm4f232/drivers`, with `cfal96x64x16.c` containing the source code and `cfal96x64x16.h` containing the API definitions for use by applications.

### 5.2 API Functions

#### Functions

- void `CFAL96x64x16Init` (void)

#### Variables

- const `tDisplay` `g_sCFAL96x64x16`

#### 5.2.1 Function Documentation

##### 5.2.1.1 CFAL96x64x16Init

Initializes the display driver.

**Prototype:**

```
void  
CFAL96x64x16Init (void)
```

**Description:**

This function initializes the SSD1332 display controller on the panel, preparing it to display data.

**Returns:**

None.

## 5.2.2 Variable Documentation

### 5.2.2.1 g\_sCFAL96x64x16

**Definition:**

```
const tDisplay g_sCFAL96x64x16
```

**Description:**

The display structure that describes the driver for the Crystalfontz CFAL9664-F-B1 OLED panel with SSD 1332 controller.

## 5.3 Programming Example

The following example shows how to initialize the display and prepare to draw on it using the graphics library.

```
tContext sContext;

//
// Initialize the display.
//
CFAL96x64x16Init();

//
// Initialize a graphics library drawing context.
//
GrContextInit(&sContext, &g_sCFAL96x64x16);
```

## 6 Command Line Processing Module

Introduction .....	29
API Functions .....	29
Programming Example .....	31

### 6.1 Introduction

The command line processor allows a simple command line interface to be made available in an application, for example via a UART. It takes a buffer containing a string (which must be obtained by the application) and breaks it up into a command and arguments (in traditional C “argc, argv” format). The command is then found in a command table and the corresponding function in the table is called to process the command.

This module is contained in `utils/cmdline.c`, with `utils/cmdline.h` containing the API definitions for use by applications.

### 6.2 API Functions

#### Data Structures

- `tCmdLineEntry`

#### Defines

- `CMDLINE_BAD_CMD`
- `CMDLINE_TOO_MANY_ARGS`

#### Functions

- `int CmdLineProcess (char *pcCmdLine)`

#### Variables

- `tCmdLineEntry g_sCmdTable[]`

## 6.2.1 Data Structure Documentation

### 6.2.1.1 tCmdLineEntry

**Definition:**

```
typedef struct
{
    const char *pcCmd;
    pfnCmdLine pfnCmd;
    const char *pcHelp;
}
tCmdLineEntry
```

**Members:**

**pcCmd** A pointer to a string containing the name of the command.

**pfnCmd** A function pointer to the implementation of the command.

**pcHelp** A pointer to a string of brief help text for the command.

**Description:**

Structure for an entry in the command list table.

## 6.2.2 Define Documentation

### 6.2.2.1 CMDLINE\_BAD\_CMD

**Definition:**

```
#define CMDLINE_BAD_CMD
```

**Description:**

Defines the value that is returned if the command is not found.

### 6.2.2.2 CMDLINE\_TOO\_MANY\_ARGS

**Definition:**

```
#define CMDLINE_TOO_MANY_ARGS
```

**Description:**

Defines the value that is returned if there are too many arguments.

## 6.2.3 Function Documentation

### 6.2.3.1 CmdLineProcess

Process a command line string into arguments and execute the command.

**Prototype:**

```
int
CmdLineProcess(char *pcCmdLine)
```

**Parameters:**

**pcCmdLine** points to a string that contains a command line that was obtained by an application by some means.

**Description:**

This function will take the supplied command line string and break it up into individual arguments. The first argument is treated as a command and is searched for in the command table. If the command is found, then the command function is called and all of the command line arguments are passed in the normal argc, argv form.

The command table is contained in an array named `g_sCmdTable` which must be provided by the application.

**Returns:**

Returns **CMDLINE\_BAD\_CMD** if the command is not found, **CMDLINE\_TOO\_MANY\_ARGS** if there are more arguments than can be parsed. Otherwise it returns the code that was returned by the command function.

## 6.2.4 Variable Documentation

### 6.2.4.1 g\_sCmdTable

**Definition:**

```
tCmdLineEntry g_sCmdTable[ ]
```

**Description:**

This is the command table that must be provided by the application.

## 6.3 Programming Example

The following example shows how to process a command line.

```
//
// Code for the "foo" command.
//
int
ProcessFoo(int argc, char *argv[])
{
    //
    // Do something, using argc and argv if the command takes arguments.
    //
}

//
// Code for the "bar" command.
//
int
ProcessBar(int argc, char *argv[])
{
    //
    // Do something, using argc and argv if the command takes arguments.
    //
}
```

```
//
// Code for the "help" command.
//
int
ProcessHelp(int argc, char *argv[])
{
    //
    // Provide help.
    //
}

//
// The table of commands supported by this application.
//
tCmdLineEntry g_sCmdTable[] =
{
    { "foo", ProcessFoo, "The first command." },
    { "bar", ProcessBar, "The second command." },
    { "help", ProcessHelp, "Application help." }
};

//
// Read a process a command.
//
int
Test(void)
{
    unsigned char pucCmd[256];

    //
    // Retrieve a command from the user into pucCmd.
    //
    ...

    //
    // Process the command line.
    //
    return(CmdLineProcess(pucCmd));
}
```



## 7 CPU Usage Module

Introduction .....	33
API Functions .....	33
Programming Example .....	34

### 7.1 Introduction

The CPU utilization module uses one of the system timers and peripheral clock gating to determine the percentage of the time that the processor is being clocked. For the most part, the processor is executing code whenever it is being clocked (exceptions occur when the clocking is being configured, which only happens at startup, and when entering/exiting an interrupt handler, when the processor is performing stacking operations on behalf of the application).

The specified timer is configured to run when the processor is in run mode and to not run when the processor is in sleep mode. Therefore, the timer will only count when the processor is being clocked. Comparing the number of clocks the timer counted during a fixed period to the number of clocks in the fixed period provides the percentage utilization.

In order for this to be effective, the application must put the processor to sleep when it has no work to do (instead of busy waiting). If the processor never goes to sleep (either because of a continual stream of work to do or a busy loop), the processor utilization will be reported as 100%.

Since deep-sleep mode changes the clocking of the system, the computed processor usage may be incorrect if deep-sleep mode is utilized. The number of clocks the processor spends in run mode will be properly counted, but the timing period may not be accurate (unless extraordinary measures are taken to ensure timing period accuracy).

The accuracy of the computed CPU utilization depends upon the regularity with which `CPUUsageTick()` is called by the application. If the CPU usage is constant, but `CPUUsageTick()` is called sporadically, the reported CPU usage will fluctuate as well despite the fact that the CPU usage is actually constant.

This module is contained in `utils/cpu_usage.c`, with `utils/cpu_usage.h` containing the API definitions for use by applications.

### 7.2 API Functions

#### Functions

- void `CPUUsageInit` (unsigned long ulClockRate, unsigned long ulRate, unsigned long ulTimer)
- unsigned long `CPUUsageTick` (void)

## 7.2.1 Function Documentation

### 7.2.1.1 CPUUsageInit

Initializes the CPU usage measurement module.

**Prototype:**

```
void
CPUUsageInit(unsigned long ulClockRate,
              unsigned long ulRate,
              unsigned long ulTimer)
```

**Parameters:**

***ulClockRate*** is the rate of the clock supplied to the timer module.

***ulRate*** is the number of times per second that [CPUUsageTick\(\)](#) is called.

***ulTimer*** is the index of the timer module to use.

**Description:**

This function prepares the CPU usage measurement module for measuring the CPU usage of the application.

**Returns:**

None.

### 7.2.1.2 CPUUsageTick

Updates the CPU usage for the new timing period.

**Prototype:**

```
unsigned long
CPUUsageTick(void)
```

**Description:**

This function, when called at the end of a timing period, will update the CPU usage.

**Returns:**

Returns the CPU usage percentage as a 16.16 fixed-point value.

## 7.3 Programming Example

The following example shows how to use the CPU usage module to measure the CPU usage where the foreground simply burns some cycles.

```
//
// The CPU usage for the most recent time period.
//
unsigned long g_ulCPUUsage;

//
// Handles the SysTick interrupt.
```

```
//
void
SysTickIntHandler(void)
{
    //
    // Compute the CPU usage for the last time period.
    //
    g_ulCPUUsage = CPUUsageTick();
}

//
// The main application.
//
int
main(void)
{
    //
    // Initialize the CPU usage module, using timer 0.
    //
    CPUUsageInit(8000000, 100, 0);

    //
    // Initialize SysTick to interrupt at 100 Hz.
    //
    SysTickPeriodSet(8000000 / 100);
    SysTickIntEnable();
    SysTickEnable();

    //
    // Loop forever.
    //
    while(1)
    {
        //
        // Delay for a little bit so that CPU usage is not zero.
        //
        SysCtlDelay(100);

        //
        // Put the processor to sleep.
        //
        SysCtlSleep();
    }
}
```



## 8 CRC Module

Introduction .....	37
API Functions .....	37
Programming Example .....	40

### 8.1 Introduction

The CRC module provides functions to compute the CRC-8-CCITT and CRC-16 of a buffer of data. Support is provided for computing a running CRC, where a partial CRC is computed on one portion of the data, and then continued at a later time on another portion of the data. This is useful when computing the CRC on a stream of data that is coming in via a serial link (for example).

A CRC is useful for detecting errors that occur during the transmission of data over a communications channel or during storage in a memory (such as flash). However, a CRC does not provide protection against an intentional modification or tampering of the data.

This module is contained in `utils/crc.c`, with `utils/crc.h` containing the API definitions for use by applications.

### 8.2 API Functions

#### Functions

- unsigned short [Crc16](#) (unsigned short `usCrc`, const unsigned char `*pucData`, unsigned long `ulCount`)
- unsigned short [Crc16Array](#) (unsigned long `ulWordLen`, const unsigned long `*pulData`)
- void [Crc16Array3](#) (unsigned long `ulWordLen`, const unsigned long `*pulData`, unsigned short `*pusCrc3`)
- unsigned char [Crc8CCITT](#) (unsigned char `ucCrc`, const unsigned char `*pucData`, unsigned long `ulCount`)

#### 8.2.1 Function Documentation

##### 8.2.1.1 Crc16

Calculates the CRC-16 of an array of bytes.

**Prototype:**

```
unsigned short
Crc16(unsigned short usCrc,
      const unsigned char *pucData,
      unsigned long ulCount)
```

**Parameters:**

***usCrc*** is the starting CRC-16 value.

***pucData*** is a pointer to the data buffer.

***ulCount*** is the number of bytes in the data buffer.

**Description:**

This function is used to calculate the CRC-16 of the input buffer. The CRC-16 is computed in a running fashion, meaning that the entire data block that is to have its CRC-16 computed does not need to be supplied all at once. If the input buffer contains the entire block of data, then ***usCrc*** should be set to 0. If, however, the entire block of data is not available, then ***usCrc*** should be set to 0 for the first portion of the data, and then the returned value should be passed back in as ***usCrc*** for the next portion of the data.

For example, to compute the CRC-16 of a block that has been split into three pieces, use the following:

```
usCrc = Crc16(0, pucData1, ulLen1);
usCrc = Crc16(usCrc, pucData2, ulLen2);
usCrc = Crc16(usCrc, pucData3, ulLen3);
```

Computing a CRC-16 in a running fashion is useful in cases where the data is arriving via a serial link (for example) and is therefore not all available at one time.

**Returns:**

The CRC-16 of the input data.

### 8.2.1.2 Crc16Array

Calculates the CRC-16 of an array of words.

**Prototype:**

```
unsigned short
Crc16Array(unsigned long ulWordLen,
           const unsigned long *pulData)
```

**Parameters:**

***ulWordLen*** is the length of the array in words (the number of bytes divided by 4).

***pulData*** is a pointer to the data buffer.

**Description:**

This function is a wrapper around the running CRC-16 function, providing the CRC-16 for a single block of data.

**Returns:**

The CRC-16 of the input data.

### 8.2.1.3 Crc16Array3

Calculates three CRC-16s of an array of words.

**Prototype:**

```
void
Crc16Array3(unsigned long ulWordLen,
```

```
const unsigned long *pulData,
unsigned short *pusCrc3)
```

**Parameters:**

**ulWordLen** is the length of the array in words (the number of bytes divided by 4).

**pulData** is a pointer to the data buffer.

**pusCrc3** is a pointer to an array in which to place the three CRC-16 values.

**Description:**

This function is used to calculate three CRC-16s of the input buffer; the first uses every byte from the array, the second uses only the even-index bytes from the array (in other words, bytes 0, 2, 4, etc.), and the third uses only the odd-index bytes from the array (in other words, bytes 1, 3, 5, etc.).

**Returns:**

None

### 8.2.1.4 Crc8CCITT

Calculates the CRC-8-CCITT of an array of bytes.

**Prototype:**

```
unsigned char
Crc8CCITT(unsigned char ucCrc,
const unsigned char *pucData,
unsigned long ulCount)
```

**Parameters:**

**ucCrc** is the starting CRC-8-CCITT value.

**pucData** is a pointer to the data buffer.

**ulCount** is the number of bytes in the data buffer.

**Description:**

This function is used to calculate the CRC-8-CCITT of the input buffer. The CRC-8-CCITT is computed in a running fashion, meaning that the entire data block that is to have its CRC-8-CCITT computed does not need to be supplied all at once. If the input buffer contains the entire block of data, then **ucCrc** should be set to 0. If, however, the entire block of data is not available, then **ucCrc** should be set to 0 for the first portion of the data, and then the returned value should be passed back in as **ucCrc** for the next portion of the data.

For example, to compute the CRC-8-CCITT of a block that has been split into three pieces, use the following:

```
ucCrc = Crc8CCITT(0, pucData1, ulLen1);
ucCrc = Crc8CCITT(ucCrc, pucData2, ulLen2);
ucCrc = Crc8CCITT(ucCrc, pucData3, ulLen3);
```

Computing a CRC-8-CCITT in a running fashion is useful in cases where the data is arriving via a serial link (for example) and is therefore not all available at one time.

**Returns:**

The CRC-8-CCITT of the input data.

## 8.3 Programming Example

The following example shows how to compute the CRC-16 of a buffer of data.

```
unsigned long ulIdx, ulValue;
unsigned char pucData[256];

//
// Fill pucData with some data.
//
for(ulIdx = 0; ulIdx < 256; ulIdx++)
{
    pucData[ulIdx] = ulIdx;
}

//
// Compute the CRC-16 of the data.
//
ulValue = Crc16(0, pucData, 256);
```



## 9 Flash Parameter Block Module

Introduction .....	41
API Functions .....	41
Programming Example .....	43

### 9.1 Introduction

The flash parameter block module provides a simple, fault-tolerant, persistent storage mechanism for storing parameter information for an application.

The [FlashPBlockInit\(\)](#) function is used to initialize a parameter block. The primary conditions for the parameter block are that flash region used to store the parameter blocks must contain at least two erase blocks of flash to ensure fault tolerance, and the size of the parameter block must be an integral divisor of the the size of an erase block. [FlashPBlockGet\(\)](#) and [FlashPBlockSave\(\)](#) are used to read and write parameter block data into the parameter region. The only constraints on the content of the parameter block are that the first two bytes of the block are reserved for use by the read/write functions as a sequence number and checksum, respectively.

This module is contained in `utils/flash_pb.c`, with `utils/flash_pb.h` containing the API definitions for use by applications.

### 9.2 API Functions

#### Functions

- unsigned char \* [FlashPBlockGet](#) (void)
- void [FlashPBlockInit](#) (unsigned long ulStart, unsigned long ulEnd, unsigned long ulSize)
- void [FlashPBlockSave](#) (unsigned char \*pucBuffer)

#### 9.2.1 Function Documentation

##### 9.2.1.1 FlashPBlockGet

Gets the address of the most recent parameter block.

**Prototype:**

```
unsigned char *  
FlashPBlockGet (void)
```

**Description:**

This function returns the address of the most recent parameter block that is stored in flash.

**Returns:**

Returns the address of the most recent parameter block, or NULL if there are no valid parameter blocks in flash.

### 9.2.1.2 FlashPBlockInit

Initializes the flash parameter block.

**Prototype:**

```
void  
FlashPBlockInit(unsigned long ulStart,  
                unsigned long ulEnd,  
                unsigned long ulSize)
```

**Parameters:**

**ulStart** is the address of the flash memory to be used for storing flash parameter blocks; this must be the start of an erase block in the flash.

**ulEnd** is the address of the end of flash memory to be used for storing flash parameter blocks; this must be the start of an erase block in the flash (the first block that is NOT part of the flash memory to be used), or the address of the first word after the flash array if the last block of flash is to be used.

**ulSize** is the size of the parameter block when stored in flash; this must be a power of two less than or equal to the flash erase block size (typically 1024).

**Description:**

This function initializes a fault-tolerant, persistent storage mechanism for a parameter block for an application. The last several erase blocks of flash (as specified by *ulStart* and *ulEnd*) are used for the storage; more than one erase block is required in order to be fault-tolerant.

A parameter block is an array of bytes that contain the persistent parameters for the application. The only special requirement for the parameter block is that the first byte is a sequence number (explained in [FlashPBlockSave\(\)](#)) and the second byte is a checksum used to validate the correctness of the data (the checksum byte is the byte such that the sum of all bytes in the parameter block is zero).

The portion of flash for parameter block storage is split into N equal-sized regions, where each region is the size of a parameter block (*ulSize*). Each region is scanned to find the most recent valid parameter block. The region that has a valid checksum and has the highest sequence number (with special consideration given to wrapping back to zero) is considered to be the current parameter block.

In order to make this efficient and effective, three conditions must be met. The first is *ulStart* and *ulEnd* must be specified such that at least two erase blocks of flash are dedicated to parameter block storage. If not, fault tolerance can not be guaranteed since an erase of a single block will leave a window where there are no valid parameter blocks in flash. The second condition is that the size (*ulSize*) of the parameter block must be an integral divisor of the size of an erase block of flash. If not, a parameter block will end up spanning between two erase blocks of flash, making it more difficult to manage. The final condition is that the size of the flash dedicated to parameter blocks (*ulEnd* - *ulStart*) divided by the parameter block size (*ulSize*) must be less than or equal to 128. If not, it will not be possible in all cases to determine which parameter block is the most recent (specifically when dealing with the sequence number wrapping back to zero).

When the microcontroller is initially programmed, the flash blocks used for parameter block storage are left in an erased state.

This function must be called before any other flash parameter block functions are called.

**Returns:**

None.

### 9.2.1.3 FlashPBSave

Writes a new parameter block to flash.

**Prototype:**

```
void  
FlashPBSave(unsigned char *pucBuffer)
```

**Parameters:**

***pucBuffer*** is the address of the parameter block to be written to flash.

**Description:**

This function will write a parameter block to flash. Saving the new parameter blocks involves three steps:

- Setting the sequence number such that it is one greater than the sequence number of the latest parameter block in flash.
- Computing the checksum of the parameter block.
- Writing the parameter block into the storage immediately following the latest parameter block in flash; if that storage is at the start of an erase block, that block is erased first.

By this process, there is always a valid parameter block in flash. If power is lost while writing a new parameter block, the checksum will not match and the partially written parameter block will be ignored. This is what makes this fault-tolerant.

Another benefit of this scheme is that it provides wear leveling on the flash. Since multiple parameter blocks fit into each erase block of flash, and multiple erase blocks are used for parameter block storage, it takes quite a few parameter block saves before flash is re-written.

**Returns:**

None.

## 9.3 Programming Example

The following example shows how to use the flash parameter block module to read the contents of a flash parameter block.

```
unsigned char pucBuffer[16], *pucPB;  
  
//  
// Initialize the flash parameter block module, using the last two pages of  
// a 64 KB device as the parameter block.  
//  
FlashPBInit(0xf800, 0x10000, 16);  
  
//  
// Read the current parameter block.  
//  
pucPB = FlashPBGet();  
if(pucPB)  
{  
    memcpy(pucBuffer, pucPB);  
}
```



## 10 Integer Square Root Module

Introduction .....	45
API Functions .....	45
Programming Example .....	46

### 10.1 Introduction

The integer square root module provides an integer version of the square root operation that can be used instead of the floating point version provided in the C library. The algorithm used is a derivative of the manual pencil-and-paper method that used to be taught in school, and is closely related to the pencil-and-paper division method that is likely still taught in school.

For full details of the algorithm, see the article by Jack W. Crenshaw in the February 1998 issue of Embedded System Programming. It can be found online at <http://www.embedded.com/98/9802fe2.htm>.

This module is contained in `utils/isqrt.c`, with `utils/isqrt.h` containing the API definitions for use by applications.

### 10.2 API Functions

#### Functions

- unsigned long `isqrt` (unsigned long `ulValue`)

#### 10.2.1 Function Documentation

##### 10.2.1.1 `isqrt`

Compute the integer square root of an integer.

**Prototype:**

```
unsigned long  
isqrt(unsigned long ulValue)
```

**Parameters:**

***ulValue*** is the value whose square root is desired.

**Description:**

This function will compute the integer square root of the given input value. Since the value returned is also an integer, it is actually better defined as the largest integer whose square is less than or equal to the input value.

**Returns:**

Returns the square root of the input value.

## 10.3 Programming Example

The following example shows how to compute the square root of a number.

```
unsigned long ulValue;  
  
//  
// Get the square root of 52378. The result returned will be 228, which is  
// the largest integer less than or equal to the square root of 52378.  
//  
ulValue = isqrt(52378);
```

# 11 Ring Buffer Module

Introduction .....	47
API Functions .....	47
Programming Example .....	53

## 11.1 Introduction

The ring buffer module provides a set of functions allowing management of a block of memory as a ring buffer. This is typically used in buffering transmit or receive data for a communication channel but has many other uses including implementing queues and FIFOs.

This module is contained in `utils/ringbuf.c`, with `utils/ringbuf.h` containing the API definitions for use by applications.

## 11.2 API Functions

### Functions

- void [RingBufAdvanceRead](#) (tRingBufObject \*ptRingBuf, unsigned long ulNumBytes)
- void [RingBufAdvanceWrite](#) (tRingBufObject \*ptRingBuf, unsigned long ulNumBytes)
- unsigned long [RingBufContigFree](#) (tRingBufObject \*ptRingBuf)
- unsigned long [RingBufContigUsed](#) (tRingBufObject \*ptRingBuf)
- tBoolean [RingBufEmpty](#) (tRingBufObject \*ptRingBuf)
- void [RingBufFlush](#) (tRingBufObject \*ptRingBuf)
- unsigned long [RingBufFree](#) (tRingBufObject \*ptRingBuf)
- tBoolean [RingBufFull](#) (tRingBufObject \*ptRingBuf)
- void [RingBufInit](#) (tRingBufObject \*ptRingBuf, unsigned char \*pucBuf, unsigned long ulSize)
- void [RingBufRead](#) (tRingBufObject \*ptRingBuf, unsigned char \*pucData, unsigned long ulLength)
- unsigned char [RingBufReadOne](#) (tRingBufObject \*ptRingBuf)
- unsigned long [RingBufSize](#) (tRingBufObject \*ptRingBuf)
- unsigned long [RingBufUsed](#) (tRingBufObject \*ptRingBuf)
- void [RingBufWrite](#) (tRingBufObject \*ptRingBuf, unsigned char \*pucData, unsigned long ulLength)
- void [RingBufWriteOne](#) (tRingBufObject \*ptRingBuf, unsigned char ucData)

### 11.2.1 Function Documentation

#### 11.2.1.1 RingBufAdvanceRead

Remove bytes from the ring buffer by advancing the read index.

**Prototype:**

```
void  
RingBufAdvanceRead(tRingBufObject *ptRingBuf,  
                   unsigned long ulNumBytes)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer from which bytes are to be removed.  
***ulNumBytes*** is the number of bytes to be removed from the buffer.

**Description:**

This function advances the ring buffer read index by a given number of bytes, removing that number of bytes of data from the buffer. If *ulNumBytes* is larger than the number of bytes currently in the buffer, the buffer is emptied.

**Returns:**

None.

### 11.2.1.2 RingBufAdvanceWrite

Add bytes to the ring buffer by advancing the write index.

**Prototype:**

```
void  
RingBufAdvanceWrite(tRingBufObject *ptRingBuf,  
                   unsigned long ulNumBytes)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer to which bytes have been added.  
***ulNumBytes*** is the number of bytes added to the buffer.

**Description:**

This function should be used by clients who wish to add data to the buffer directly rather than via calls to [RingBufWrite\(\)](#) or [RingBufWriteOne\(\)](#). It advances the write index by a given number of bytes. If the *ulNumBytes* parameter is larger than the amount of free space in the buffer, the read pointer will be advanced to cater for the addition. Note that this will result in some of the oldest data in the buffer being discarded.

**Returns:**

None.

### 11.2.1.3 RingBufContigFree

Returns number of contiguous free bytes available in a ring buffer.

**Prototype:**

```
unsigned long  
RingBufContigFree(tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** is the ring buffer object to check.



**Description:**

This function returns the number of contiguous free bytes ahead of the current write pointer in the ring buffer.

**Returns:**

Returns the number of contiguous bytes available in the ring buffer.

#### 11.2.1.4 RingBufContigUsed

Returns number of contiguous bytes of data stored in ring buffer ahead of the current read pointer.

**Prototype:**

```
unsigned long  
RingBufContigUsed(tRingBufObject *ptRingBuf)
```

**Parameters:**

**ptRingBuf** is the ring buffer object to check.

**Description:**

This function returns the number of contiguous bytes of data available in the ring buffer ahead of the current read pointer. This represents the largest block of data which does not straddle the buffer wrap.

**Returns:**

Returns the number of contiguous bytes available.

#### 11.2.1.5 RingBufEmpty

Determines whether the ring buffer whose pointers and size are provided is empty or not.

**Prototype:**

```
tBoolean  
RingBufEmpty(tRingBufObject *ptRingBuf)
```

**Parameters:**

**ptRingBuf** is the ring buffer object to empty.

**Description:**

This function is used to determine whether or not a given ring buffer is empty. The structure is specifically to ensure that we do not see warnings from the compiler related to the order of volatile accesses being undefined.

**Returns:**

Returns **true** if the buffer is empty or **false** otherwise.

#### 11.2.1.6 RingBufFlush

Empties the ring buffer.

**Prototype:**

```
void  
RingBufFlush(tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** is the ring buffer object to empty.

**Description:**

Discards all data from the ring buffer.

**Returns:**

None.

### 11.2.1.7 RingBufFree

Returns number of bytes available in a ring buffer.

**Prototype:**

```
unsigned long  
RingBufFree(tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** is the ring buffer object to check.

**Description:**

This function returns the number of bytes available in the ring buffer.

**Returns:**

Returns the number of bytes available in the ring buffer.

### 11.2.1.8 RingBufFull

Determines whether the ring buffer whose pointers and size are provided is full or not.

**Prototype:**

```
tBoolean  
RingBufFull(tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** is the ring buffer object to empty.

**Description:**

This function is used to determine whether or not a given ring buffer is full. The structure is specifically to ensure that we do not see warnings from the compiler related to the order of volatile accesses being undefined.

**Returns:**

Returns **true** if the buffer is full or **false** otherwise.

### 11.2.1.9 RingBufInit

Initialize a ring buffer object.

**Prototype:**

```
void  
RingBufInit (tRingBufObject *ptRingBuf,  
             unsigned char *pucBuf,  
             unsigned long ulSize)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer to be initialized.  
***pucBuf*** points to the data buffer to be used for the ring buffer.  
***ulSize*** is the size of the buffer in bytes.

**Description:**

This function initializes a ring buffer object, preparing it to store data.

**Returns:**

None.

### 11.2.1.10 RingBufRead

Reads data from a ring buffer.

**Prototype:**

```
void  
RingBufRead (tRingBufObject *ptRingBuf,  
             unsigned char *pucData,  
             unsigned long ulLength)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer to be read from.  
***pucData*** points to where the data should be stored.  
***ulLength*** is the number of bytes to be read.

**Description:**

This function reads a sequence of bytes from a ring buffer.

**Returns:**

None.

### 11.2.1.11 RingBufReadOne

Reads a single byte of data from a ring buffer.

**Prototype:**

```
unsigned char  
RingBufReadOne (tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer to be written to.

**Description:**

This function reads a single byte of data from a ring buffer.

**Returns:**

The byte read from the ring buffer.

#### 11.2.1.12 RingBufSize

Return size in bytes of a ring buffer.

**Prototype:**

```
unsigned long  
RingBufSize(tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** is the ring buffer object to check.

**Description:**

This function returns the size of the ring buffer.

**Returns:**

Returns the size in bytes of the ring buffer.

#### 11.2.1.13 RingBufUsed

Returns number of bytes stored in ring buffer.

**Prototype:**

```
unsigned long  
RingBufUsed(tRingBufObject *ptRingBuf)
```

**Parameters:**

***ptRingBuf*** is the ring buffer object to check.

**Description:**

This function returns the number of bytes stored in the ring buffer.

**Returns:**

Returns the number of bytes stored in the ring buffer.

#### 11.2.1.14 RingBufWrite

Writes data to a ring buffer.

**Prototype:**

```
void  
RingBufWrite(tRingBufObject *ptRingBuf,  
             unsigned char *pucData,  
             unsigned long ulLength)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer to be written to.  
***pucData*** points to the data to be written.  
***ulLength*** is the number of bytes to be written.

**Description:**

This function write a sequence of bytes into a ring buffer.

**Returns:**

None.

### 11.2.1.15 RingBufWriteOne

Writes a single byte of data to a ring buffer.

**Prototype:**

```
void  
RingBufWriteOne(tRingBufObject *ptRingBuf,  
               unsigned char ucData)
```

**Parameters:**

***ptRingBuf*** points to the ring buffer to be written to.  
***ucData*** is the byte to be written.

**Description:**

This function writes a single byte of data into a ring buffer.

**Returns:**

None.

## 11.3 Programming Example

The following example shows how to pass data through the ring buffer.

```
char pcBuffer[128], pcData[16];  
tRingBufObject sRingBuf;  
  
//  
// Initialize the ring buffer.  
//  
RingBufInit(&sRingBuf, pcBuffer, sizeof(pcBuffer));  
  
//  
// Write some data into the ring buffer.  
//  
RingBufWrite(&sRingBuf, "Hello World", 11);
```

```
//  
// Read the data out of the ring buffer.  
//  
RingBufRead(&sRingBuf, pData, 11);
```

## 12 Simple Task Scheduler Module

Introduction .....	55
API Functions .....	55
Programming Example .....	60

### 12.1 Introduction

The simple task scheduler module offers an easy way to implement applications which rely upon a group of functions being called at regular time intervals. The module makes use of an application-defined task table listing functions to be called. Each task is defined by a function pointer, a parameter that will be passed to that function, the period between consecutive calls to the function and a flag indicating whether that particular task is enabled.

The scheduler makes use of the SysTick counter and interrupt to track time and calls enabled functions when the appropriate period has elapsed since the last call to that function.

In addition to providing the task table `g_psSchedulerTable[]` to the module, the application must also define a global variable `g_ulSchedulerNumTasks` containing the number of task entries in the table. The module also requires exclusive access to the SysTick hardware and the application must hook the scheduler's SysTick interrupt handler to the appropriate interrupt vector. Although the scheduler owns SysTick, functions are provided to allow the current system time to be queried and to calculate elapsed time between two system time values or between an earlier time value and the present time.

All times passed to the scheduler or returned from it are expressed in terms of system ticks. The basic system tick rate is set by the application when it initializes the scheduler module.

This module is contained in `utils/scheduler.c`, with `utils/scheduler.h` containing the API definitions for use by applications.

### 12.2 API Functions

#### Data Structures

- `tSchedulerTask`

#### Functions

- unsigned long `SchedulerElapsedTicksCalc` (unsigned long ulTickStart, unsigned long ulTickEnd)
- unsigned long `SchedulerElapsedTicksGet` (unsigned long ulTickCount)
- void `SchedulerInit` (unsigned long ulTicksPerSecond)
- void `SchedulerRun` (void)
- void `SchedulerSysTickIntHandler` (void)
- void `SchedulerTaskDisable` (unsigned long ulIndex)
- void `SchedulerTaskEnable` (unsigned long ulIndex, tBoolean bRunNow)

- unsigned long [SchedulerTickCountGet](#) (void)

## Variables

- [tSchedulerTask](#) [g\\_psSchedulerTable](#)[]
- unsigned long [g\\_ulSchedulerNumTasks](#)

## 12.2.1 Data Structure Documentation

### 12.2.1.1 tSchedulerTask

#### Definition:

```
typedef struct
{
    void (*pfnFunction) (void *);
    void *pvParam;
    unsigned long ulFrequencyTicks;
    unsigned long ulLastCall;
    tBoolean bActive;
}
tSchedulerTask
```

#### Members:

**pfnFunction** A pointer to the function which is to be called periodically by the scheduler.

**pvParam** The parameter which is to be passed to this function when it is called.

**ulFrequencyTicks** The frequency the function is to be called expressed in terms of system ticks. If this value is 0, the function will be called on every call to SchedulerRun.

**ulLastCall** Tick count when this function was last called. This field is updated by the scheduler.

**bActive** A flag indicating whether or not this task is active. If true, the function will be called periodically. If false, the function is disabled and will not be called.

#### Description:

The structure defining a function which the scheduler will call periodically.

## 12.2.2 Function Documentation

### 12.2.2.1 SchedulerElapsedTicksCalc

Returns the number of ticks elapsed between two times.

#### Prototype:

```
unsigned long
SchedulerElapsedTicksCalc(unsigned long ulTickStart,
                          unsigned long ulTickEnd)
```

#### Parameters:

**ulTickStart** is the system tick count for the start of the period.

**ulTickEnd** is the system tick count for the end of the period.



**Description:**

This function may be called by a client to determine the number of ticks which have elapsed between provided starting and ending tick counts. The function takes into account wrapping cases where the end tick count is lower than the starting count assuming that the ending tick count always represents a later time than the starting count.

**Returns:**

The number of ticks elapsed between the provided start and end counts.

### 12.2.2.2 SchedulerElapsedTicksGet

Returns the number of ticks elapsed since the provided tick count.

**Prototype:**

```
unsigned long  
SchedulerElapsedTicksGet(unsigned long ulTickCount)
```

**Parameters:**

***ulTickCount*** is the tick count from which to determine the elapsed time.

**Description:**

This function may be called by a client to determine how much time has passed since a particular tick count provided in the *ulTickCount* parameter. This function takes into account wrapping of the global tick counter and assumes that the provided tick count always represents a time in the past. The returned value will, of course, be wrong if the tick counter has wrapped more than once since the passed *ulTickCount*. As a result, please do not use this function if you are dealing with timeouts of 497 days or longer (assuming you use a 10mS tick period).

**Returns:**

The number of ticks elapsed since the provided tick count.

### 12.2.2.3 SchedulerInit

Initializes the task scheduler.

**Prototype:**

```
void  
SchedulerInit(unsigned long ulTicksPerSecond)
```

**Parameters:**

***ulTicksPerSecond*** sets the basic frequency of the SysTick interrupt used by the scheduler to determine when to run the various task functions.

**Description:**

This function must be called during application startup to configure the SysTick timer. This is used by the scheduler module to determine when each of the functions provided in the `g_psSchedulerTable` array is called.

The caller is responsible for ensuring that [SchedulerSysTickIntHandler\(\)](#) has previously been installed in the SYSTICK vector in the vector table and must also ensure that interrupts are enabled at the CPU level.

Note that this call does not start the scheduler calling the configured functions. All function calls are made in the context of later calls to [SchedulerRun\(\)](#). This call merely configures the SysTick interrupt that is used by the scheduler to determine what the current system time is.

**Returns:**

None.

#### 12.2.2.4 SchedulerRun

Instructs the scheduler to update its task table and make calls to functions needing called.

**Prototype:**

```
void  
SchedulerRun(void)
```

**Description:**

This function must be called periodically by the client to allow the scheduler to make calls to any configured task functions if it is their time to be called. The call must be made at least as frequently as the most frequent task configured in the `g_psSchedulerTable` array.

Although the scheduler makes use of the SysTick interrupt, all calls to functions configured in `g_psSchedulerTable` are made in the context of [SchedulerRun\(\)](#).

**Returns:**

None.

#### 12.2.2.5 SchedulerSysTickIntHandler

Handles the SysTick interrupt on behalf of the scheduler module.

**Prototype:**

```
void  
SchedulerSysTickIntHandler(void)
```

**Description:**

Applications using the scheduler module must ensure that this function is hooked to the SysTick interrupt vector.

**Returns:**

None.

#### 12.2.2.6 SchedulerTaskDisable

Disables a task and prevents the scheduler from calling it.

**Prototype:**

```
void  
SchedulerTaskDisable(unsigned long ulIndex)
```

**Parameters:**

**ulIndex** is the index of the task which is to be disabled in the global *g\_psSchedulerTable* array.

**Description:**

This function marks one of the configured tasks as inactive and prevents [SchedulerRun\(\)](#) from calling it. The task may be reenabled by calling [SchedulerTaskEnable\(\)](#).

**Returns:**

None.

### 12.2.2.7 SchedulerTaskEnable

Enables a task and allows the scheduler to call it periodically.

**Prototype:**

```
void  
SchedulerTaskEnable(unsigned long ulIndex,  
                    tBoolean bRunNow)
```

**Parameters:**

**ulIndex** is the index of the task which is to be enabled in the global *g\_psSchedulerTable* array.

**bRunNow** is **true** if the task is to be run on the next call to [SchedulerRun\(\)](#) or **false** if one whole period is to elapse before the task is run.

**Description:**

This function marks one of the configured tasks as enabled and causes [SchedulerRun\(\)](#) to call that task periodically. The caller may choose to have the enabled task run for the first time on the next call to [SchedulerRun\(\)](#) or to wait one full task period before making the first call.

**Returns:**

None.

### 12.2.2.8 SchedulerTickCountGet

Returns the current system time in ticks since power on.

**Prototype:**

```
unsigned long  
SchedulerTickCountGet(void)
```

**Description:**

This function may be called by a client to retrieve the current system time. The value returned is a count of ticks elapsed since the system last booted.

**Returns:**

Tick count since last boot.

## 12.2.3 Variable Documentation

### 12.2.3.1 g\_psSchedulerTable

**Definition:**

```
tSchedulerTask g_psSchedulerTable[ ]
```

**Description:**

This global table must be populated by the client and contains information on each function that the scheduler is to call.

### 12.2.3.2 g\_ulSchedulerNumTasks

**Definition:**

```
unsigned long g_ulSchedulerNumTasks
```

**Description:**

This global variable must be exported by the client. It must contain the number of entries in the g\_psSchedulerTable array.

## 12.3 Programming Example

The following example shows how to use the task scheduler module. This code illustrates a simple application which toggles two LEDs at different rates and updates a scrolling text string on the display.

```
//*****  
//  
// Definition of the system tick rate. This results in a tick period of 10mS.  
//  
//*****  
#define TICKS_PER_SECOND 100  
  
//*****  
//  
// Prototypes of functions which will be called by the scheduler.  
//  
//*****  
static void ScrollTextBanner(void *pvParam);  
static void ToggleLED(void *pvParam);  
  
//*****  
//  
// This table defines all the tasks that the scheduler is to run, the periods  
// between calls to those tasks, and the parameter to pass to the task.  
//  
//*****  
tSchedulerTask g_psSchedulerTable[] =  
{  
    //  
    // Scroll the text banner 1 character to the left. This function is called  
    // every 20 ticks (5 times per second).  
    //  
    { ScrollTextBanner, (void *)0, 20, 0, true},  
}
```

```

//
// Toggle LED number 0 every 50 ticks (twice per second).
//
{ ToggleLED, (void *)0, 50, 0, true},

//
// Toggle LED number 1 every 100 ticks (once per second).
//
{ ToggleLED, (void *)1, 100, 0, true},
};

//*****
//
// The number of entries in the global scheduler task table.
//
//*****
unsigned long g_ulSchedulerNumTasks = (sizeof(g_psSchedulerTable) /
                                      sizeof(tSchedulerTask));

//*****
//
// This function is called by the scheduler to toggle one of two LEDs
//
//*****
static void
ToggleLED(void *pvParam)
{
    long lState;

    ulState = GPIOPinRead(LED_GPIO_BASE
                          (pvParam ? LED1_GPIO_PIN : LED0_GPIO_PIN));
    GPIOPinWrite(LED_GPIO_BASE, (pvParam ? LED1_GPIO_PIN : LED0_GPIO_PIN),
                 ~lState);
}

//*****
//
// This function is called by the scheduler to scroll a line of text on the
// display.
//
//*****
static void
ScrollTextBanner(void *pvParam)
{
    //
    // Left as an exercise for the reader.
    //
}

//*****
//
// Application main task.
//
//*****
int
main(void)
{
    //
    // Initialize system clock and any peripherals that are to be used.
    //
    SystemInit();

    //
    // Initialize the task scheduler and configure the SysTick to interrupt
    // 100 times per second.

```

```
//
SchedulerInit(TICKS_PER_SECOND);

//
// Turn on interrupts at the CPU level.
//
IntMasterEnable();

//
// Drop into the main loop.
//
while(1)
{
    //
    // Tell the scheduler to call any periodic tasks that are due to be
    // called.
    //
    SchedulerRun();
}
}
```

## 13 Sine Calculation Module

Introduction .....	63
API Functions .....	63
Programming Example .....	64

### 13.1 Introduction

This module provides a fixed-point sine function. The input angle is a 0.32 fixed-point value that is the percentage of 360 degrees. This has two benefits; the sine function does not have to handle angles that are outside the range of 0 degrees through 360 degrees (in fact, 360 degrees can not be represented since it would wrap to 0 degrees), and the computation of the angle can be simplified since it does not have to deal with wrapping at values that are not natural for binary arithmetic (such as 360 degrees or  $2\pi$  radians).

A sine table is used to find the approximate value for a given input angle. The table contains 128 entries that range from 0 degrees through 90 degrees and the symmetry of the sine function is used to determine the value between 90 degrees and 360 degrees. The maximum error caused by this table-based approach is 0.00618, which occurs near 0 and 180 degrees.

This module is contained in `utils/sine.c`, with `utils/sine.h` containing the API definitions for use by applications.

### 13.2 API Functions

#### Defines

- `cosine`(ulAngle)

#### Functions

- long `sine` (unsigned long ulAngle)

#### 13.2.1 Define Documentation

##### 13.2.1.1 cosine

Computes an approximation of the cosine of the input angle.

#### Definition:

```
#define cosine(ulAngle)
```

#### Parameters:

**ulAngle** is an angle expressed as a 0.32 fixed-point value that is the percentage of the way around a circle.

**Description:**

This function computes the cosine for the given input angle. The angle is specified in 0.32 fixed point format, and is therefore always between 0 and 360 degrees, inclusive of 0 and exclusive of 360.

**Returns:**

Returns the cosine of the angle, in 16.16 fixed point format.

## 13.2.2 Function Documentation

### 13.2.2.1 sine

Computes an approximation of the sine of the input angle.

**Prototype:**

```
long  
sine(unsigned long ulAngle)
```

**Parameters:**

***ulAngle*** is an angle expressed as a 0.32 fixed-point value that is the percentage of the way around a circle.

**Description:**

This function computes the sine for the given input angle. The angle is specified in 0.32 fixed point format, and is therefore always between 0 and 360 degrees, inclusive of 0 and exclusive of 360.

**Returns:**

Returns the sine of the angle, in 16.16 fixed point format.

## 13.3 Programming Example

The following example shows how to produce a sine wave with 7 degrees between successive values.

```
unsigned long ulValue;  
  
//  
// Produce a sine wave with each step being 7 degrees advanced from the  
// previous.  
//  
for(ulValue = 0; ; ulValue += 0x04FA4FA4)  
{  
    //  
    // Compute the sine at this angle and do something with the result.  
    //  
    sine(ulValue);  
}
```



# 14 Micro Standard Library Module

Introduction .....	65
API Functions .....	65
Programming Example .....	74

## 14.1 Introduction

The micro standard library module provides a set of small implementations of functions normally found in the C library. These functions provide reduced or greatly reduced functionality in order to remain small while still being useful for most embedded applications.

The following functions are provided, along with the C library equivalent:

Function	C library equivalent
<code>usprintf</code>	<code>sprintf</code>
<code>usnprintf</code>	<code>snprintf</code>
<code>uvsnprintf</code>	<code>vsnprintf</code>
<code>ustrnicmp</code>	<code>strnicmp</code>
<code>ustrtoul</code>	<code>strtoul</code>
<code>ustrstr</code>	<code>strstr</code>
<code>ulocaltime</code>	<code>localtime</code>

This module is contained in `utils/ustdlib.c`, with `utils/ustdlib.h` containing the API definitions for use by applications.

## 14.2 API Functions

### Data Structures

- [tTime](#)

### Functions

- void [ulocaltime](#) (unsigned long ulTime, [tTime](#) \*psTime)
- unsigned long [umktime](#) ([tTime](#) \*psTime)
- int [urand](#) (void)
- int [usnprintf](#) (char \*pcBuf, unsigned long ulSize, const char \*pcString,...)
- int [usprintf](#) (char \*pcBuf, const char \*pcString,...)
- void [usrand](#) (unsigned long ulSeed)
- int [ustrcasecmp](#) (const char \*pcStr1, const char \*pcStr2)
- int [ustrcmp](#) (const char \*pcStr1, const char \*pcStr2)
- int [ustrlen](#) (const char \*pcStr)
- int [ustrncmp](#) (const char \*pcStr1, const char \*pcStr2, int iCount)

- char \* [ustrncpy](#) (char \*pcDst, const char \*pcSrc, int iNum)
- int [ustrnicmp](#) (const char \*pcStr1, const char \*pcStr2, int iCount)
- char \* [ustrstr](#) (const char \*pcHaystack, const char \*pcNeedle)
- unsigned long [ustrtoul](#) (const char \*pcStr, const char \*\*ppcStrRet, int iBase)
- int [uvsnprintf](#) (char \*pcBuf, unsigned long ulSize, const char \*pcString, va\_list vaArgP)

## 14.2.1 Data Structure Documentation

### 14.2.1.1 tTime

**Definition:**

```
typedef struct
{
    unsigned short usYear;
    unsigned char ucMon;
    unsigned char ucMday;
    unsigned char ucWday;
    unsigned char ucHour;
    unsigned char ucMin;
    unsigned char ucSec;
}
tTime
```

**Members:**

**usYear** The number of years since 0 AD.  
**ucMon** The month, where January is 0 and December is 11.  
**ucMday** The day of the month.  
**ucWday** The day of the week, where Sunday is 0 and Saturday is 6.  
**ucHour** The number of hours.  
**ucMin** The number of minutes.  
**ucSec** The number of seconds.

**Description:**

A structure that contains the broken down date and time.

## 14.2.2 Function Documentation

### 14.2.2.1 ulocaltime

Converts from seconds to calendar date and time.

**Prototype:**

```
void
ulocaltime(unsigned long ulTime,
            tTime *psTime)
```

**Parameters:**

**ulTime** is the number of seconds.  
**psTime** is a pointer to the time structure that is filled in with the broken down date and time.

**Description:**

This function converts a number of seconds since midnight GMT on January 1, 1970 (traditional Unix epoch) into the equivalent month, day, year, hours, minutes, and seconds representation.

**Returns:**

None.

#### 14.2.2.2 umktime

Converts calendar date and time to seconds.

**Prototype:**

```
unsigned long  
umktime(tTime *psTime)
```

**Parameters:**

*psTime* is a pointer to the time structure that is filled in with the broken down date and time.

**Description:**

This function converts the date and time represented by the *psTime* structure pointer to the number of seconds since midnight GMT on January 1, 1970 (traditional Unix epoch).

**Returns:**

Returns the calendar time and date as seconds. If the conversion was not possible then the function returns (unsigned long)(-1).

#### 14.2.2.3 urand

Generate a new (pseudo) random number

**Prototype:**

```
int  
urand(void)
```

**Description:**

This function is very similar to the C library `rand()` function. It will generate a pseudo-random number sequence based on the seed value.

**Returns:**

A pseudo-random number will be returned.

#### 14.2.2.4 usnprintf

A simple `snprintf` function supporting `%c`, `%d`, `%p`, `%s`, `%u`, `%x`, and `%X`.

**Prototype:**

```
int  
usnprintf(char *pcBuf,  
          unsigned long ulSize,  
          const char *pcString,  
          ...)
```

**Parameters:**

***pcBuf*** is the buffer where the converted string is stored.

***ulSize*** is the size of the buffer.

***pcString*** is the format string.

... are the optional arguments, which depend on the contents of the format string.

**Description:**

This function is very similar to the C library `sprintf()` function. Only the following formatting characters are supported:

- %c to print a character
- %d to print a decimal value
- %s to print a string
- %u to print an unsigned decimal value
- %x to print a hexadecimal value using lower case letters
- %X to print a hexadecimal value using upper case letters (not lower case letters as would typically be used)
- %p to print a pointer as a hexadecimal value
- %% to print out a % character

For %d, %p, %s, %u, %x, and %X, an optional number may reside between the % and the format character, which specifies the minimum number of characters to use for that value; if preceded by a 0 then the extra characters will be filled with zeros instead of spaces. For example, "%8d" will use eight characters to print the decimal value with spaces added to reach eight; "%08d" will use eight characters as well but will add zeros instead of spaces.

The type of the arguments after *pcString* must match the requirements of the format string. For example, if an integer was passed where a string was expected, an error of some kind will most likely occur.

The function will copy at most *ulSize* - 1 characters into the buffer *pcBuf*. One space is reserved in the buffer for the null termination character.

The function will return the number of characters that would be converted as if there were no limit on the buffer size. Therefore it is possible for the function to return a count that is greater than the specified buffer size. If this happens, it means that the output was truncated.

**Returns:**

Returns the number of characters that were to be stored, not including the NULL termination character, regardless of space in the buffer.

### 14.2.2.5 usprintf

A simple `sprintf` function supporting %c, %d, %p, %s, %u, %x, and %X.

**Prototype:**

```
int
usprintf(char *pcBuf,
         const char *pcString,
         ...)
```

**Parameters:**

***pcBuf*** is the buffer where the converted string is stored.

***pcString*** is the format string.

... are the optional arguments, which depend on the contents of the format string.

**Description:**

This function is very similar to the C library `sprintf()` function. Only the following formatting characters are supported:

- `%c` to print a character
- `%d` to print a decimal value
- `%s` to print a string
- `%u` to print an unsigned decimal value
- `%x` to print a hexadecimal value using lower case letters
- `%X` to print a hexadecimal value using upper case letters (not upper case letters as would typically be used)
- `%p` to print a pointer as a hexadecimal value
- `%%` to print out a `%` character

For `%d`, `%p`, `%s`, `%u`, `%x`, and `%X`, an optional number may reside between the `%` and the format character, which specifies the minimum number of characters to use for that value; if preceded by a 0 then the extra characters will be filled with zeros instead of spaces. For example, `"%8d"` will use eight characters to print the decimal value with spaces added to reach eight; `"%08d"` will use eight characters as well but will add zeros instead of spaces.

The type of the arguments after *pcString* must match the requirements of the format string. For example, if an integer was passed where a string was expected, an error of some kind will most likely occur.

The caller must ensure that the buffer *pcBuf* is large enough to hold the entire converted string, including the null termination character.

**Returns:**

Returns the count of characters that were written to the output buffer, not including the NULL termination character.

## 14.2.2.6 `usrand`

Set the random number generator seed.

**Prototype:**

```
void  
usrand(unsigned long ulSeed)
```

**Parameters:**

***ulSeed*** is the new seed value to use for the random number generator.

**Description:**

This function is very similar to the C library `srand()` function. It will set the seed value used in the `urand()` function.

**Returns:**

None

#### 14.2.2.7 `ustrcasecmp`

Compares two strings without regard to case.

**Prototype:**

```
int
ustrcasecmp(const char *pcStr1,
            const char *pcStr2)
```

**Parameters:**

***pcStr1*** points to the first string to be compared.  
***pcStr2*** points to the second string to be compared.

**Description:**

This function is very similar to the C library `strcasecmp()` function. It compares two strings without regard to case. The comparison ends if a terminating NULL character is found in either string. In this case, the shorter string is deemed the lesser.

**Returns:**

Returns 0 if the two strings are equal, -1 if *pcStr1* is less than *pcStr2* and 1 if *pcStr1* is greater than *pcStr2*.

#### 14.2.2.8 `ustrcmp`

Compares two strings.

**Prototype:**

```
int
ustrcmp(const char *pcStr1,
        const char *pcStr2)
```

**Parameters:**

***pcStr1*** points to the first string to be compared.  
***pcStr2*** points to the second string to be compared.

**Description:**

This function is very similar to the C library `strcmp()` function. It compares two strings, taking case into account. The comparison ends if a terminating NULL character is found in either string. In this case, the shorter string is deemed the lesser.

**Returns:**

Returns 0 if the two strings are equal, -1 if *pcStr1* is less than *pcStr2* and 1 if *pcStr1* is greater than *pcStr2*.

#### 14.2.2.9 `ustrlen`

Retruns the length of a null-terminated string.

**Prototype:**

```
int
ustrlen(const char *pcStr)
```

**Parameters:**

***pcStr*** is a pointer to the string whose length is to be found.

**Description:**

This function is very similar to the C library `strlen()` function. It determines the length of the null-terminated string passed and returns this to the caller.

This implementation assumes that single byte character strings are passed and will return incorrect values if passed some UTF-8 strings.

**Returns:**

Returns the length of the string pointed to by ***pcStr***.

#### 14.2.2.10 `ustrncmp`

Compares two strings.

**Prototype:**

```
int
ustrncmp(const char *pcStr1,
         const char *pcStr2,
         int iCount)
```

**Parameters:**

***pcStr1*** points to the first string to be compared.

***pcStr2*** points to the second string to be compared.

***iCount*** is the maximum number of characters to compare.

**Description:**

This function is very similar to the C library `strncmp()` function. It compares at most ***iCount*** characters of two strings taking case into account. The comparison ends if a terminating NULL character is found in either string before ***iCount*** characters are compared. In this case, the shorter string is deemed the lesser.

**Returns:**

Returns 0 if the two strings are equal, -1 if ***pcStr1*** is less than ***pcStr2*** and 1 if ***pcStr1*** is greater than ***pcStr2***.

#### 14.2.2.11 `ustrncpy`

Copies a certain number of characters from one string to another.

**Prototype:**

```
char *
ustrncpy(char *pcDst,
         const char *pcSrc,
         int iNum)
```

**Parameters:**

***pcDst*** is a pointer to the destination buffer into which characters are to be copied.

***pcSrc*** is a pointer to the string from which characters are to be copied.

***iNum*** is the number of characters to copy to the destination buffer.

**Description:**

This function copies at most *iNum* characters from the string pointed to by *pcSrc* into the buffer pointed to by *pcDst*. If the end of *pcSrc* is found before *iNum* characters have been copied, remaining characters in *pcDst* will be padded with zeroes until *iNum* characters have been written. Note that the destination string will only be NULL terminated if the number of characters to be copied is greater than the length of *pcSrc*.

**Returns:**

Returns *pcDst*.

#### 14.2.2.12 ustrnicmp

Compares two strings without regard to case.

**Prototype:**

```
int
ustrnicmp(const char *pcStr1,
          const char *pcStr2,
          int iCount)
```

**Parameters:**

***pcStr1*** points to the first string to be compared.

***pcStr2*** points to the second string to be compared.

***iCount*** is the maximum number of characters to compare.

**Description:**

This function is very similar to the C library `strnicmp()` function. It compares at most *iCount* characters of two strings without regard to case. The comparison ends if a terminating NULL character is found in either string before *iCount* characters are compared. In this case, the shorter string is deemed the lesser.

**Returns:**

Returns 0 if the two strings are equal, -1 if *pcStr1* is less than *pcStr2* and 1 if *pcStr1* is greater than *pcStr2*.

#### 14.2.2.13 ustrstr

Finds a substring within a string.

**Prototype:**

```
char *
ustrstr(const char *pcHaystack,
        const char *pcNeedle)
```

**Parameters:**

***pcHaystack*** is a pointer to the string that will be searched.

***pcNeedle*** is a pointer to the substring that is to be found within *pcHaystack*.



**Description:**

This function is very similar to the C library `strstr()` function. It scans a string for the first instance of a given substring and returns a pointer to that substring. If the substring cannot be found, a NULL pointer is returned.

**Returns:**

Returns a pointer to the first occurrence of *pcNeedle* within *pcHaystack* or NULL if no match is found.

#### 14.2.2.14 strtoul

Converts a string into its numeric equivalent.

**Prototype:**

```
unsigned long
strtoul(const char *pcStr,
        const char **ppcStrRet,
        int iBase)
```

**Parameters:**

**pcStr** is a pointer to the string containing the integer.

**ppcStrRet** is a pointer that will be set to the first character past the integer in the string.

**iBase** is the radix to use for the conversion; can be zero to auto-select the radix or between 2 and 16 to explicitly specify the radix.

**Description:**

This function is very similar to the C library `strtoul()` function. It scans a string for the first token (that is, non-white space) and converts the value at that location in the string into an integer value.

**Returns:**

Returns the result of the conversion.

#### 14.2.2.15 uvsnprintf

A simple `vsnprintf` function supporting %c, %d, %p, %s, %u, %x, and %X.

**Prototype:**

```
int
uvsnprintf(char *pcBuf,
            unsigned long ulSize,
            const char *pcString,
            va_list vaArgP)
```

**Parameters:**

**pcBuf** points to the buffer where the converted string is stored.

**ulSize** is the size of the buffer.

**pcString** is the format string.

**vaArgP** is the list of optional arguments, which depend on the contents of the format string.

**Description:**

This function is very similar to the C library `vsnprintf()` function. Only the following formatting characters are supported:

- `%c` to print a character
- `%d` to print a decimal value
- `%s` to print a string
- `%u` to print an unsigned decimal value
- `%x` to print a hexadecimal value using lower case letters
- `%X` to print a hexadecimal value using upper case letters (not lower case letters as would typically be used)
- `%p` to print a pointer as a hexadecimal value
- `%%` to print out a `%` character

For `%d`, `%p`, `%s`, `%u`, `%x`, and `%X`, an optional number may reside between the `%` and the format character, which specifies the minimum number of characters to use for that value; if preceded by a 0 then the extra characters will be filled with zeros instead of spaces. For example, `"%8d"` will use eight characters to print the decimal value with spaces added to reach eight; `"%08d"` will use eight characters as well but will add zeroes instead of spaces.

The type of the arguments after *pcString* must match the requirements of the format string. For example, if an integer was passed where a string was expected, an error of some kind will most likely occur.

The *ulSize* parameter limits the number of characters that will be stored in the buffer pointed to by *pcBuf* to prevent the possibility of a buffer overflow. The buffer size should be large enough to hold the expected converted output string, including the null termination character.

The function will return the number of characters that would be converted as if there were no limit on the buffer size. Therefore it is possible for the function to return a count that is greater than the specified buffer size. If this happens, it means that the output was truncated.

**Returns:**

Returns the number of characters that were to be stored, not including the NULL termination character, regardless of space in the buffer.

## 14.3 Programming Example

The following example shows how to use some of the micro standard library functions.

```
unsigned long ulValue;
char pcBuffer[32];
tTime sTime;

//
// Convert the number in pcBuffer (previous read from somewhere) into an
// integer. Note that this supports converting decimal values (such as
// 4583), octal values (such as 036583), and hexadecimal values (such as
// 0x3425).
//
ulValue = strtoul(pcBuffer, 0, 0);

//
// Convert that integer from a number of seconds into a broken down date.
```

```
//
ulocaltime(ulValue, &sTime);

//
// Print out the corresponding time of day in military format.
//
usprintf(pcBuffer, "%02d:%02d", sTime.ucHour, sTime.ucMin);
```



## 15 UART Standard IO Module

Introduction .....	77
API Functions .....	78
Programming Example .....	84

### 15.1 Introduction

The UART standard IO module provides a simple interface to a UART that is similar to the standard IO package available in the C library. Only a very small subset of the normal functions are provided; [UARTprintf\(\)](#) is an equivalent to the C library `printf()` function and [UARTgets\(\)](#) is an equivalent to the C library `fgets()` function.

This module is contained in `utils/uartstdio.c`, with `utils/uartstdio.h` containing the API definitions for use by applications.

#### 15.1.1 Unbuffered Operation

Unbuffered operation is selected by not defining **UART\_BUFFERED** when building the UART standard IO module. In unbuffered mode, calls to the module will not return until the operation has been completed. So, for example, a call to [UARTprintf\(\)](#) will not return until the entire string has been placed into the UART's FIFO. If it is not possible for the function to complete its operation immediately, it will busy wait.

#### 15.1.2 Buffered Operation

Buffered operation is selected by defining **UART\_BUFFERED** when building the UART standard IO module. In buffered mode, there is a larger UART data FIFO in SRAM that extends the size of the hardware FIFO. Interrupts from the UART are used to transfer data between the SRAM buffer and the hardware FIFO. It is the responsibility of the application to ensure that [UARTStdioIntHandler\(\)](#) is called when the UART interrupt occurs; typically this is accomplished by placing it in the vector table in the startup code for the application.

In addition to providing a larger UART buffer, the behavior of [UARTprintf\(\)](#) is slightly modified. If the output buffer is full, [UARTprintf\(\)](#) will discard the remaining characters from the string instead of waiting until space becomes available in the buffer. If this behavior is not desired, [UARTFlushTx\(\)](#) may be called to ensure that the transmit buffer is emptied prior to adding new data via [UARTprintf\(\)](#) (though this will not work if the string to be printed is larger than the buffer).

[UARTPeek\(\)](#) can be used to determine whether a line end is present prior to calling [UARTgets\(\)](#) if a non-blocking operation is required. In cases where the buffer supplied on [UARTgets\(\)](#) fills before a line termination character is received, the call will return with a full buffer.

## 15.2 API Functions

### Functions

- void [UARTEchoSet](#) (tBoolean bEnable)
- void [UARTFlushRx](#) (void)
- void [UARTFlushTx](#) (tBoolean bDiscard)
- unsigned char [UARTgetc](#) (void)
- int [UARTgets](#) (char \*pcBuf, unsigned long ulLen)
- int [UARTPeek](#) (unsigned char ucChar)
- void [UARTprintf](#) (const char \*pcString,...)
- int [UARTRxBytesAvail](#) (void)
- void [UARTStdioInit](#) (unsigned long ulPortNum)
- void [UARTStdioInitExpClk](#) (unsigned long ulPortNum, unsigned long ulBaud)
- void [UARTStdioIntHandler](#) (void)
- int [UARTTxBytesFree](#) (void)
- int [UARTwrite](#) (const char \*pcBuf, unsigned long ulLen)

### 15.2.1 Function Documentation

#### 15.2.1.1 UARTEchoSet

Enables or disables echoing of received characters to the transmitter.

**Prototype:**

```
void
UARTEchoSet (tBoolean bEnable)
```

**Parameters:**

**bEnable** must be set to **true** to enable echo or **false** to disable it.

**Description:**

This function, available only when the module is built to operate in buffered mode using **UART\_BUFFERED**, may be used to control whether or not received characters are automatically echoed back to the transmitter. By default, echo is enabled and this is typically the desired behavior if the module is being used to support a serial command line. In applications where this module is being used to provide a convenient, buffered serial interface over which application-specific binary protocols are being run, however, echo may be undesirable and this function can be used to disable it.

**Returns:**

None.

#### 15.2.1.2 UARTFlushRx

Flushes the receive buffer.

**Prototype:**

```
void
UARTFlushRx(void)
```

**Description:**

This function, available only when the module is built to operate in buffered mode using **UART\_BUFFERED**, may be used to discard any data received from the UART but not yet read using [UARTgets\(\)](#).

**Returns:**

None.

### 15.2.1.3 UARTFlushTx

Flushes the transmit buffer.

**Prototype:**

```
void
UARTFlushTx(tBoolean bDiscard)
```

**Parameters:**

**bDiscard** indicates whether any remaining data in the buffer should be discarded (**true**) or transmitted (**false**).

**Description:**

This function, available only when the module is built to operate in buffered mode using **UART\_BUFFERED**, may be used to flush the transmit buffer, either discarding or transmitting any data received via calls to [UARTprintf\(\)](#) that is waiting to be transmitted. On return, the transmit buffer will be empty.

**Returns:**

None.

### 15.2.1.4 UARTgetc

Read a single character from the UART, blocking if necessary.

**Prototype:**

```
unsigned char
UARTgetc(void)
```

**Description:**

This function will receive a single character from the UART and store it at the supplied address.

In both buffered and unbuffered modes, this function will block until a character is received. If non-blocking operation is required in buffered mode, a call to [UARTRxAvail\(\)](#) may be made to determine whether any characters are currently available for reading.

**Returns:**

Returns the character read.

### 15.2.1.5 UARTgets

A simple UART based get string function, with some line processing.

**Prototype:**

```
int
UARTgets(char *pcBuf,
          unsigned long ulLen)
```

**Parameters:**

**pcBuf** points to a buffer for the incoming string from the UART.

**ulLen** is the length of the buffer for storage of the string, including the trailing 0.

**Description:**

This function will receive a string from the UART input and store the characters in the buffer pointed to by *pcBuf*. The characters will continue to be stored until a termination character is received. The termination characters are CR, LF, or ESC. A CRLF pair is treated as a single termination character. The termination characters are not stored in the string. The string will be terminated with a 0 and the function will return.

In both buffered and unbuffered modes, this function will block until a termination character is received. If non-blocking operation is required in buffered mode, a call to [UARTPeek\(\)](#) may be made to determine whether a termination character already exists in the receive buffer prior to calling [UARTgets\(\)](#).

Since the string will be null terminated, the user must ensure that the buffer is sized to allow for the additional null character.

**Returns:**

Returns the count of characters that were stored, not including the trailing 0.

### 15.2.1.6 UARTPeek

Looks ahead in the receive buffer for a particular character.

**Prototype:**

```
int
UARTPeek(unsigned char ucChar)
```

**Parameters:**

**ucChar** is the character that is to be searched for.

**Description:**

This function, available only when the module is built to operate in buffered mode using **UART\_BUFFERED**, may be used to look ahead in the receive buffer for a particular character and report its position if found. It is typically used to determine whether a complete line of user input is available, in which case ucChar should be set to CR ('\r') which is used as the line end marker in the receive buffer.

**Returns:**

Returns -1 to indicate that the requested character does not exist in the receive buffer. Returns a non-negative number if the character was found in which case the value represents the position of the first instance of *ucChar* relative to the receive buffer read pointer.



### 15.2.1.7 UARTprintf

A simple UART based printf function supporting %c, %d, %p, %s, %u, %x, and %X.

**Prototype:**

```
void
UARTprintf(const char *pcString,
           ...)
```

**Parameters:**

***pcString*** is the format string.

**...** are the optional arguments, which depend on the contents of the format string.

**Description:**

This function is very similar to the C library `fprintf()` function. All of its output will be sent to the UART. Only the following formatting characters are supported:

- %c to print a character
- %d to print a decimal value
- %s to print a string
- %u to print an unsigned decimal value
- %x to print a hexadecimal value using lower case letters
- %X to print a hexadecimal value using upper case letters (not lower case letters as would typically be used)
- %p to print a pointer as a hexadecimal value
- %% to print out a % character

For %s, %d, %u, %p, %x, and %X, an optional number may reside between the % and the format character, which specifies the minimum number of characters to use for that value; if preceded by a 0 then the extra characters will be filled with zeros instead of spaces. For example, “%8d” will use eight characters to print the decimal value with spaces added to reach eight; “%08d” will use eight characters as well but will add zeroes instead of spaces.

The type of the arguments after *pcString* must match the requirements of the format string. For example, if an integer was passed where a string was expected, an error of some kind will most likely occur.

**Returns:**

None.

### 15.2.1.8 UARTRxBytesAvail

Returns the number of bytes available in the receive buffer.

**Prototype:**

```
int
UARTRxBytesAvail(void)
```

**Description:**

This function, available only when the module is built to operate in buffered mode using **UART\_BUFFERED**, may be used to determine the number of bytes of data currently available in the receive buffer.

**Returns:**

Returns the number of available bytes.

### 15.2.1.9 UARTStdioInit

Initializes the UART console.

**Prototype:**

```
void
UARTStdioInit(unsigned long ulPortNum)
```

**Parameters:**

***ulPortNum*** is the number of UART port to use for the serial console (0-2)

**Description:**

This function will initialize the specified serial port to be used as a serial console. The serial parameters will be set to 115200, 8-N-1. An application wishing to use a different baud rate may call [UARTStdioInitExpClk\(\)](#) instead of this function.

This function or [UARTStdioInitExpClk\(\)](#) must be called prior to using any of the other UART console functions: [UARTprintf\(\)](#) or [UARTgets\(\)](#). In order for this function to work correctly, [SysCtlClockSet\(\)](#) must be called prior to calling this function.

It is assumed that the caller has previously configured the relevant UART pins for operation as a UART rather than as GPIOs.

**Returns:**

None.

### 15.2.1.10 UARTStdioInitExpClk

Initializes the UART console and allows the baud rate to be selected.

**Prototype:**

```
void
UARTStdioInitExpClk(unsigned long ulPortNum,
                    unsigned long ulBaud)
```

**Parameters:**

***ulPortNum*** is the number of UART port to use for the serial console (0-2)

***ulBaud*** is the bit rate that the UART is to be configured to use.

**Description:**

This function will initialize the specified serial port to be used as a serial console. The serial parameters will be set to 8-N-1 and the bit rate set according to the value of the *ulBaud* parameter.

This function or [UARTStdioInit\(\)](#) must be called prior to using any of the other UART console functions: [UARTprintf\(\)](#) or [UARTgets\(\)](#). In order for this function to work correctly, [SysCtlClockSet\(\)](#) must be called prior to calling this function. An application wishing to use 115,200 baud may call [UARTStdioInit\(\)](#) instead of this function but should not call both functions.

It is assumed that the caller has previously configured the relevant UART pins for operation as a UART rather than as GPIOs.

**Returns:**

None.

#### 15.2.1.11 UARTStdioIntHandler

Handles UART interrupts.

**Prototype:**

```
void
UARTStdioIntHandler(void)
```

**Description:**

This function handles interrupts from the UART. It will copy data from the transmit buffer to the UART transmit FIFO if space is available, and it will copy data from the UART receive FIFO to the receive buffer if data is available.

**Returns:**

None.

#### 15.2.1.12 UARTTxBytesFree

Returns the number of bytes free in the transmit buffer.

**Prototype:**

```
int
UARTTxBytesFree(void)
```

**Description:**

This function, available only when the module is built to operate in buffered mode using **UART\_BUFFERED**, may be used to determine the amount of space currently available in the transmit buffer.

**Returns:**

Returns the number of free bytes.

#### 15.2.1.13 UARTwrite

Writes a string of characters to the UART output.

**Prototype:**

```
int
UARTwrite(const char *pcBuf,
          unsigned long ulLen)
```

**Parameters:**

**pcBuf** points to a buffer containing the string to transmit.

**ulLen** is the length of the string to transmit.

**Description:**

This function will transmit the string to the UART output. The number of characters transmitted is determined by the *ulLen* parameter. This function does no interpretation or translation of any characters. Since the output is sent to a UART, any LF (/n) characters encountered will be replaced with a CRLF pair.

Besides using the *ulLen* parameter to stop transmitting the string, if a null character (0) is encountered, then no more characters will be transmitted and the function will return.

In non-buffered mode, this function is blocking and will not return until all the characters have been written to the output FIFO. In buffered mode, the characters are written to the UART transmit buffer and the call returns immediately. If insufficient space remains in the transmit buffer, additional characters are discarded.

**Returns:**

Returns the count of characters written.

## 15.3 Programming Example

The following example shows how to use the UART standard IO module to write a string to the UART “console”.

```
//  
// Configure the appropriate pins as UART pins; in this case, PA0/PA1 are  
// used for UART0.  
//  
SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOA);  
GPIOPinTypeUART(GPIO_PORTA_BASE, GPIO_PIN_0 | GPIO_PIN_1);  
  
//  
// Initialize the UART standard IO module.  
//  
UARTStdioInit(0);  
  
//  
// Print a string.  
//  
UARTprintf("Hello world!\n");
```



---

# IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

## Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

## Applications

Automotive and Transportation	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

**TI E2E Community Home Page**

[e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2011-2012, Texas Instruments Incorporated