MCU SDK

User's Guide

Literature Number: SPRUHD4A
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Contents

Read This First

About This Manual

This manual describes the MCU Software Development Kit (SDK). The version number as of the publication of this manual is v1.0.

Notational Conventions

This document uses the following conventions:

- Program listings, program examples, and interactive displays are shown in a special typeface. Examples use a bold version of the special typeface for emphasis.

  Here is a sample program listing:

```
#include <xdc/runtime/System.h>
int main(){
    System_printf("Hello World!\n");
    return (0);
}
```

- Square brackets ([and]) identify an optional parameter. If you use an optional parameter, you specify the information within the brackets. Unless the square brackets are in a **bold** typeface, do not enter the brackets themselves.

Trademarks

July 13, 2012

About the MCU SDK

This chapter provides an overview of the MCU SDK (Micro-Controller Software Development Kit).

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1.1 What is the MCU SDK?

The MCU SDK (Micro-controller Software Development Kit) delivers components that enable engineers to develop applications on Texas Instruments micro-controller devices. The SDK is compromised of multiple software components and examples of how to use these components together.

The MCU SDK gives developers a one-stop RTOS solution for developing applications for TI embedded microcontrollers. It provides an OS kernel, communications support, drivers, and more. It is tightly integrated with TI's Code Composer Studio development environment. In addition, examples are provided to demonstrate the use of each functional area and each supported device and as a starting point for your own projects.

The MCU SDK contains its own source files, pre-compiled libraries (both instrumented and non-instrumented), and examples. Additionally, the MCU SDK contains a number of components within the MCU SDK's "`products`" subdirectory as shown here.

The MCU SDK installs versions of these components that support only the device families supported by the MCU SDK. Currently, the MCU SDK provides support for the following boards:

- **TMDXDOCKH52C1** (both M3 and 28x sides of this Concerto board)
- **DK-LM3S9D96** (Stellaris board)
- **EKS-LM4F232** (Stellaris board)

1.2 SYS/BIOS

SYS/BIOS (previously called DSP/BIOS) is an advanced real-time operating system from Texas Instruments for use in a wide range of DSPs, ARMs, and microcontrollers. It is designed for use in embedded applications that need real-time scheduling, synchronization, and instrumentation. SYS/BIOS is designed to minimize memory and CPU requirements on the target. SYS/BIOS provides a wide range of services, such as:

- Preemptive, deterministic multi-threading
- Hardware abstraction
- Memory management
- Configuration tools
- Real-time analysis

The FatFs module used by several MCU SDK examples is part of SYS/BIOS.

For more information about SYS/BIOS, see the following:

SYS/BIOS 6 Getting Started Guide. <sysbios_install>/docs/Bios_Getting_Started_Guide.pdf

SYS/BIOS User's Guide (SPRUEX3)

SYS/BIOS online reference (also called "CDOC").
Open from CCS help or run <sysbios_install>/docs/cdoc/index.html.

SYS/BIOS on TI Embedded Processors Wiki

BIOS forum on TI's E2E Community

1.3 XDCtools

XDCtools is a separate software component provided by Texas Instruments that provides the underlying tooling needed for configuring and building SYS/BIOS, IPC, NDK, and UIA.

- XDCtools provides the XGCONF configuration file editor and scripting language. This is used to configure modules in a number of the components that make up the MCU SDK.
- XDCtools provides the tools used to build the configuration file. These tools are used automatically by CCS if your project contains a *.cfg file. This build step generates source code files that are then compiled and linked with your application code.
- XDCtools provides a number of modules and runtime APIs that the MCU SDK and its components leverage for memory allocation, logging, system control, and more.

XDCtools is sometimes referred to as "RTSC" (pronounced "rit-see"—Real Time Software Components), which is the name for the open-source project within the Eclipse.org ecosystem for providing reusable software components (called "packages") for use in embedded systems. For more about how XDCtools and SYS/BIOS are related, see the SYS/BIOS User's Guide (SPRUEX3).

For more information about XDCtools, see the following:

XDCtools online reference (also called "CDOC").
Open from CCS help or run <xdc_install>/docs/xdctools.chm.

RTSC-Pedia Wiki

BIOS forum on TI's E2E Community

1.4 IPC

IPC is a component containing packages that are designed to allow communication between processors in a multi-processor environment and communication to peripherals. This communication includes message passing, streams, and linked lists. These work transparently in both uni-processor and multi-processor configurations.

The ti.sdo.ipc package contains modules and interfaces for interprocessor communication. The ti.sdo.io package contains modules and interfaces to support peripheral communication. The ti.sdo.utils package contains utility modules for supporting the ti.sdo.ipc modules and other modules.

IPC is designed for use on processors running SYS/BIOS applications. IPC can be used to communicate with the following:

- Other threads on the same processor
- Threads on other processors running SYS/BIOS
- Threads on GPP processors running SysLink

For more information about IPC, see the following:

IPC User's Guide (SPRUGO6)

IPC online API reference. Run <ipc_install>/docs/doxygen/index.html.

IPC online configuration reference (also called "CDOC").
Open from CCS help or run <ipc_install>/docs/cdoc/index.html.

1.5 NDK

The Network Developer's Kit (NDK) is a platform for development and demonstration of network enabled applications on TI embedded processors, currently limited to the TMS320C6000 family and ARM processors. The NDK stack serves as a rapid prototyping platform for the development of network and packet processing applications. It can be used to add network connectivity to existing applications for communications, configuration, and control. Using the components provided in the NDK, developers can quickly move from development concepts to working implementations attached to the network.

The NDK is a networking stack that operates on top of SYS/BIOS.

For more information about NDK, see the following:

NDK User's Guide (SPRU523)

NDK Programmer's Reference Guide (SPRU524)

NDK on TI Embedded Processors Wiki

BIOS forum on TI's E2E Community

1.6 UIA

The Unified Instrumentation Architecture (UIA) provides target content that aids in the creation and gathering of instrumentation data (for example, Log data).

The System Analyzer tool suite, which is part of CCS 5.2, provides a consistent and portable way to instrument software. It enables software to be re-used with a variety of silicon devices, software applications, and product contexts. It works together with UIA to provide visibility into the real-time performance and behavior of software running on TI's embedded single-core and multicore devices.

For more information about UIA and System Analyzer, see the following:

System Analyzer User's Guide (SPRUH43)

UIA online reference (also called "CDOC"). Open from CCS help or run <uia_install>/docs/cdoc/index.html.

System Analyzer on TI Embedded Processors Wiki

1.7 MWare

MWare is the M3 portion of ControlSuite, a software package that provides support for F28M35x (Concerto) devices. It includes low-level drivers and examples.

The version of MWare provided with the MCU SDK differs from the version in ControlSuite in that the `driverlib` library has been rebuilt using the `--define=RTOS_SUPPLIED_INTERRUPTS` compiler option.

To indicate that the version has been modified, the name of the folder that contains MWare has an added "x". For example `<mcusdk_install>\products\MWare_v140x`.

For more information about MWare and ControlSuite, see the following:

Documents in <mcu_sdk_install>/products/MWare_##/docs

ControlSuite on TI Embedded Processors Wiki

ControlSuite Product Folder

1.8 StellarisWare

This software is an extensive suite of software designed to simplify and speed development of Stellaris-based (ARM Cortex-M) microcontroller applications.

For more information about StellarisWare, see the following:

Documents in <mcu_sdk_install>/products/StellarisWare_####/docs

StellarisWare Product Folder

Online StellarisWare Workshop

1.9 Drivers

The MCU SDK includes drivers for the following peripherals. These drivers are in the `<install_dir>/packages/ti/drivers` directory. MCU SDK examples show how to use these drivers. Note that all of these drivers are built on top of MWare.

- **EMAC.** Ethernet driver used by the networking stack (NDK) and not intended to be called directly.
- **SDSPI.** SD driver used by FatFs and not intended to be interfaced directly.
- **I^2C.** API set intended to be used directly by the application or middleware.
- **GPIO.** API set intended to be used directly by the application or middleware to manage the GPIO pins and ports on the board.
- **UART.** API set intended to be used directly by the application to communicate with the UART.
- **USBMSCHFatFs.** USB MSC Host under FatFs (for flash drives). This driver is used by FatFS and is not intended to be called directly.
- **Other USB functionality.** See the USB examples for reference modules that provide support for the Human Interface Device (HID) class (mouse and keyboard) and Communications Device Class (CDC). This code is provided as part of the examples, not as a separate driver.

See Chapter 6 for more information about the drivers in the MCU SDK.

1.10 For More Information

To learn more about the MCU SDK and the software components used with it, refer to the following documentation. In addition, you can select a component in the TI Resource Explorer under **MCU SDK > Products** to see the release notes for that component.

- **MCU SDK**
  - MCU SDK Getting Started Guide (SPRUHD3)
  - SYS/BIOS on TI Embedded Processors Wiki
  - BIOS forum on TI's E2E Community
- **Code Composer Studio (CCS)**
  - CCS online help
  - CCSv5 on TI Embedded Processors Wiki
  - Code Composer forum on TI's E2E Community
- **SYS/BIOS**
  - SYS/BIOS 6 Getting Started Guide. <sysbios_install>/docs/Bios_Getting_Started_Guide.pdf
  - SYS/BIOS User's Guide (SPRUEX3)
  - SYS/BIOS online reference (also called "CDOC").
    Open from CCS help or run <sysbios_install>/docs/cdoc/index.html.
  - SYS/BIOS on TI Embedded Processors Wiki
  - BIOS forum on TI's E2E Community
  - SYS/BIOS 6.x Product Folder
  - Embedded Software Download Page

- **XDCtools**
  - XDCtools online reference. Open from CCS help or run <xdc_install>/docs/xdctools.chm.
  - RTSC-Pedia Wiki
  - BIOS forum on TI's E2E Community
  - Embedded Software Download Page
- **IPC**
  - IPC User's Guide (SPRUGO6)
  - IPC online API reference. Run <ipc_install>/docs/doxygen/index.html.
  - IPC online configuration reference. Open from CCS help or run <ipc_install>/docs/cdoc/index.html.
  - Embedded Software Download Page
- **NDK**
  - NDK User's Guide (SPRU523)
  - NDK Programmer's Reference Guide (SPRU524)
  - NDK on TI Embedded Processors Wiki
  - BIOS forum on TI's E2E Community
  - Embedded Software Download Page
- **UIA**
  - System Analyzer User's Guide (SPRUH43)
  - UIA online reference. Open from CCS help or run <uia_install>/docs/cdoc/index.html.
  - System Analyzer on TI Embedded Processors Wiki
  - Embedded Software Download Page
- **MWare and ControlSuite**
  - Documents in <mcu_sdk_install>/products/MWare_##/docs
  - ControlSuite on TI Embedded Processors Wiki
  - ControlSuite Product Folder
- **StellarisWare**
  - Documents in <mcu_sdk_install>/products/StellarisWare_####/docs
  - StellarisWare Product Folder
  - Online StellarisWare Workshop
- **FatFS API**
  - API documentation
- **Microcontroller devices**
  - Concerto F28M35x Technical Reference Manual
  - C2000 on TI Embedded Processors Wiki
  - Concerto on TI Embedded Processors Wiki
  - Concerto Product Folder
  - Microcontrollers forum on TI's E2E Community

- **SD Cards**
  - Specification
- **I²C**
  - Specification
- **FatFs API**
  - API documentation

Examples for the MCU SDK

The MCU SDK comes with a number of examples that illustrate on how to use the individual components. This chapter provides details about each example.

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2.1 Example Overview

The components and hardware used by the MCU SDK examples are shown in the following table:

Table 2-1. Components Used by MCU SDK Examples

Example	SYS/BIOS	FatFs		USB Devices			I²C	UART	NDK / EMAC	UIA	IPC	GPIO (& LED)
		SD Card / SDSPI	USB Drive	HID	CDC	MSC						
Empty MCU SDK Project (Section 2.2.1)	X									X		X
Demo for M3 / Demo for C28 (2.2.2) *	X	X			X		X	X	X	X	X	X
TCP Echo (2.2.3) *	X								X	X		X
FatSD: FatFs File Copy (2.2.4)	X	X								X		X
FatSD Raw: FatFs File Copy using FatFs APIs (2.2.5)	X	X								X		X
I²C EEPROM: Communications with the onboard EEPROM (2.2.6) *	X						X			X		X
UART Console (2.2.7)	X				X			X**		X		X
UART Echo (2.2.8)	X							X		X		X
FatSD USB Copy: (SD Card and USB Drive) (2.2.9)	X	X	X			X				X		X
USB Keyboard Device (2.2.10)	X			X						X		X
USB Keyboard Host (2.2.11)	X			X						X		X
USB Mouse Device (2.2.12)	X			X						X		X
USB Mouse Host (2.2.13)	X			X						X		X
USB Serial Device (2.2.14)	X				X					X		X
USB CDC Mouse Device (2.2.15)	X			X	X					X		X

* The Demo example is not available for the DK-LM3S9D96 and EKS-LM4F232 boards. The TCP Echo and I²C examples are not available for the EKS-LM4F232 board. I²C communications with the onboard EEPROM for DK-LM3S9D96 requires an additional daughterboard.

** UART is used by SysFlex for sending System_printf() and printf() output to a console. Other examples use SysMin.

See the "Example Settings" section of the MCU SDK Getting Started Guide (SPRUHD3) for jumper, switch, and other settings required to run these examples on the supported boards.

2.2 Example Descriptions

A number of examples are provided with the MCU SDK. These use sub-components provided with the MCU SDK.

The following sub-sections briefly describe each example and lists the key C source, configuration, and linker command files used in each example. The examples share the following features:

- There is a separate readme.txt file for each of the examples. These files are added to your CCS project when you use the TI Resource Explorer to create a project. You can open the readme.txt file within CCS.
- All examples except UART Console use the SysMin System Support module. System_printf() output can be viewed with the RTOS Object View (ROV) tool.
- Most use the ti.uia.sysbios.LoggingSetup module. The default is to use the STOPMODE uploadMode. (The Demo and UART Console examples use the LoggerIdle module.)

2.2.1 Empty MCU SDK Project

This example provides a blank project you can use as starting point in creating a project that utilizes the MCU SDK. It contains some common code excerpts that enable different MCU SDK product components. It is usually easier to start with a more full-featured MCU SDK example that already uses some of the components and modules your application will need. But, the "empty" projects are available in case you would like to start with a template that has few features.

This example project is not created though the TI Resource Explorer. Instead, create this example as follows:

1. Choose the **Project > New CCS Project** menu command. (This has the same effect as using the **File > New > CCS Project** menu command.)
2. Name the project and select the device as you would when creating other CCS projects.
3. In the **Project templates and examples** list, expand the **MCU SDK** category and select one of the **Empty MCUSDK Project** items.
4. Click **Next**, and then click **Finish**.

- Key C files: empty.c, <*board*>.c/.h
- Key configuration files: empty.cfg
- Linker command file: <*board*>.cmd

5. Add to the example as needed to implement your application.

Note: Additional configuration might be needed as you add to the example. For example, if you add networking, you will likely need to increase the heap sizes.

2.2.2 Demo for M3 / Demo for C28 (for TMDXDOCKH52C1)

Components: SYS/BIOS; FatFs SD Card (SPI); I^2C Driver; Networking (NDK); IPC; Instrumentation (UIA)

This dual-core example is a sample project that incorporates several different MCU SDK components for demonstration purposes. It features an HTTP server (NDK) that functions as a main GUI for controlling and display data graphically.

On the M3, this demo processes other tasks such as temperature readings using the I^2C driver, inter-processor communications (IPC) for temperature conversions, and FatFs SD card support for data logging. While all the processes are being executed, CPU load usage and task statics are being generated using UIA.

- Key C files: demo.c/.h, <*board*>.c/.h, cmdline.c, default.h, dspchip.h, jquery.flot.min.h, jquery.min.h, layout.css.h, logobar.h, webpage.c
- Key configuration files: demo.cfg
- Linker command file: demo.cmd
- Description file: readme.txt

This example uses the LoggerIdle module and the USB driver instead of Stop mode for transferring data from the target to System Analyzer.

See the readme.txt file in the project for jumper settings, LED indicators, and external components used specifically by this example.

See the "Example Settings" section of the MCU SDK Getting Started Guide (SPRUHD3) for how to make the application use the correct MAC address for your board.

This is a dual-core example. Another example runs on the C28x side of the Concerto device along with the M3 application. The C28x application receives the IPC communication, converts the temperature from Celsius to Fahrenheit, and sends the converted temperature back to the M3 side of the device.

Use the following startup sequence to run this dual-core example:

1. In CCS, choose **Target > Connect Target** to connect first to the M3 and then to the C28.
2. Do a CPU reset on the M3.
3. Do a CPU reset on the C28.
4. Load (or restart if already loaded) the M3 application and run.
5. Load (or restart if already loaded) the C28 application and run.

By default, the application is configured as shown below so that CCS can load and run both the M3 and C28 applications. If you want to boot both cores from flash, rather than loading and running the applications from within CCS, you should set the Boot.bootC28 parameter to **true** in the demo.cfg configuration file for the M3 application. After building and loading, you can power cycle the board; the targets will boot the images out of flash.

```
/* Setting the Boot.bootC28 to false allows a user to load and run both cores
 * from CCS. If you want to boot both cores from flash, you'll need
 * to set Boot.bootC28 to true. This tells the M3 to initiate boot of the C28.
 */
var Boot = xdc.useModule('ti.catalog.arm.cortexm3.concertoInit.Boot');
Boot.bootFromFlash = true;
Boot.bootC28 = false;    /* Set to true if running from flash. */
```

2.2.3 TCP Echo Example

Components: SYS/BIOS; Networking (NDK); Instrumentation (UIA)

This example uses the NDK stack to accept incoming TCP packets and echo them to the sender.

First, the example creates a TCP socket by calling the socket() API. Then, it accepts an incoming request on port 1000. It dynamically creates a SYS/BIOS Task object that is responsible for receiving incoming packets and echoing them back to the sender.

The MCU SDK provides a Linux and Windows command-line tool called tcpSendReceive that can be used to test the functionality of the example. It sends a 1024-byte packet to the target and waits for a reply. If verifies the first and last byte for correctness. It prints out the status every 1000 packets. The source and binaries for tcpSendReceive are provided in the <mcusdk_install>\packages\examples\tools directory.

For the DK-LM3S9D96, see the readme.txt file in the project for jumper settings and LED indicators used specifically by this example.

See the "Example Settings" section of the MCU SDK Getting Started Guide (SPRUHD3) for how to make the application use the correct MAC address for your board.

- Key C files: tcpEcho.c, <*board*>.c/.h
- Key configuration files: tcpEcho.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.4 FatSD Example: FatFs File Copy with SD Card

Components: SYS/BIOS; FatFs SD Card (SPI); Instrumentation (UIA)

This example copies a file called `input.txt` to `output.txt` using the runtime support library's CIO functions.

The FatFs software is delivered with the FatFs API. Wrappers have been provided for these APIs in SYS/BIOS, so the CIO function calls provided by the runtime support library can be called to access files on the SD card.

First, the example attempts to open a file called `input.txt` from the SD card. If the file does not exist, one is created and filled with some text. Next, a file called `output.txt` file is created on the SD card and opened in write-only mode. If the file already exists on the SD card, it will be overwritten. After the contents of `input.txt` are copied to `output.txt`, both files are closed. Finally, `output.txt` is opened in read-only mode, and its contents are sent to the CCS console (STDOUT).

- Key C files: fatsd.c, <*board*>.c/.h
- Key configuration files: fatsd.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.5 FatSD Raw Example: FatFs File Copy Using FatFs APIs and SD Card

Components: SYS/BIOS; FatFs SD Card (SPI); Instrumentation (UIA)

This example performs similarly to the “FatFs File Copy example (SD Card)” (see Section 2.2.4). However, it uses the FatFs APIs instead of the CIO functions provided by the runtime support library. API documentation for the FatFs APIs is provided at http://elm-chan.org/fsw/ff/00index_e.html.

- Key C files: fatsdraw.c, <*board*>.c/.h
- Key configuration files: fatsdraw.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.6 I2C EEPROM Example: I^2C Communications with Onboard EEPROM

Components: SYS/BIOS; I^2C Driver; Instrumentation (UIA)

This example uses the MCU SDK's I^2C driver to communicate with an available onboard I^2C EEPROM on the TMDXDOCKH52C1 development board.

First, the application "erases" one page of EEPROM by writing a page full of 0xFF values. To verify that the EEPROM was erased, the same page is read back and compared. If it is successfully erased, a page with known data is written to the erased page. The write action is verified by reading the contents back and comparing it with the known data.

When instrumentation is enabled, the I^2C driver prints logs using UIA for debugging purposes.

- Key C files: i2ceeprom.c, <*board*>.c/.h
- Key configuration files: i2ceeprom.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

I^2C communications with the onboard EEPROM for DK-LM3S9D96 requires additional daughterboard. The I^2C example is not available for the EKS-LM4F232 board.

2.2.7 UART Console Example

Components: SYS/BIOS; Instrumentation (UIA)

This example uses the MCU SDK UART driver and cstdio to setup stdin and stdout through the UART and implement a basic console task.

The UART Console example uses SysFlex, which allows System_printf() output to go to a function that prints out one character at a time. In the UART Console example, the SysFlex System Support module is configured to use UART0, which is set at 115,200 bps 8-N-1. On the development boards, UART0 is connected to the USB FTDI chip. This chip features an interface to a virtual serial COM port which can be used with a standard serial terminal.

This example initializes the UART and a UART device is added to the system. The seven functions are found in uartsdio.c and uartstdio.h. Open will create a UART in blocking read and write mode with data processing turned on. Data processing includes echoing characters back, returning when a newline character is received, writing a return character before a newline is written and replacing return characters read in with a newline character. Read and write will call the respective UART functions using the stdio buffers and size. Lseek, unlink, and rename are not implemented for the UART device.

The new UART device is opened for writing to stdout and reading from stdin and both are configured with a 128-byte buffer and line buffering. A task is created that will implement the console. This task loops forever, waiting for commands to be entered using scanf. Acceptable commands are help, load, sleep, and exit. Help displays a list of commands. Load displays the CPU and console task load. Sleep prompts the user for a duration in milliseconds and puts the console task to sleep. Exit causes the console task to exit. All stdio calls will block while reading or writing, allowing lower priority threads to run.

This example uses the LoggerIdle module and the USB driver instead of Stop mode for transferring data from the target to System Analyzer.

These data processing settings will effectively treat the target line endings as a single newline character and the host line endings as DOS format (CRLF). PC terminal setting may have to be changed to reflect these expectations.

- Key C files: uartconsole.c, <*board*>.c/.h, uartstdio.c/.h
- Key configuration files: uartconsole.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.8 UART Echo Example

Components: SYS/BIOS; Instrumentation (UIA)

This example uses the MCU SDK UART driver to echo characters in a task across the UART.

The example initializes the UART and creates a UART in blocking read and write mode with all data processing turned off. The UART_open() function returns a UART_Handle that is used in all UART read and write calls to identify the UART used. A task is created that will loop forever, reading in 1 character from the UART and then writing that character back to the UART. Since the UART is in blocking mode, read and write will block on a semaphore while data is read and written. Blocking allows lower-priority threads to run. When the read or write is finished, the semaphore will be posted and the function will return the number of bytes read or written.

There is a UART_open() parameter that enables echoing read characters automatically. For this example, this parameter is turned off. However, it is enabled in the UART Console example (see Section 2.2.7).

There is no data processing on the device. If you see unexpected behavior, such as missing CR or LF characters, check your PC terminal settings.

- Key C files: uartecho.c, UARTUtils.c/.h, <*board*>.c/.h
- Key configuration files: uartecho.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.9 FatSD USB Copy Example: FatFs File Copy with SD Card and USB Drive

Components: SYS/BIOS; FatFs SD Card (SPI); FatFs USB Drive (USB Host MSC); Instrumentation (UIA)

This example performs similarly to the "FatFs File Copy example (SD Card)" (see Section 2.2.4). It reads `input.txt` from the SD Card. However, it stores the `output.txt` file on a USB flash drive instead of the SD card. This example uses the runtime support library's CIO functions.

- Key C files: fatsdusbcopy.c, <*board*>.c/.h
- Key configuration files: fatsdusbcopy.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.10 USB Keyboard Device Example

Components: SYS/BIOS, USB Device HID; Instrumentation (UIA)

This example uses the USB driver to simulate a keyboard HID (Human Interface Device) class device sending press and release button events.

Within main(), this application performs general board setup, initializes the LEDs, initializes USB0 as a device. It also dynamically creates one SYS/BIOS Task object.

The taskFxn blocks until the USB library has been connected to the USB host. When connected, the task reads the current LED state, which is sent by the USB host controller. The task then updates the LEDs accordingly. After updating the LEDs, the task polls a GPIO input pin to detect a HIGH to LOW state transition, and sends a string to the USB host when that transition occurs. After sending the string, the task goes to sleep for 100 system ticks.

- Key C files: USBKBD.c/.h, usbkeyboarddevice.c, <*board*>.c/.h
- Key configuration files: usbkeyboarddevice.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.11 USB Keyboard Host Example

Components: SYS/BIOS, USB Device HID; Instrumentation (UIA)

This example uses the USB driver to receive characters from a keyboard HID (Human Interface Device) device.

Within main(), this application performs general board setup, initializes the LEDs, and initializes USB0 as a device. It also dynamically creates one SYS/BIOS Task object.

Within a loop, the taskFxn task blocks until it is connected to the USB keyboard device and updates the status of the scroll-lock and CAPS lock LEDs. It then performs different actions depending on how USEGETCHAR is defined. USEGETCHAR mode is used by default unless you change the `#define USEGETCHAR 1` statement in usbkeyboardhost.c.

If USEGETCHAR is true, the taskFxn gets a single character at a time from the keyboard device and sends it to System_printf().

If USEGETCHAR is false, the taskFxn gets the number of characters defined for BUFFLENGTH from the keyboard device and sends that line and the number of characters received to System_printf().

- Key C files: USBKBH.c/.h, usbkeyboardhost.c, <*board*>.c/.h
- Key configuration files: usbkeyboardhost.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

Using the USB controller in host mode on the TMDXDOCKH52C1 requires a hardware modification to the control card. See the "USB Host Mode Board Modification" section of the MCU SDK Getting Started Guide (SPRUHD3) for details.

2.2.12 USB Mouse Device Example

Components: SYS/BIOS, USB Device HID; Instrumentation (UIA)

This example uses the USB driver to simulate a mouse HID (Human Interface Device) class device sending mouse movement and click events.

Within main(), this application performs general board setup, initializes the LEDs, and initializes USB0 as a device. It also dynamically creates one SYS/BIOS Task object.

The taskFxn blocks until the USB library has been connected to the USB host. When it determines the device is connected to a USB host, it sends pre-programmed X, Y coordinate offsets and the GPIO input pin's value as mouse button1 (a left-click) to the host. The X,Y coordinate offsets in the mouseLookupTable array move the mouse pointer to form a figure 8.

- Key C files: USBMD.c/.h, usbmousedevice.c, <*board*>.c/.h
- Key configuration files: usbmousedevice.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.13 USB Mouse Host Example

Components: SYS/BIOS, USB Device HID; Instrumentation (UIA)

This example uses the USB driver to receive the current state of a mouse HID (Human Interface Device) device, which includes the most recent X and Y positional offset values and a mouse button state.

Within main(), this application performs general board setup, initializes the LEDs, and initializes USB0 as a device. It also dynamically creates one SYS/BIOS Task object.

Within a loop, the taskFxn task blocks until it is connected to the USB mouse device. It then gets the current mouse state data structure, updates the status of the GPIOs to match the states of mouse buttons 1 and 2, and sends the current X,Y coordinate offsets to System_printf(). It sleeps for 100 system ticks before running the loop again.

- Key C files: USBMH.c/.h, usbmousehost.c, <*board*>.c/.h
- Key configuration files: usbmousehost.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

Using the USB controller in host mode on the TMDXDOCKH52C1 requires a hardware modification to the control card. See the "USB Host Mode Board Modification" section of the MCU SDK Getting Started Guide (SPRUHD3) for details.

2.2.14 USB Serial Device Example

Components: SYS/BIOS, USB Device CDC; Instrumentation (UIA)

This example uses the USB driver to transmit and receive data via the USB Communications Device Class (CDC) to a virtual USB COM port on a host workstation.

Within main(), this application performs general board setup, initializes the LEDs, and initializes USB0 as a device. It also dynamically creates two SYS/BIOS Task objects.

The taskFxn blocks until the USB library has been connected to the USB host. Then, the taskFxn task periodically sends an array of bytes to the USB host. It also toggles a GPIO and outputs a message whenever it sends data.

The taskFxn1 blocks until the USB library has been connected to the USB host. Then, the taskFxn1 task receives serial data sent by the host and prints using the SysMin system provider. The task also toggles a GPIO and outputs a message whenever it receives data. This task blocks while the device is not connected to the USB host or if no data was received.

- Key C files: USBCDCD.c/.h, usbserialdevice.c, <*board*>.c/.h
- Key configuration files: usbserialdevice.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

2.2.15 USB CDC Mouse Device Example

Components: SYS/BIOS, USB Device MSC; Instrumentation (UIA)

This example uses the USB Communications Device Class (CDC) device to simulate a mouse HID (Human Interface Device) class device sending mouse movement and click events.

Within main(), this application performs general board setup, initializes the LEDs, and initializes USB0 as a device. It also dynamically creates two SYS/BIOS Task objects.

The taskFxn blocks until the USB library has been connected to the USB host. When it determines the device is connected to a USB host, it sends pre-programmed X, Y coordinate offsets and the GPIO input pin's value as mouse button1 (a left-click) to the host. The X,Y coordinate offsets in the mouseLookupTable array move the mouse pointer to form a figure 8.

The taskFxn1 blocks until the USB library has been connected to the USB host. Then, the taskFxn1 task receives serial data sent by the host and prints it using the SysMin system provider. The task also toggles a GPIO and outputs a message whenever it receives data. This task blocks while the device is not connected to the USB host or if no data was received.

- Key C files: USBCDCMOUSE.c/.h, usbcdcmousedevice.c, <*board*>.c/.h
- Key configuration files: usbcdcmousedevice.cfg
- Linker command file: <*board*>.cmd
- Description file: readme.txt

Instrumentation with the MCU SDK

This chapter describes how to instrument your application with log calls and view the data with System Analyzer (SA).

Topic **Page**

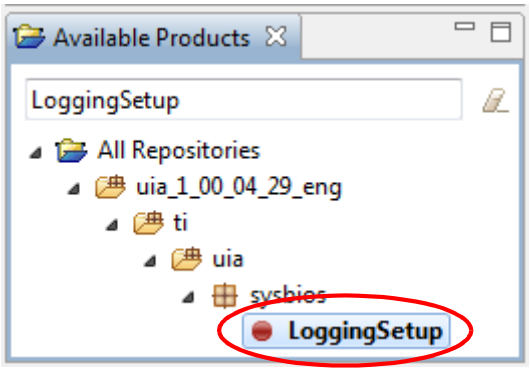
3.1 Overview

MCU SDK uses the Unified Instrumentation Architecture (UIA) to instrument your application with log calls. The data can be viewed and visualized with System Analyzer (SA) to create execution graphs, load graphs and more. For detailed information on using UIA and SA refer to the Getting Started Guide in the <uia_install>/docs directory and the System Analyzer User's Guide (SPRUH43).

3.2 Adding Logging to a Project

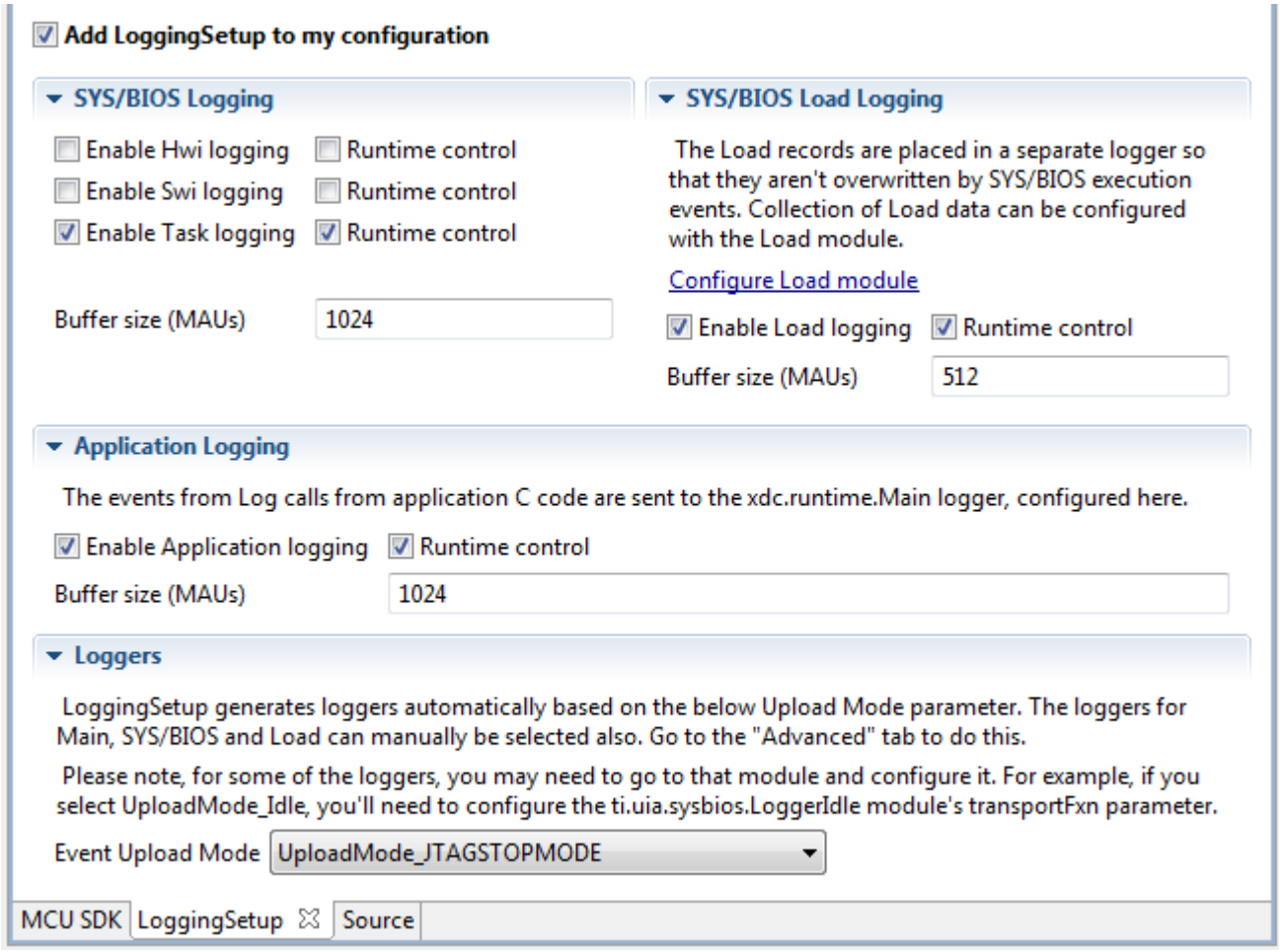
To add SYS/BIOS logging to a project, follow these steps:

1. Double-click on the configuration file (.cfg) for your project to open it with the XGCONF editor.
2. If LoggingSetup is already listed in your Outline pane, skip to Step 5.
3. In the "Available Products" area, type **LoggingSetup** in the field at the top that says "type filter text". This expands the hierarchy to select the **All Repositories > uia_#_##_##_## > ti > uia > sysbios > LoggingSetup** module.



4. Right-click on the LoggingSetup module, and select **Use LoggingSetup**. This adds the LoggingSetup module to your project and opens the configuration page for the module.
5. Use the configuration page for the LoggingSetup module as follows:
   a) In the **SYS/BIOS Logging** area, use the check boxes to select what types of threads you want to be logged—hardware interrupts (Hwi), software interrupts (Swi), and tasks. If you check the **Runtime control** box, you can turn that type of logging on or off at runtime.
   b) In the **SYS/BIOS Load Logging** area, you can click the **Configure Load module** link if you want the CPU load to be logged. Then check the box in the CPU Load Monitor page to add the CPU load monitoring module to the configuration. You can also choose which types of thread loads to monitor.
   c) In the **Application Logging** area, you configure the logger to use in your main application. Calls to Log_info(), Log_warning(), and Log_error() in your main application as well as any instrumented driver logs will be sent to this logger.

d) By default, LoggingSetup creates a logger that sends events over JTAG when the target is halted (for example, in StopMode). You can change the upload mode or assign your own logger by clicking the **Advanced** button to use the advanced options. For instructions, see Section 3.3.



The examples provided with the MCU SDK include and configure the LoggingSetup module. For more information on using LoggingSetup refer to Section 5.3.1 in the System Analyzer User's Guide (SPRUH43).

3.3 Using Log Events

You can add Log events to your application and control whether Log events are processed by drivers as described in the following sub-sections.

3.3.1 Adding Log Events to your Code

Your application can send messages to a Log using the standard Log module APIs (xdc.runtime.Log).

Log calls are of the format `Log_typeN(String, arg1, arg2… argN)`. Valid types are print, info, warning and error. N is the number of arguments between 0 and 5. For example:

```
Log_info2("tsk1 Entering. arg0,1 = %d %d", arg0, arg1)
```

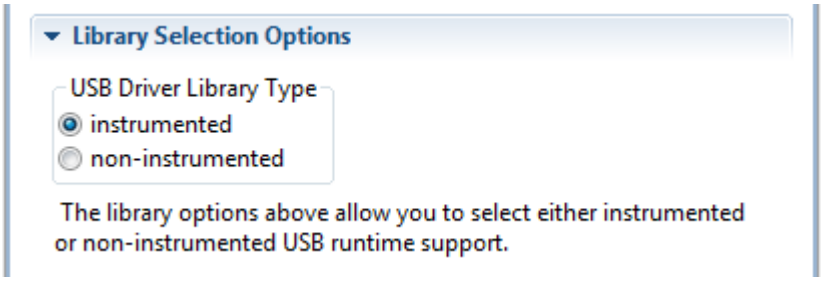
See the SYS/BIOS Log example project for more use cases.

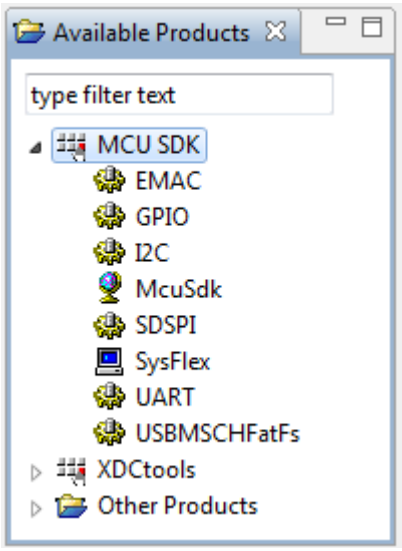
3.3.2 Using Instrumented or Non-Instrumented Libraries

The MCU SDK drivers allow you to control whether Log events are handled by choosing to build with the instrumented or non-instrumented libraries. The instrumented libraries process Log events while the non-instrumented libraries do not.

To select the type of library to build with, follow these steps:

1. Double-click on the configuration file (.cfg) for your project to open it with the XGCONF editor.
2. In the “Available Products” area, select the MCU SDK driver whose behavior you want to control. For example, if your target is the M3 side of the Concerto device, you can configure the EMAC, GPIO, I^{2}C, SDSPI, UART, and USBMSCHFatFs driver libraries.
3. On the configuration page, choose whether to use the instrumented or non-instrumented libraries.





Refer to the individual drivers in Chapter 6 for details about what is logged and which Diags masks are used.

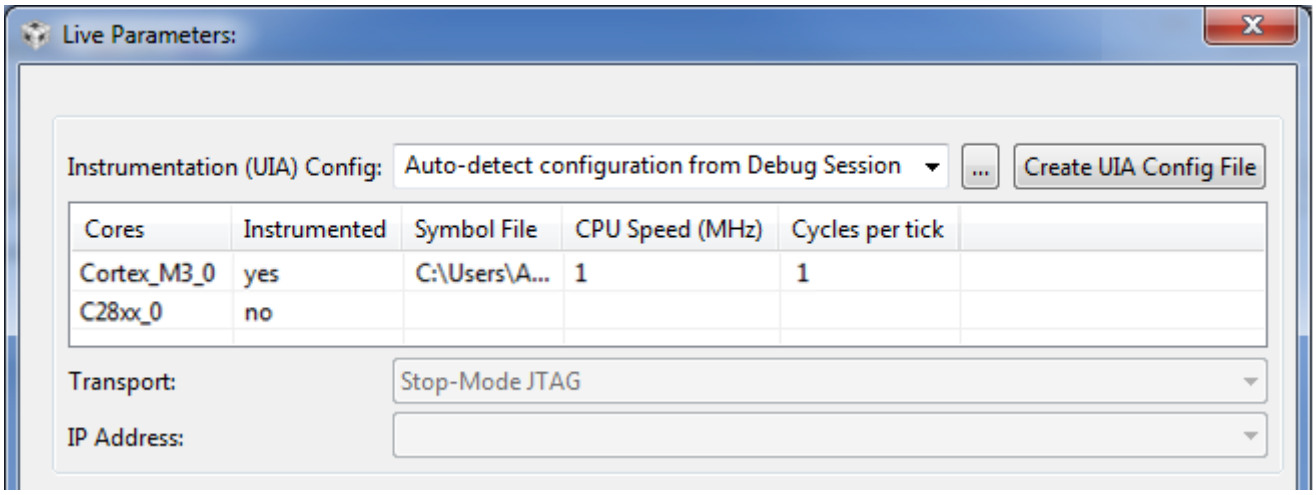
3.4 Viewing the Logs

You can use CCS to view Log messages using the System Analyzer and/or ROV tools.

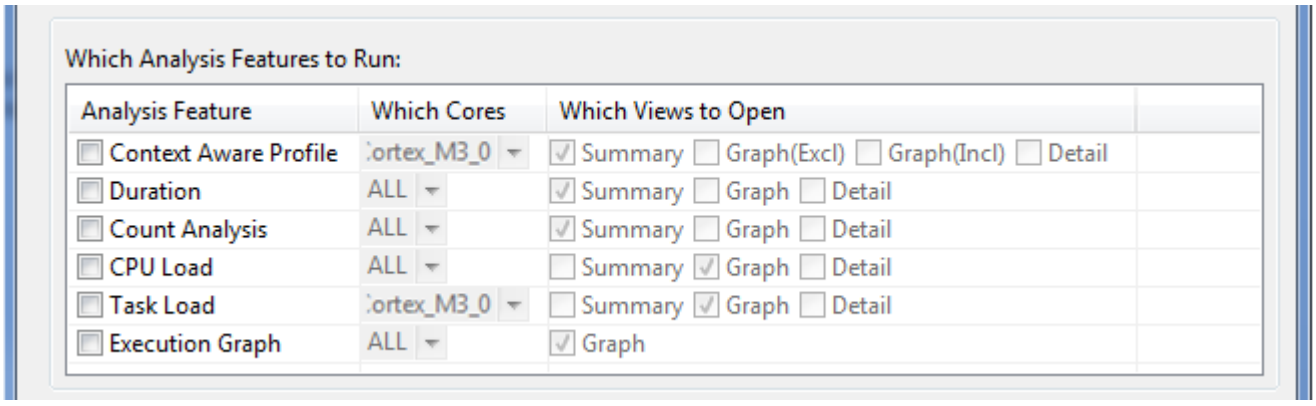
3.4.1 Using System Analyzer

After you have built and run your application, follow these steps in the CCS Debug view to see Log messages from your application with System Analyzer:

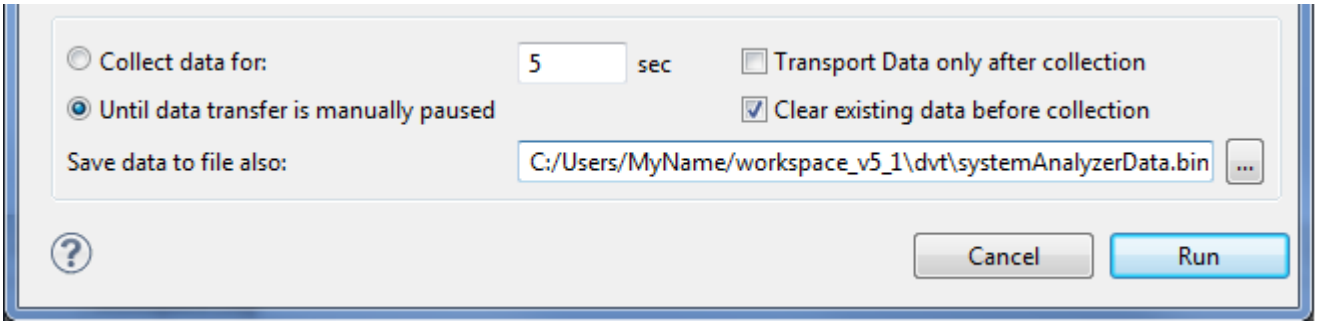
1. Open System Analyzer by selecting **Tools > System Analyzer > Live**.
2. Choose to auto-detect the UIA configuration or create your own configuration.
3. System Analyzer will detect the type of transport you are using. For UART or USB, type the COM port that is connected to the device in the **Port Name** field.



4. Select additional views to run.



5. Configure System Analyzer to run for a set time or forever (that is, until you manually pause the data transfer). You can also choose when to process the data (Transport Data only after collection), whether to clear existing data and save the data to a file which can be imported back into SA.



If you save the data to a file, you can analyze it later by selecting **Tools > System Analyzer > Open Binary File**.

See Section 4.2 ("Starting a Live System Analyzer Session") in the System Analyzer User's Guide (SPRUH43) for more about using this dialog.

3.4.2 Viewing Log Records in ROV

The RTOS Object View (ROV) can be used to view log events stored on the target.

After you have built and run your application, you can open the ROV tool in the CCS Debug view by selecting **Tools > RTOS Object View (ROV)** and then navigating to the logging module you want to view (for example, LoggerStopMode or LoggerIdle). When the target is halted, ROV repopulates the data. Select the **Records** tab to view log events still stored in the buffer. For loggers configured to use JTAG, the records shown here are also uploaded to System Analyzer. If you are using the LoggerIdle module, these are the records that have not yet been sent.

See the http://rtsc.eclipse.org/docs-tip/RTSC_Object_Viewer web page for more about using the RTOS Object View (ROV) tool.

Debugging MCU SDK Applications

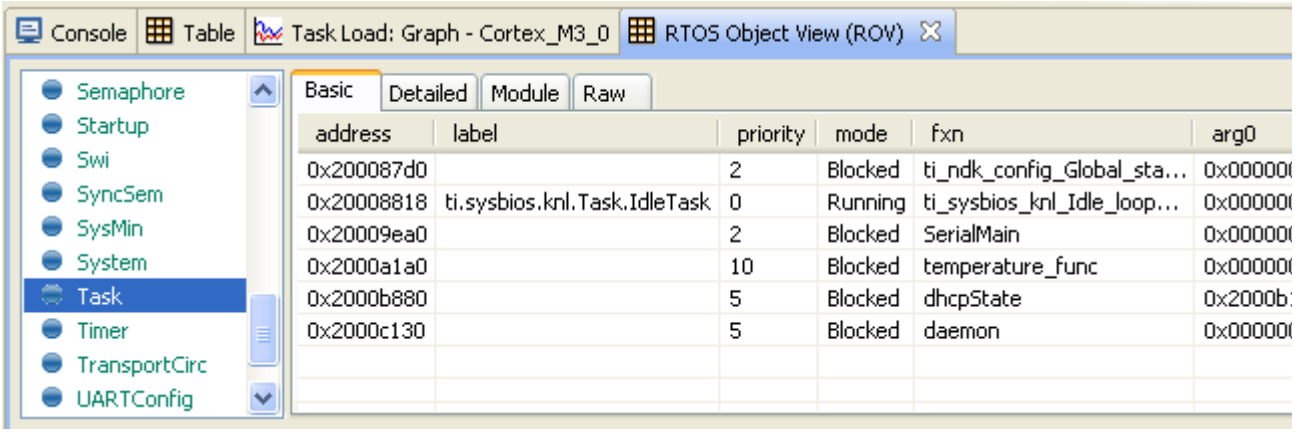
This chapter provides information about ways to debug your MCU SDK applications.

Topic **Page**

4.1 Using CCS Debugging Tools

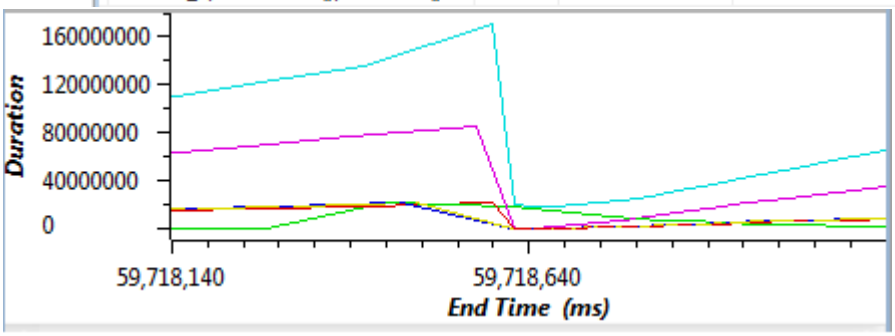
Within Code Composer Studio (CCS), there are several tools you can use to debug your MCU SDK applications:

- **RTOS Object View (ROV)** is a stop-mode debugging tool, which means it can receive data about an application only when the target is halted, not when it is running. ROV is a tool provided by the XDCtools component. For information, see the RTSC-pedia page about ROV at http://rtsc.eclipse.org/docstip/RTSC_Object_Viewer. ROV gets information from many of the modules your applications are likely to use.



- **System Analyzer** includes analysis features for viewing the CPU and thread loads, the execution sequence, thread durations, and context profiling. The features include graphs, detailed logs, and summary logs. These views gather data from the UIA component. For information, see the System Analyzer User's Guide (SPRUH43).

Name	Count	Incl Count Min	Incl Count Max	Incl Count Average
C64XP_0, serverFxn(), doLoad().0	14	2000203	2051632	2,003,924.71
C64XP_1, serverFxn(), doLoad().0	15	2000194	2000640	2,000,245.80
C64XP_2, serverFxn(), doLoad().0	16	2000195	2000622	2,000,244.00



- **Printf-style output** lets you use the tried-and-true debugging mechanism of sending execution information to the console. For information, see "Generating printf Output" on page 31.
- **Standard CCS IDE features** provide many tools for debugging your applications. In CCS, choose **Help > Help Contents** and open the **Code Composer Help > Views and Editors** category for a list of debugging tools and more information. These debugging features include:
  - Source-level debugger
  - Assembly-level debugger
  - Breakpoints (software and hardware)
  - Register, memory, cache, variable, and expression views
  - Pin and port connect views
  - Trace Analyzer view
- **Exception Handling** is provided by SYS/BIOS. If this module is enabled, the execution state is saved into a buffer that can be viewed with the ROV tool when an exception occurs. Details of the behavior of this module are target-specific. In the CCS online help, see the SYS/BIOS API Reference help on the ti.sysbios.family.c64p.Exception module or the ti.sysbios.family.arm.exc.Exception module for details.
- **Assert Handling** is provided by XDCtools. It provides configurable diagnostics similar to the standard C assert() macro. In the CCS online help, see the XDCtools API Reference help on the xdc.runtime.Assert module for details.

4.2 Generating printf Output

Along with many advanced GUI debugging features described in “Using CCS Debugging Tools” on page 29, MCUSDK provides flexibility with the tried-and-true printf method of debugging. MCUSDK supports both the standard printf() and a more flexible replacement called System_printf().

4.2.1 Output with printf()

By default, the printf() function outputs data to a CIO buffer on the target. When CCS is attached to the target (for example, via JTAG or USB), the printf() output is displayed in the Console window. It is important to realize that when the CIO buffer is full or a ‘\n’ is output, a CIO breakpoint is hit on the target. This allows CCS to read the data and output the characters to the console. Once the data is read, CCS resumes running the target. This interruption of the target can have significant impact on a real-time system. Because of this interruption and the associated performance overhead, use of the printf() API is discouraged.

The UART Console example shows how to route the printf() output to a UART via the add_device() API.

4.2.2 Output with System_printf()

The xdc.runtime.System module provided by the XDCtools component offers a more flexible and potentially better-performing replacement to printf() called System_printf().

The System module allows different low-level implementations (System Support implementation) to be plugged in based on your needs. You can plug in the System Support implementation you want to use via the application configuration. Your choice does not require any changes to the runtime code.

Currently the following System Support implementations are available:

- **SysMin:** Stores output to an internal buffer. The buffer is flushed to stdout (which goes to the CCS Console view) when System_flush() is called or when an application terminates (for example, when BIOS_exit() or exit() is called). When the buffer is full, the oldest characters are over-written. Characters that have not been sent to stdout can be viewed via the RTOS Object View (ROV) tool. The SysMin module is part of the XDCtools component. Its full module path is xdc.runtime.SysMin.
- **SysFlex:** Allows a user to plug in their functions. The UART Console example (Section 2.2.7) provides a set of functions that use the UART. The SysFlex module is a utility provided by the MCU SDK. Its full module path is ti.mcusdk.utils.SysFlex.
- **SysStd:** Sends the characters to the standard printf() function. The SysStd module is part of the XDCtools component. Its full module path is xdc.runtime.SysStd.

All MCU SDK examples use the SysMin module except for the UART Console example, which uses SysFlex and routes the output to a UART.

The following table shows the pros and cons of each approach:

Table 4-1 System providers shipped with MCU SDK

System Provider	Pros	Cons
SysMin	• Good performance	• Requires RAM (but size is configurable) • Potentially lose data • Out-of-box experience • To view in CCS console, you must add System_flush() or have the application terminate • Can use ROV to view output, but requires you halt the target
SysFlex	• Does not require CCS • Flexible	• Ties up resource • Might impact real-time performance
SysStd	• Easy to use (just like printf)	• Bad to use (just like printf). CCS halts target when CIO buffer is full or a '\n' is written • Cannot be called from a SYS/BIOS Hwi or Swi thread

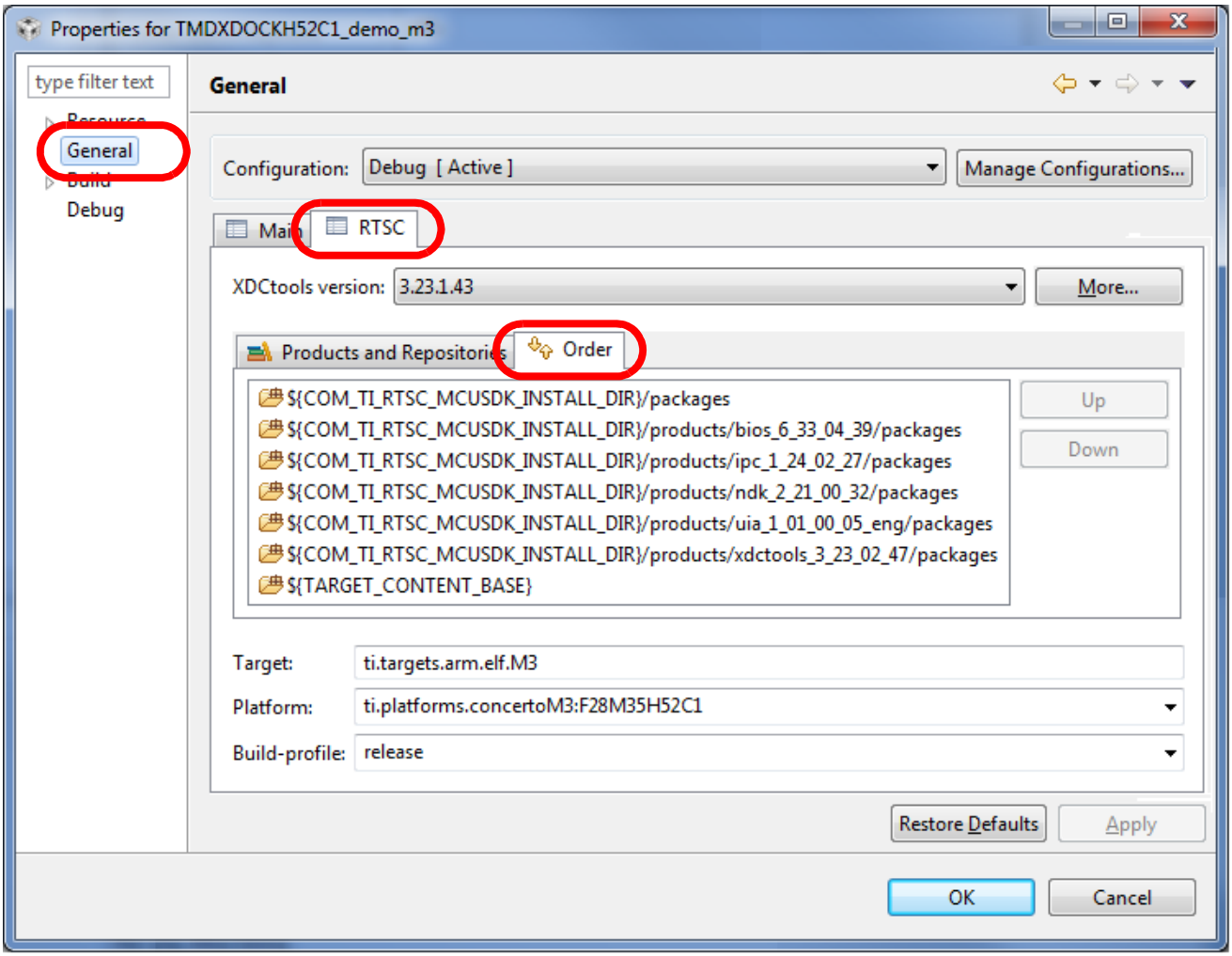
See "SysFlex Module" on page 67 for how to configure the System Provider you want to use and how to plug in your own functions if you are using the SysFlex provider.

Please note, the System module also provides the additional APIs that can be used instead of standard 'C' functions: System_abort(), System_atexit(), System_exit(), System_putch(), and System_flush().

4.3 Controlling Software Versions for Use with MCU SDK

You do not need to add the MCU SDK's "products" subdirectory to the RTSC (also called XDCtools) discovery path. Once CCS has found the main MCU SDK directory, it will also find the additional components provided in that tree.

In addition, the components installed with the MCU SDK will be used as needed by examples you import with the TI Resource Explorer. When you choose **Project > Properties** a project that uses the MCU SDK, the subprojects are not checked in the **RTSC** tab of the **General** category. However, the version installed with the MCU SDK is automatically used for sub-components that are needed by the example. You can see these components and which versions are used by going to the **Order** tab.



If, at a later time, you install newer software versions that you want to use instead of the versions installed with the MCU SDK, you can use the **Products and Repositories** tab to add those versions to your project and the **Up** and **Down** buttons in the **Orders** tab to make your newer versions take precedence over the versions installed with the MCU SDK. However, you should be aware that is it possible that newer component versions may not be completely compatible with your version of the MCU SDK.

Note that in the **RTSC** tab, the XDCtools version in the drop-down list is the version that controls UI behavior in CCS, such as the XGCONF editor and various RTSC dialog layouts. The XDCtools version is the list of products is the version used for APIs and configuration, such as the xdc.runtime modules.

4.4 Understanding the Build Flow

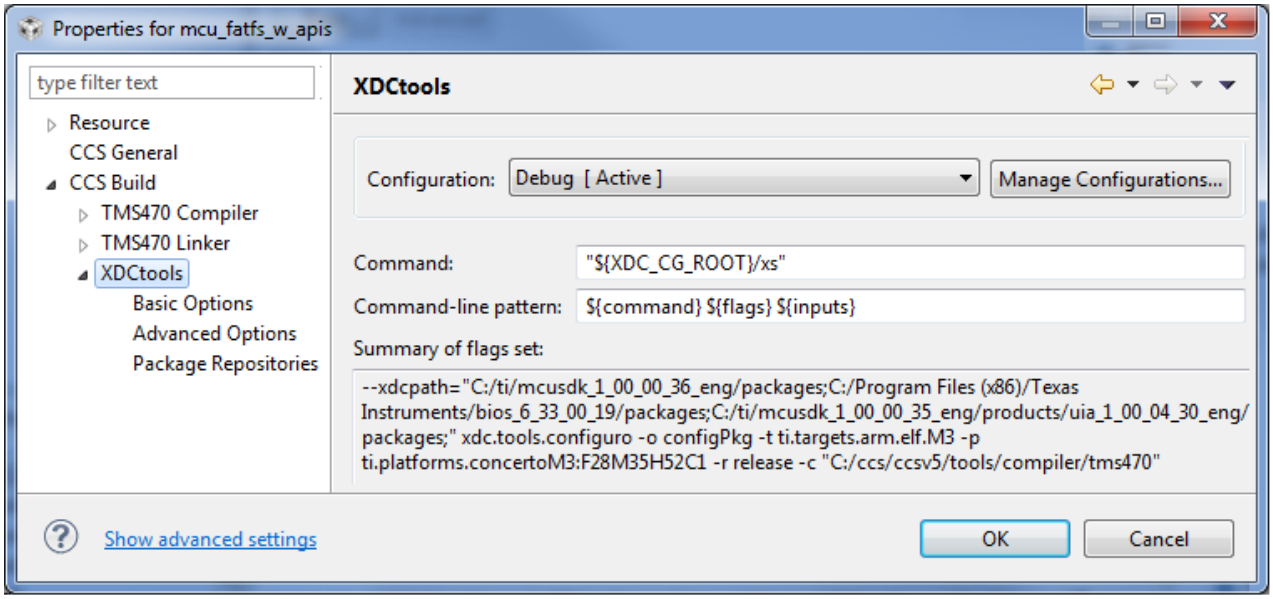
The build flow for MCU SDK applications begins with an extra step to process the configuration file (*.cfg) in the project. The configuration file is a script file with syntax similar to JavaScript. You can edit it graphically in CCS using the XGCONF tool. The configuration configures which modules in the MCU SDK components are used, sets global behavior parameters for modules, and statically creates objects managed by the modules. Static configuration has several advantages, including reducing code memory use by the application. Components that can be configured using this file include XDCtools, SYS/BIOS, MCU SDK, IPC, NDK, and UIA.

The configuration file is processed by the XDCtools component. If you look at the messages printed during the build, you will see a command line that runs the “xs” executable in the XDCtools component with the “xdc.tools.configuro” tool specified. For example:

```
'Invoking: XDCtools'

"<>/xs" --xdcpath="<mcusdk_install>/packages;
<bios_install>/packages;<uia_install>/packages;" xdc.tools.configuro -o configPkg
-t ti.targets.arm.elf.M3 -p ti.platforms.concertoM3:F28M35H52C1 -r release
-c "C:/ccs/ccsv5/tools/compiler/tms470" "../fatsdraw.cfg"
```

In CCS, you can control the command-line options used with XDCtools by choosing **Project > Properties** from the menus and selecting the **CCS Build > XDCtools** category.



Target settings for processing your individual project are in the **RTSC** tab of the **CCS General** category. (RTSC is the name for the Eclipse specification implemented by XDCtools.)

When XDCtools processes your *.cfg file, the code is generated in the <project_dir>/Debug/configPkg directory. This code is compiled so that it can be linked with your final application. In addition, a compiler.opt file is created for use during program compilation, and a linker.cmd file is created for use in linking the application. You should not modify the files in the <project_dir>/Debug/configPkg directory after they are generated, since they will be overwritten the next time you build.

For more information about the build flow, see Chapter 2 of the SYS/BIOS User’s Guide (SPRUEX3). For command-line details about xdc.tools.configuro, see the RTSC-pedia reference topic.

Board-Specific Files

This chapter provides information that is specific to targets for which you can use the MCU SDK.

Topic Page

5.1 Overview

Currently, the MCU SDK provides support for the following boards:

- **TMDXDOCKH52C1.** This is the Concerto Experimenter Kit Board. Concerto devices contain both M3 and 28x subsystems. This kit is ideal for initial device exploration and testing. It features a F28M35H52C1 microcontroller-based controlCARD.
- **DK-LM3S9D96.** This is the Stellaris Development Kit, which provides a feature-rich development platform. The Stellaris LM3S9D96 is an ARM Cortex-M3-based microcontroller. This board features fully-integrated Ethernet, CAN, and USB OTG/Host/Device.
- **EKS-LM4F232.** This is also a Stellaris board.

5.2 Board-Specific Code Files

The MCU SDK examples contain a board-specific C file (and its companion header file). These files perform board-specific configuration of the drivers provided by the MCU SDK. For example, they perform the following:

- GPIO port and pin configuration
- LED configuration
- SDSPI configuration

In addition, the board-specific files provide the following functions that you can use in your applications, where <*board*> is TMDXDOCKH52C1 (Concerto) or DK_LM3S9D96 (Stellaris). These are typically called from main().

- <*board*>_initGeneral() function
- <*board*>_initEMAC() function (TMDXDOCKH52C1 and DK-LM3S9D96 only)
- <*board*>_initI2C() function (TMDXDOCKH52C1 and DK-LM3S9D96 only)
- <*board*>_initGPIO() function
- <*board*>_initSDSPI() function
- <*board*>_initUART() function
- <*board*>_initUSB() function
- <*board*>_initUSBMSCHFatFs() function

5.3 Linker Command Files

All of the MCU SDK examples contain a <*board*>.cmd linker command file. A different file is provided for each supported board. These files define memory segments and memory sections used by the application.

5.4 Target Configuration Files

Each MCU SDK example contains a CCS Target Configuration File (*.ccxml). This file specifies the connection and device for the project for use in starting a debugging session. You can double-click on this file in the Project Explorer to edit it.

For the Demo example, you should not use the demo_c28 target configuration file. Instead, use the demo_m3 target configuration and connect to the C28 and load that application manually as described in Section 2.2.2.

MCU SDK Drivers

This chapter provides information about the drivers provided with the MCU SDK.

Topic **Page**

6.1 Overview

The MCU SDK includes drivers for a number of peripherals. These drivers are in the `<mcu_sdk_dir>/packages/ti/drivers` directory. MCU SDK examples show how to use these drivers. Note that all of these drivers are built on top of MWare and StellarisWare. This chapter contains a section for each driver.

- **EMAC.** Ethernet driver used by the networking stack (NDK) and not intended to be called directly.
- **UART.** API set intended to be used directly by the application to communicate with the UART.
- **I^2C.** API set intended to be used directly by the application or middleware.
- **GPIO.** API set intended to be used directly by the application or middleware to manage the GPIO pins and ports on the board.
- **SD.** SD driver used by the FatFs and not intended to be interfaced directly.
- **USBMSCHFatFs.** USB MSC Host under FatFs (for flash drives)
- **Other USB functionality.** See the USB examples for reference modules that provide support for the Human Interface Device (HID) class (mouse and keyboard) and Communications Device Class (CDC). This code is provided as part of the examples, not as a separate driver.

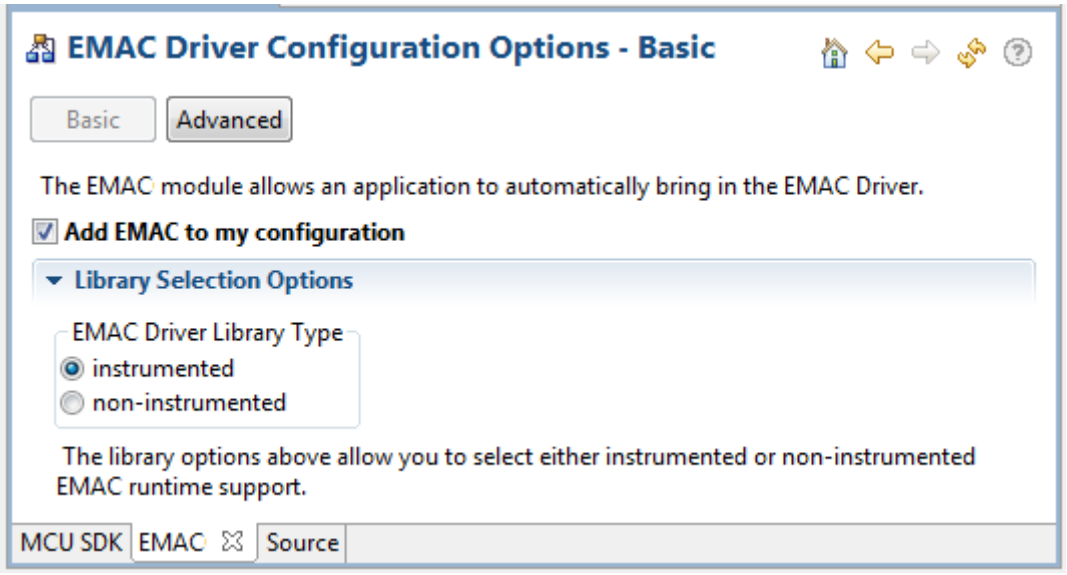
6.2 Driver Framework

The MCU SDK drivers have a common framework for static configuration and for a set of APIs that all drivers implement. This section describes that common framework. The driver-specific sections after the framework description provide details about individual implementations.

6.2.1 Static Configuration

All MCU SDK drivers have a configuration module that must be included in an application's configuration file (.cfg) in order for that application to use the driver. The configuration module pulls in the correct library for the driver based on the configures device and instrumentation. In addition, it enables use of the RTOS Object View (ROV) tool for the driver.

Add a driver module to the configuration graphically by selecting the module in the Available Products view and checking the "Add *Driver* to my configuration" box (where *Driver* is the MCU SDK driver name).



Alternately you can edit the configuration file with a text editor. Add the following lines, where *Driver* is the MCU SDK driver name. If you omit the second line, the instrumented libraries are used by default.

```
var Driver = xdc.useModule('ti.drivers.Driver');
Driver.libType = Driver.LibType_Instrumented;
```

6.2.2 Driver Object Declarations

All MCU SDK drivers require the application to allocate data storage for several structures to be used by the driver. The types for these structures are defined in the driver header file, which is located in *<mcusdk_install_dir>*\packages\ti\drivers.

The first structure is an array of hardware attributes. The driver header file defines a structure to hold one set of hardware attributes for the driver:

```
typedef struct Driver_HWAttrs {
    type   field1;
           ...
    type   fieldn;
} Driver_HWAttrs;
```

Then, the application must declare an array of these structures with the size of the array equal to the number of instances (peripherals) the driver will use. The application also fills in the hardware attribute values for each instance.

```
const Driver_HWAttrs driverHWAttrs[driverCount] = {
    {value1, ..., valuen},
    {value1, ..., valuen},
    ...
}
```

The second structure is an array of driver objects with the same size as the array of hardware attributes. The data in these structures should be filled in and used only by the driver. The application should not access fields in the driver object structure.

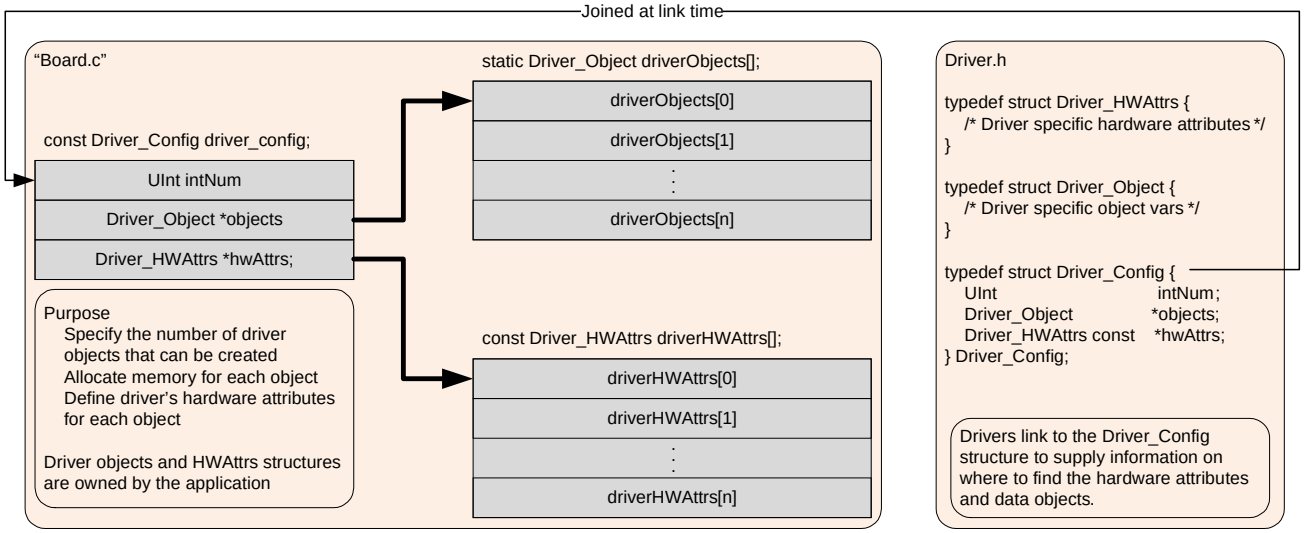
```
static Driver_Object driverObjects[driverCount];
```

The final structure is the configuration data structure. It includes the number of instances to use, a pointer to the hardware attributes, and a pointer to the driver objects. All examples implement the driver data structures in the included board files and should be used as a reference. An enum is used to select the instance index as well as to provide the number of driver instances implemented.

```
const Driver_Config driver_config {
    driverCount;
    driverObjects;
    driverHWAttrs;
}
```

The Driver_config struct has been designed to allow the HWAttrs to be stored in flash instead of RAM.

The driver configuration is shown in the following diagram:



6.2.3 Dynamic Configuration and Common APIs

MCU SDK drivers all implement the following APIs (with the exception of the GPIO driver*).

- `Void Driver_init(Void)`
  - Initializes the driver. Must be called only once and before any calls to the other driver APIs. Generally, this is done before SYS/BIOS is started.
  - The board files in the examples call this function for you.
- `Void Driver_Params_init(Driver_Params *params)`
  - Initializes the driver's parameter structure to default values. All drivers, with the exception of GPIO, implement the Params structure. The Params structure is empty for some drivers.
- `Driver_Handle Driver_open(UInt index, Driver_Params *params)`
  - Opens the driver instance specified by the index with the params provided.
  - If the params field is NULL, the driver uses default values. See specific drivers for their defaults.
  - Returns a handle that will be used by other driver APIs and should be saved.
  - If there is an error opening the driver or the driver has already been opened, *Driver_open*() returns NULL.
- `Void Driver_close(Driver_Handle handle)`
  - Closes the driver instance that was opened, specified by the driver handle returned during open.
  - Closes the driver immediately, without checking if the driver is currently in use. It is up to the application to determine when to call *Driver*_close() and to ensure it doesn't disrupt on-going driver activity.

* The GPIO driver implements only GPIO_init() to avoid complicating the driver. See Section 6.6 for information on using the GPIO driver.

6.3 EMAC Driver

This is the Ethernet driver used by the networking stack (NDK).

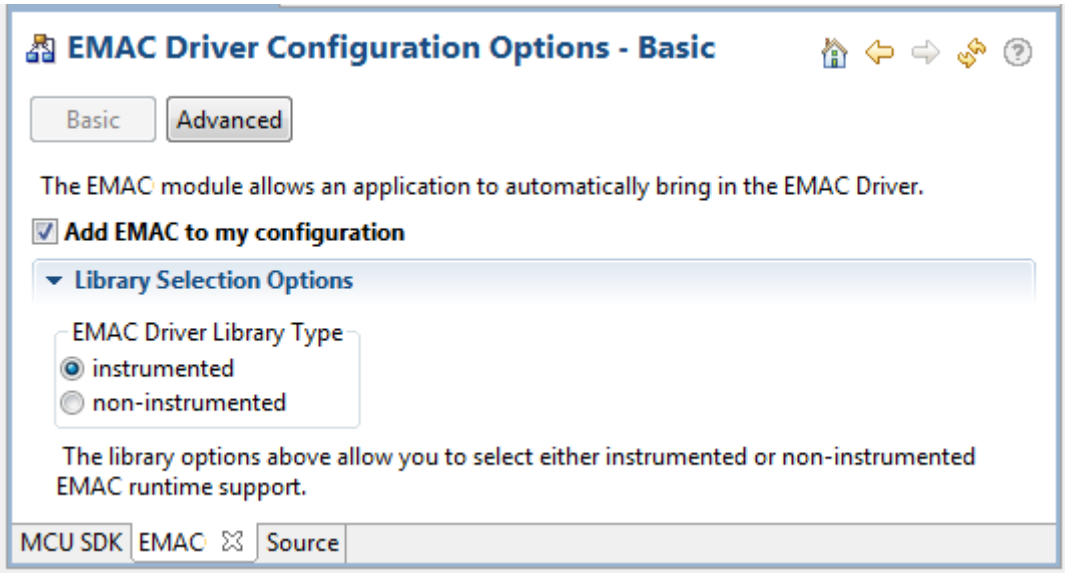
The EMAC driver is not supported for the EKS-LM4F232 board.

6.3.1 Static Configuration

To use the EMAC module, the application needs to include the EMAC module into the application's configuration file (.cfg). This can be accomplished textually:

```
var EMAC = xdc.useModule('ti.drivers.EMAC');
EMAC.libType = EMAC.LibType_Instrumented;
```

or graphically:



6.3.2 Runtime Configuration

As the overview in Section 6.2.2 indicates, the EMAC driver requires the application to initialize board-specific portions of the EMAC and provide the EMAC driver with the EMAC_config structure.

6.3.2.1 Board-Specific Configuration

The <board>.c files contain a <*board*>_initEMAC() function that must be called to initialize the board-specific EMAC peripheral settings. This function also calls the EMAC_init() to initialize the EMAC driver.

6.3.2.2 EMAC_config Structure

The <*board*>.c file also declare the EMAC_config structure. This structure must be provided to the EMAC driver. It must be initialized before the EMAC_init() function is called and cannot be changed afterwards.

For details about the individual fields of this structure, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.3.3 APIs

To use the EMAC module APIs, the EMAC header file should be included in an application as follows:

```
#include <ti/drivers/EMAC.h>
```

The following EMAC API is provided:

- **EMAC_init()** sets up the EMAC driver. This function must be called before the NDK stack thread is started.

For details, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

See the NDK documentation for information about NDK APIs that can be used if the EMAC driver is enabled and initialized.

6.3.4 Usage

The EMAC driver is designed to be used by the NDK. The only function that must be called is the EMAC_init() function. This function must be called before BIOS_start() is called to ensure that the driver is initialized before the NDK starts.

6.3.5 Instrumentation

The EMAC driver logs the following actions using the Log_print() APIs provided by SYS/BIOS.

- EMAC driver setup success or failure.
- EMAC started or stopped.
- EMAC failed to receive or transmit a packet.
- EMAC successfully sent or received a packet.
- No packet could be allocated.
- Packet is too small for the received buffer.

Logging is controlled by the Diags_USER1 and Diags_USER2 masks. Diags_USER1 is for general information and Diags_USER2 is for more detailed information.

The EMAC driver provides the following ROV information through the EMAC module.

- Basic parameters:
  - intVectId
  - macAddr
  - libType
- Statistics:
  - rxCount
  - rxDropped
  - txSent
  - txDropped

6.3.6 Examples

The TCP Echo (Section 2.2.3) and Demo (Section 2.2.2) examples included with the MCU SDK use the EMAC driver.

6.4 UART Driver

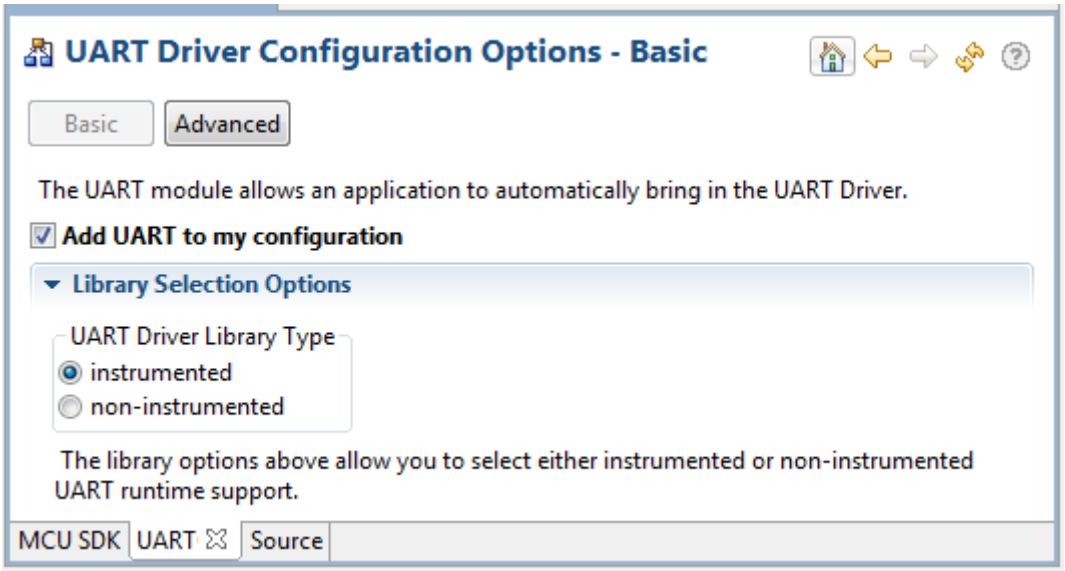
A UART is used to translate data between the chip and a serial port. The UART driver simplifies reading and writing to any of the UART peripherals on the board with multiple modes of operation and performance. These include blocking, non-blocking, and polling as well as text/binary mode, echo and return characters.

6.4.1 Static Configuration

To use the UART driver, the application needs to include the UART module into the application's configuration file (.cfg). This can be accomplished textually:

```
var UART = xdc.useModule('ti.drivers.UART');
UART.libType = UART.LibType_Instrumented;
```

or graphically:



6.4.2 Runtime Configuration

As the overview in Section 6.2.2 indicates, the UART driver requires the application to initialize board-specific portions of the UART and provide the UART driver with the UART_config structure.

6.4.2.1 Board-Specific Configuration

The <board>.c files contain a <*board*>_initUART() function that must be called to initialize the board-specific UART peripheral settings. This function also calls the UART_init() to initialize the UART driver.

6.4.2.2 UART_config Structure

The <*board*>.c file also declare the UART_config structure. This structure must be provided to the UART driver. It must be initialized before the UART_init() function is called and cannot be changed afterwards.

For details about the individual fields of this structure, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.4.3 APIs

In order to use the UART module APIs, the UART header file should be included in an application as follows:

```
#include <ti/drivers/UART.h>
```

The following are the UART APIs:

- **UART_init()** initializes the UART module.
- **UART_Params_init ()** initializes the UART_Params struct to its defaults for use in calls to UART_open().
- **UART_open()** opens a UART instance.
- **UART_close()** closes a UART instance.
- **UART_write()** writes a buffer of characters to the UART.
- **UART_writePolling()** writes a buffer to the UART in the context of the call and returns when finished.
- **UART_writeCancel()** cancels the current write action and unblocks or make the callback.
- **UART_read()** reads a buffer of characters to the UART.
- **UART_readPolling()** reads a buffer to the UART in the context of the call and returns when finished.
- **UART_readCancel()** cancels the current read action and unblocks or make the callback.

For details, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.4.4 Usage

The UART driver does not configure any board peripherals or pins; this must be completed before any calls to the UART driver. The examples call Board_initUART(), which is mapped to a specific initUART() function for the board. The board-specific initUART() functions are provided in the board .c and .h files. For example, a sample UART setup is provided in the TMDXDOCKH52C1_initUART() function in the TMDXDOCKH52C1.c file. This function sets up the peripheral and pins used by UART0 for operation through the JTAG emulation connection (no extra hardware needed). The examples that use the UART driver call the Board_initUART() function from within main().

Once the peripherals are set up, the application must initialize the UART driver by calling UART_init(). If you add the provided board setup files to your project, you can call the Board_initUART() function within main().

Once the UART has been initialized, you can open UART instances. Only one UART index can be used at a time. If the index is already in use, the driver returns NULL and logs a warning. Opening a UART requires four steps:

1. Create and initialize a UART_Params structure.
2. Fill in the desired parameters.
3. Call UART_open() passing in the index of the UART from the configuration structure and Params.
4. Save the UART handle that is returned by UART_open(). This handle will be used to read and write to the UART you just created.

For example:

```
UART_Handle uart;
UART_Params uartParams;

Board_initUART();          // Calls UART_init for you

/* Create a UART with data processing off. */
UART_Params_init(&uartParams);
uartParams.writeDataMode = UART_DATA_BINARY;
uartParams.readDataMode = UART_DATA_BINARY;
uartParams.readReturnMode = UART_RETURN_FULL;
uartParams.readEcho = UART_ECHO_OFF;

uart = UART_open(Board_UART, &uartParams);
```

Options for the writeMode and readMode parameters are UART_MODE_BLOCKING and UART_MODE_CALLBACK.

- UART_MODE_BLOCKING uses a semaphore to block while data is being sent. The context of the call must be a SYS/BIOS Task.
- UART_MODE_CALLBACK is non-blocking and will return while data is being sent in the context of a Hwi. The UART driver will call the callback function whenever a write or read finishes. In some cases, the action might have been canceled or received a newline, so the number of bytes sent/received are passed in. Your implementation of the callback function can use this information as needed.

Options for the writeDataMode and readDataMode parameters are UART_MODE_BINARY and UART_MODE_TEXT. If the data mode is UART_MODE_BINARY, the data is passed as is, without processing. If the data mode is UART_MODE_TEXT, write actions add a return before a newline character, and read actions replace a return with a newline. This effectively treats all device line endings as LF and all host PC line endings as CRLF.

Options for the readReturnMode parameter are UART_RETURN_FULL and UART_RETURN_NEWLINE. These determine when a read action unblocks or returns. If the return mode is UART_RETURN_FULL, the read action unblocks or returns when the buffer is full. If the return mode is UART_RETURN_NEWLINE, the read action unblocks or returns when a newline character is read.

Options for the readEcho parameter are UART_ECHO_OFF and UART_ECHO_ON. This parameter determines whether the driver echoes data back to the UART. When echo is turned on, each character that is read by the target is written back independent of any write operations. If data is received in the middle of a write and echo is turned on, the characters echoed back will be mixed in with the write data.

For details, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`.

6.4.5 Instrumentation

The UART module provides instrumentation data both by making log calls and by sending data to the ROV tool in CCS.

6.4.5.1 Logging

The UART driver is instrumented with Log events that can be viewed with UIA and System Analyzer. Diags masks can be turned on and off to provide granularity to the information that is logged.

Use Diags_USER1 to see general Log events such as success opening a UART, number of bytes read or written, and warnings/errors during operation.

Use Diags_USER2 to see more granularity when debugging. Each character read or written will be logged as well as several other key events.

The UART driver makes log calls when the following actions occur:

- UART_open() success or failure
- UART_close() success
- UART interrupt triggered
- UART_write() finished
- Byte was written
- UART_read() finished
- Byte was read
- UART_write() finished, canceled or timed out
- UART_read() finished, canceled or timed out

6.4.5.2 ROV

The UART driver provides ROV information through the UART module. All UARTs that have been created are displayed by their base address and show the following information:

- Configuration parameters:
  - Base Address
  - Write Mode
  - Read Mode
  - Write Timeout
  - Read Timeout
  - Write Data Mode
  - Read Data Mode
  - Read Return mode
  - Read Echo
- Write buffer: Contents of the write buffer
- Read buffer: Contents of the read buffer

6.4.6 Examples

The UART Console (Section 2.2.7) example included with the MCU SDK uses the UART driver with the SysFlex module to send output from System_printf() to a console.

6.5 I2C Driver

This section assumes that you have background knowledge and understanding about how the I2C protocol operates. For the full I2C specifications and user manual (UM10204), see the NXP Semiconductors website.

The I2C driver has been designed to operate as a single I2C master by performing I2C transactions between the MCU and I2C slave peripherals. The I2C driver does not support the MCU in I2C slave mode at this time. I2C is a communication protocol—the specifications define how data transactions are to occur via the I2C bus. The specifications do not define how data is to be formatted or handled, allowing for flexible implementations across different peripheral vendors. As a result, the I2C handles only the exchange of data (or transactions) between master and slaves. It is the left to the application to interpret and manipulate the contents of each specific I2C peripheral.

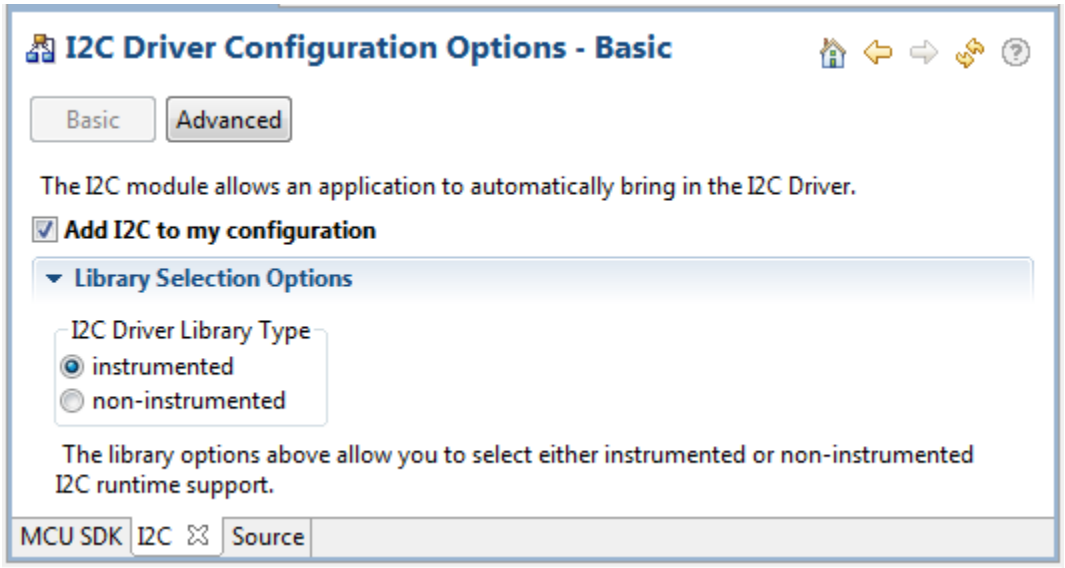
The I2C driver has been designed to operate in a RTOS environment such as SYS/BIOS. It protects its transactions with OS primitives supplied by SYS/BIOS.

6.5.1 Static Configuration

To use the I2C driver, the application needs to include the I2C module into the application's configuration file (.cfg). This can be accomplished textually:

```
var I2C = xdc.useModule('ti.drivers.I2C');
I2C.libType = I2C.LibType_Instrumented;
```

or graphically:



6.5.2 Runtime Configuration

As the overview in Section 6.2.2 indicates, the I2C driver requires the application to initialize board-specific portions of the I2C and provide the I2C driver with the I2C_config structure.

6.5.2.1 Board-Specific Configuration

The <board>.c files contain a <*board*>_initI2C() function that must be called to initialize the board-specific I^2C peripheral settings. This function also calls the I2C_init() to initialize the I^2C driver.

6.5.2.2 I2C_config Structure

The <*board*>.c file also declare the I2C_config structure. This structure must be provided to the I^2C driver. It must be initialized before the I2C_init() function is called and cannot be changed afterwards.

For details about the individual fields of this structure, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.5.3 APIs

In order to use the I^2C module APIs, the I2C.h header file should be included in an application as follows:

```
#include <ti/drivers/I2C.h>
```

The following are the I^2C APIs:

- **I2C_init()** initializes the I^2C module.
- **I2C_Params_init()** initializes an I2C_Params data structure. It defaults to Blocking mode.
- **I2C_open()** initializes a given I^2C peripheral.
- **I2C_close()** deinitializes a given I^2C peripheral.
- **I2C_transfer()** handles the I^2C transfer for SYS/BIOS.

The I2C_transfer() API can be called only from a Task context. It requires an I2C_Tramsaction structure that specifies the location of the write and read buffer, the number of bytes to be processed, and the I^2C slave address of the device.

For details, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.5.4 Usage

The application needs to supply the following structures in order to set up the framework for the driver:

- **I2C_Params** specifies the transfer mode and any callback function to be used. See Section 6.5.4.1.
- **I2C_Transaction** specifies details about a transfer to be performed. See Section 6.5.4.2.
- **I2C_Callback** specifies a function to be used if you are using callback mode. See Section 6.5.4.3.

6.5.4.1 I²C Parameters

The I2C_Params structure is used with the I2C_open() function call. If the transferMode is set to I2C_MODE_BLOCKING, the transferCallback argument is ignored. If transferMode is set to I2C_MODE_CALLBACK, a user-defined callback function must be supplied.

```
typedef struct I2C_Params {
    I2C_TransferMode transferMode;          /* Blocking or Callback mode */
    I2C_CallbackFxn  transferCallbackFxn;   /* Callback function pointer */
} I2C_Params;
```

6.5.4.2 I²C Transaction

The I2C_Transaction structure is used to specify what type of I2C_transfer needs to take place.

```
typedef struct I2C_Transaction {
    UChar *writeBuf;        /* Pointer to a buffer to be written */
    UInt   writeCount;      /* Number of bytes to be written */

    UChar *readBuf;         /* Pointer to a buffer to be read */
    UInt   readCount;       /* Number of bytes to be read */

    UChar  slaveAddress;    /* Address of the I2C slave device */

    UArg   arg;             /* User definable argument to the callback function */
    Ptr    nextPtr;         /* Driver uses this for queuing in I2C_MODE_CALLBACK */
} I2C_Transaction;
```

slaveAddress specifies the I²C slave address the I²C will communicate with. If writeCount is nonzero, I2C_transfer writes writeCount bytes from the buffer pointed by writeBuf. If readCount is nonzero, I2C_transfer reads readCount bytes into the buffer pointed by readBuf. If both writeCount and readCount are non-zero, the write operation always runs before the read operation.

The optional arg variable can only be used when the I²C driver has been opened in Callback mode. This variable is used to pass a user-defined value into the user-defined callback function.

nextPtr is used to maintain a linked-list of I2C_Transactions when the I²C driver has been opened in Callback mode. It must never be modified by the user application.

6.5.4.3 I²C Callback Function Prototype

This typedef defines the function prototype for the I²C driver's callback function for Callback mode. When the I²C driver calls this function, it supplies the associated I2C_Handle, a pointer to the I2C_Transaction that just completed, and a Boolean value indicating the transfer result. The transfer result is the same as from the I2C_transfer() when operating in Blocking mode.

```
typedef Void (*I2C_Callback)(I2C_Handle, I2C_Transaction *, Bool);
```

6.5.5 I²C Modes

The I²C driver supports two modes of operation, *blocking* and *callback* modes. The mode is determined when the I²C driver is opened using the I2C_Params data structure. If no I2C_Params structure is specified, the I²C driver defaults to blocking mode. Once opened, the only way to change the operation mode is to close and re-open the I²C instance with the new mode.

6.5.5.1 Opening in Blocking Mode

By default, the I²C driver operates in blocking mode. In blocking mode, a Task's code execution is blocked until an I²C transaction has completed. This ensures that only one I²C transaction operates at a given time. Other tasks requesting I²C transactions while a transaction is currently taking place are also placed into a blocked state and are executed in the order in which they were received.

```
I2C_Handle i2c;
UInt peripheralNum = 0;     /* Such as I2C0 */
I2C_Params i2cParams;

I2C_Params_init(&i2cParams);
i2cParams.transferMode = I2C_MODE_BLOCKING;
i2cParams.transferCallbackFxn = NULL;

i2c = I2C_open(peripheralNum, &i2cParams);
if (i2c == NULL) {
    /* Error Initializing I2C */
}
```

If no I2C_Params structure is passed to I2C_open(), default values are used. If the open call is successful, it returns a non-NULL value.

6.5.5.2 Opening in Callback Mode

In callback mode, an I²C transaction functions asynchronously, which means that it does not block a Task's code execution. After an I²C transaction has been completed, the I²C driver calls a user-provided hook function. If an I²C transaction is requested while a transaction is currently taking place, the new transaction is placed onto a queue to be processed in the order in which it was received.

```
I2C_Handle i2c;
UInt peripheralNum = 0;     /* Such as I2C0 */
I2C_Params i2cParams;

I2C_Params_init(&i2cParams);
i2cParams.transferMode = I2C_MODE_CALLBACK;
i2cParams.transferCallbackFxn = UserCallbackFxn;

i2c = I2C_open(peripheralNum, &i2cParams);
if (i2c == NULL) {
    /* Error Initializing I2C */
}
```

6.5.6 I²C Transactions

I²C can perform three types of transactions: Write, Read, and Write/Read. All I²C transactions are atomic operations with the slave peripheral. The I2C_transfer() function determines how many bytes need to be written and/or read to the designated I²C peripheral by reading the contents of an I2C_Transaction data structure.

The basic I2C_Transaction arguments include the slave peripheral's I²C address, pointers to write and read buffers, and their associated byte counters. The I²C driver always writes the contents from the write buffer before it starts reading the specified number of bytes into the read buffer. If no data needs to be written or read, simply set the corresponding counter(s) to 0.

6.5.6.1 Write Transaction (Blocking Mode)

As the name implies, an I²C write transaction writes data to a specified I²C slave peripheral. The following code writes three bytes of data to a peripheral with a 7-bit slave address of 0x50.

```
I2C_Transaction   i2cTransaction;
UChar             writeBuffer[3];
UChar             readBuffer[2];
Bool              transferOK;

i2cTransaction.slaveAddress = 0x50;     /* 7-bit peripheral slave address */
i2cTransaction.writeBuf = writeBuffer;  /* Buffer to be written */
i2cTransaction.writeCount = 3;          /* Number of bytes to be written */
i2cTransaction.readBuf = NULL;          /* Buffer to be read */
i2cTransaction.readCount = 0;           /* Number of bytes to be read */

transferOK = I2C_transfer(i2c, &i2cTransaction); /* Perform I2C transfer */
if (!transferOK) {
    /* I2C bus fault */
}
```

6.5.6.2 Read Transaction (Blocking Mode)

A read transaction reads data from a specified I²C slave peripheral. The following code reads two bytes of data from a peripheral with a 7-bit slave address of 0x50.

```
I2C_Transaction   i2cTransaction;
UChar             writeBuffer[3];
UChar             readBuffer[2];
Bool              transferOK;

i2cTransaction.slaveAddress = 0x50;     /* 7-bit peripheral slave address */
i2cTransaction.writeBuf = NULL;         /* Buffer to be written */
i2cTransaction.writeCount = 0;          /* Number of bytes to be written */
i2cTransaction.readBuf = readBuffer;    /* Buffer to be read */
i2cTransaction.readCount = 2;           /* Number of bytes to be read */

transferOK = I2C_transfer(i2c, &i2cTransaction); /* Perform I2C transfer */
if (!transferOK) {
    /* I2C bus fault */
}
```

6.5.6.3 Write/Read Transaction (Blocking Mode)

A write/read transaction first writes data to the specified peripheral. It then writes an I^2C restart bit, which starts a read operation from the peripheral. This transaction is useful if the I^2C peripheral has a pointer register that needs to be adjusted prior to reading from referenced data registers. The following code writes three bytes of data, sends a restart bit, and reads two bytes of data from a peripheral with the slave address of 0x50.

```
I2C_Transaction   i2cTransaction;
UChar             writeBuffer[3];
UChar             readBuffer[2];
Bool              transferOK;

i2cTransaction.slaveAddress = 0x50;     /* 7-bit peripheral slave address */
i2cTransaction.writeBuf = writeBuffer;  /* Buffer to be written */
i2cTransaction.writeCount = 3;          /* Number of bytes to be written */
i2cTransaction.readBuf = readBuffer;    /* Buffer to be read */
i2cTransaction.readCount = 2;           /* Number of bytes to be read */

transferOK = I2C_transfer(i2c, &i2cTransaction); /* Perform I2C transfer */
if (!transferOK) {
    /* I2C bus fault */
}
```

6.5.6.4 Write/Read Transaction (Callback Mode)

In callback mode, I^2C transfers are non-blocking transactions. After an I^2C transaction has completed, the I^2C interrupt routine calls the user-provided callback function, which was passed in when the I^2C driver was opened.

In addition to the standard I2C_Transaction arguments, an additional user-definable argument can be passed through to the callback function.

```
I2C_Transaction   i2cTransaction;
UChar             writeBuffer[3];
UChar             readBuffer[2];
Bool              transferOK;

i2cTransaction.slaveAddress = 0x50;     /* 7-bit peripheral slave address */
i2cTransaction.writeBuf = writeBuffer;  /* Buffer to be written */
i2cTransaction.writeCount = 3;          /* Number of bytes to be written */
i2cTransaction.readBuf = readBuffer;    /* Buffer to be read */
i2cTransaction.readCount = 2;           /* Number of bytes to be read */
i2cTransaction.arg = someOptionalArgument;

/* I2C_transfers will always return successful */
I2C_transfer(i2c, &i2cTransaction);     /* Perform I2C transfer */
```

6.5.6.5 Queuing Multiple I^2C Transactions

Using the callback mode, you can queue up multiple I^2C transactions. However, each I^2C transfer must use a unique instance of an I2C_Transaction data structure. In other words, it is not possible to reschedule an I2C_Transaction structure more than once. This also implies that the application must make sure the I2C_Transaction isn't reused until it knows that the I2C_Transaction is available again.

The following code posts a Semaphore after the last I2C_Transaction has completed. This is done by passing the Semaphore's handle through the I2C_Transaction data structure and evaluating it in the UserCallbackFxn.

```
Void UserCallbackFxn(I2C_Handle handle, I2C_Transaction *msg, Bool transfer) {
    if (msg->arg != NULL) {
        Semaphore_post((Semaphore_Handle)(msg->arg));
    }
}

Void taskfxn(arg0, arg1) {
    I2C_Transaction   i2cTransaction0;
    I2C_Transaction   i2cTransaction1;
    I2C_Transaction   i2cTransaction2;

    /* Set up i2cTransaction0/1/2 here */
        ...
    i2cTransaction0.arg = NULL;
    i2cTransaction1.arg = NULL;
    i2cTransaction2.arg = semaphoreHandle;

    /* Start and queue up the I2C transactions */
    I2C_transfer(i2c, &i2cTransaction0);
    I2C_transfer(i2c, &i2cTransaction1);
    I2C_transfer(i2c, &i2cTransaction2);

    /* Do other optional code here */
        ...

    /* Pend on the I2C transactions to have completed */
    Semaphore_pend(semaphoreHandle);
}
```

6.5.7 Instrumentation

The instrumented I^2C library contains Log_print() statements that help to debug I^2C transfers. The I^2C driver logs the following actions using the Log_print() APIs provided by SYS/BIOS:

- I^2C object opened or closed.
- Data written or read in the interrupt handler.
- Transfer results.

Logging is controlled by the Diags_USER1 and Diags_USER2 masks. Diags_USER1 is for general information and Diags_USER2 is for more detailed information. Diags_USER2 provides detailed logs intended to help determine where a problem may lie in the I^2C transaction. This level of diagnostics will generate a significant amount of Log entries. Use this mask when granular transfer details are needed.

The I^2C driver provides ROV information through the I2C module. All I^2Cs that have been created are displayed by their base address and show the following information:

- Basic parameters:
  - objectAddress: Address of the I^2C object.
  - baseAddress: Base address of the peripheral being used.
  - mode: Current state of the I^2C controller (Idle, Write, Read, or Error).
  - slaveAddress: The I^2C address of the peripheral with which the I^2C controller communicates.

6.5.8 Examples

The Demo (Section 2.2.2) and I^2C EEPROM (Section 2.2.6) MCU SDK examples use the I^2C driver.

6.6 GPIO Driver

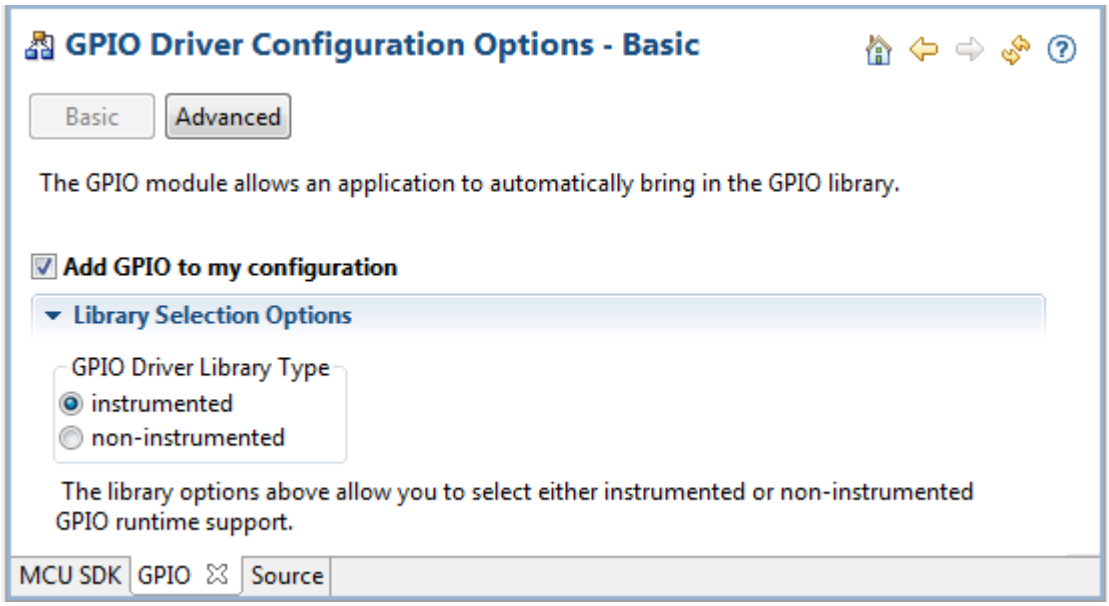
The GPIO module allows you to manage General Purpose I/O pins and ports via simple and portable APIs. The application needs to supply a GPIO_Config structure to the module. Then the application can call the remainder of the GPIO APIs. After the GPIO_init() function is called, all managed pins are set up for output or input as needed.

6.6.1 Static Configuration

To use the GPIO driver, the application needs to include the GPIO module into the application's configuration file (.cfg). This can be accomplished textually:

```
var GPIO = xdc.useModule('ti.drivers.GPIO');
GPIO.libType = GPIO.LibType_Instrumented;
```

or graphically:



6.6.2 Runtime Configuration

As the overview in Section 6.2.2 indicates, the GPIO driver requires the application to initialize board-specific portions of the GPIO and provide the GPIO driver with the GPIO_config structure.

6.6.2.1 Board-Specific Configuration

The <board>.c files contain a <*board*>_initGPIO() function that must be called to initialize the board-specific GPIO peripheral settings. This function also calls the GPIO_init() to initialize the GPIO driver.

6.6.2.2 GPIO_config Structure

The <*board*>.c file also declare the GPIO_config structure. This structure must be provided to the GPIO driver. It must be initialized before the GPIO_init() function is called and cannot be changed afterwards.

For details about the individual fields of this structure, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.6.3 APIs

In order to use the GPIO module APIs, the GPIO header file should be included in an application as follows:

```
#include <ti/drivers/GPIO.h>
```

The following are the GPIO APIs:

- **GPIO_init()** sets up the configured GPIO ports and pins.
- **GPIO_read()** gets the current state of the specified GPIO pin.
- **GPIO_write()** sets the state of the specified GPIO pin to on or off.
- **GPIO_toggle()** toggles the state of the specified GPIO pin.

For details, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the GPIO driver, but no information about the APIs.)

6.6.4 Usage

Once the GPIO_init() function has been called, the other GPIO APIs functions can be called. For example, in the DK_LM3S9D96.c file, the LED is set to off as follows:

```
Void DK_LM3S9D96_initGPIO(Void)
{
    ...
    GPIO_init();

    GPIO_write(DK_LM3S9D96_LED1, DK_LM3S9D96_LED_OFF);
}
```

6.6.5 Instrumentation

The GPIO driver logs the following actions using the Log_print() APIs provided by SYS/BIOS:

- GPIO pin read.
- GPIO pin toggled.
- GPIO pin written to.

Logging is controlled by the Diags_USER1 and Diags_USER2 masks. Diags_USER1 is for general information and Diags_USER2 is for more detailed information.

The GPIO driver provides ROV information through the GPIO module. All GPIOs that have been created are displayed by their base address and show the following information:

- Basic parameters:
  - baseAddress
  - pins
  - direction
  - value

6.6.6 Examples

All the MCU SDK examples (Section 2.2) use the GPIO driver. The GPIO_init() function is called in the board specific file (e.g. TMDXDOCKH52C1.c). A filled in GPIO_Config structure is used in the same file.

6.7 SDSPI Driver

The SDSPI FatFs driver is used to communicate with SD (Secure Digital) cards via SPI (Serial Peripheral Interface).

The SDSPI driver is a FatFs driver module for the FatFs module provided in SYS/BIOS. With the exception of the standard MCU SDK driver APIs—SDSPI_open(), SDSPI_close(), and SDSPI_init()—the SDSPI driver is exclusively used by FatFs module to handle the low-level hardware communications. See Chapter 8, "Using the FatFs File System Drivers" for usage guidelines.

The SDSPI driver only supports one SSI (SPI) peripheral at a given time. It does not utilize interrupts.

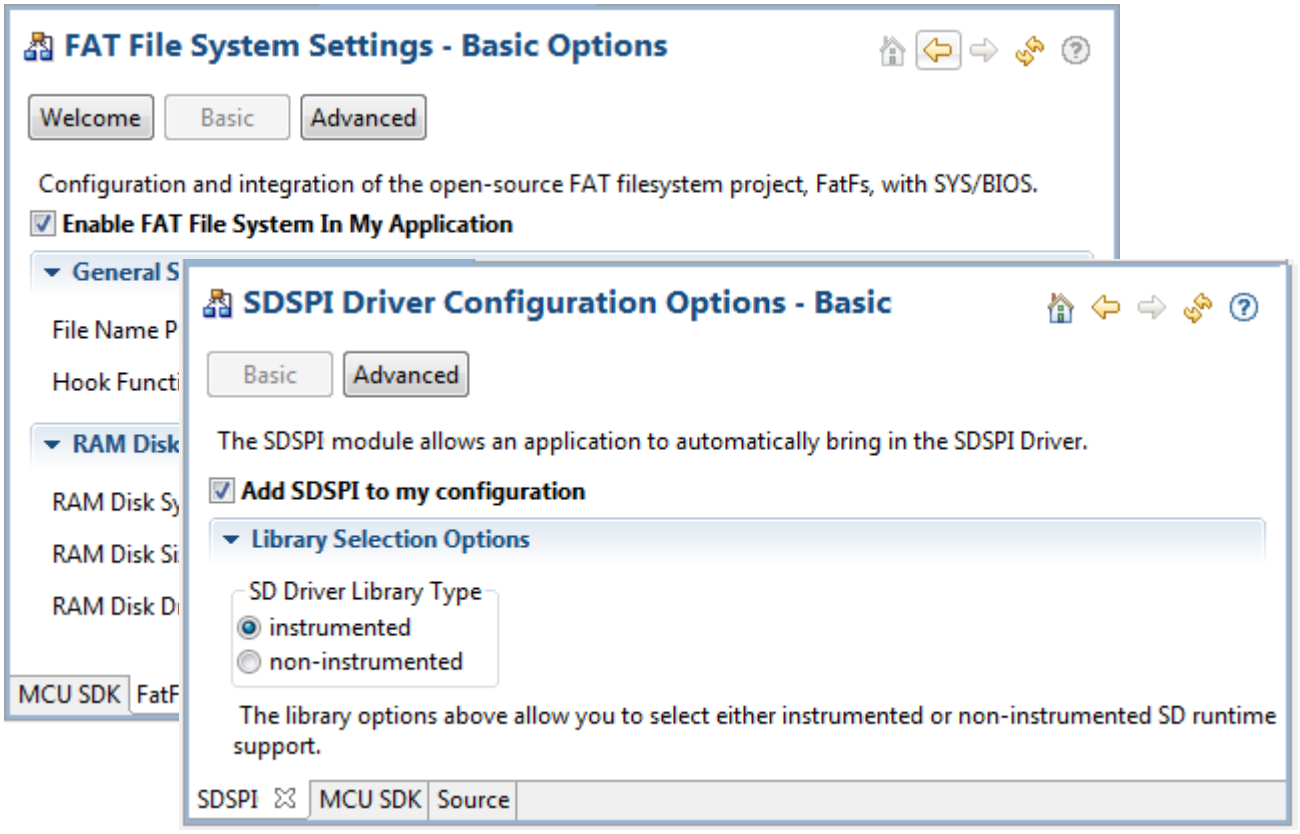
The SDSPI driver is polling based for performance reasons and due the relatively high SPI bus bit rate. This means it does not utilize the SPI's peripheral interrupts, and it consumes the entire CPU time when communicating with the SPI bus. Data transfers to or from the SD card are typically 512 bytes, which could take a significant amount of time to complete. During this time, only higher priority Tasks, Swis, and Hwis can preempt Tasks making calls that use the FatFs.

6.7.1 Static Configuration

To use the SDSPI driver, the application needs to include both the SYS/BIOS FatFS module and the SDSPI module in the application's configuration file (.cfg). This can be accomplished textually:

```
var FatFs = xdc.useModule('ti.sysbios.fatfs.FatFS');
var SDSPI = xdc.useModule('ti.drivers.SDSPI');
```

or graphically:



6.7.2 Runtime Configuration

As the overview in Section 6.2.2 indicates, the SDSPI driver requires the application to initialize board-specific portions of the SDSPI and provide the SDSPI driver with the SDSPI_config structure.

6.7.2.1 Board-Specific Configuration

The <board>.c files contain a <*board*>_initSDSPI() function that must be called to initialize the board-specific SDSPI peripheral settings. This function also calls the SDSPI_init() to initialize the SDSPI driver.

6.7.2.2 SDSPI_config Structure

The <*board*>.c file also declare the SDSPI_config structure. This structure must be provided to the SDSPI driver. It must be initialized before the SDSPI_init() function is called and cannot be changed afterwards.

For details about the individual fields of this structure, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.7.3 APIs

In order to use the SDSPI module APIs, include the SDSPI header file in an application as follows:

```
#include <ti/drivers/SDSPI.h>
```

The following are the SDSPI APIs:

- **SDSPI_init()** sets up the specified SPI and GPIO pins for operation.
- **SDSPI_open()** registers the SDSPI driver with FatFs and mounts the FatFs file system.
- **SDSPI_close()** unmounts the file system and unregisters the SDSPI driver from FatFs.
- **SDSPI_Params_init()** initializes a SDSPI_Params structure to its defaults.

For details, see the Doxygen help by opening `<mcu_sdk_install>\docs\doxygen\html\index.html`. (The CDOC help provides information about configuring the driver, but no information about the APIs.)

6.7.4 Usage

Before any FatFs or C I/O APIs can be used, the application needs to open the SDSPI driver. The SDSPI_open() function ensures that the SDSPI disk functions get registered with the FatFs module that subsequently mounts the FatFs volume to that particular drive.

```
SDSPI_Handle sdspiHandle;
SDSPI_Params sdspiParams;
UInt peripheralNum = 0;     /* Such as SPI0 */
UInt FatFsDriveNum = 0;

SDSPI_Params_init(&sdspiParams);
sdspiHandle = SDSPI_open(peripheralNum, FatFsDriveNum, &sdspiParams);
if (sdspiHandle == NULL) {
    System_abort("Error opening SDSPI\n");
}
```

Similarly, the SDSPI_close() function unmounts the FatFs volume and unregisters SDSPI disk functions.

```
SDSPI_close(sdspiHandle);
```

Note that it is up to the application to ensure the no FatFs or C I/O APIs are called before the SDSPI driver has been opened or after the SDSPI driver has been closed.

6.7.5 Instrumentation

The SDSPI driver does not make any Log calls.

The SDSPI driver provides the following information to the ROV tool through the SDSPI module.

- Basic parameters:
  - **baseAddress.** Base address of the peripheral being used to access the SD card.
  - **CardType.** The SD card type detected during the disk initialization phase. The card type can be Multi-media Memory Card (MMC), Standard SDCard (SDSC), High Capacity SDCard (SDHC), or NOCARD for an unrecognized card.
  - **diskState.** Current status of the SD card.

6.7.6 Examples

The Demo example (Section 2.2.2) and all 3 FatFs File Copy examples (Section 2.2.4, Section 2.2.5, and Section 2.2.9) included with the MCU SDK use the SDSPI driver.

6.8 USBMSCHFatFs Driver

The USBMSCHFatFs driver is a FatFs driver module that has been designed to be used by the FatFs module that comes with SYS/BIOS. With the exception of the standard MCU SDK driver APIs—_open(), _close(), and _init()—the USBMSCHFatFs driver is exclusively used by FatFs module to handle communications to a USB flash drive. See Chapter 8 for usage guidelines.

The USBMSCHFatFs driver is uses the USB Library, which is provided with StellarisWare and MWare to communicate with USB flash drives as a USB Mass Storage Class (MSC) host controller. Only one USB flash drive connected directly to the USB controller at a time is supported.

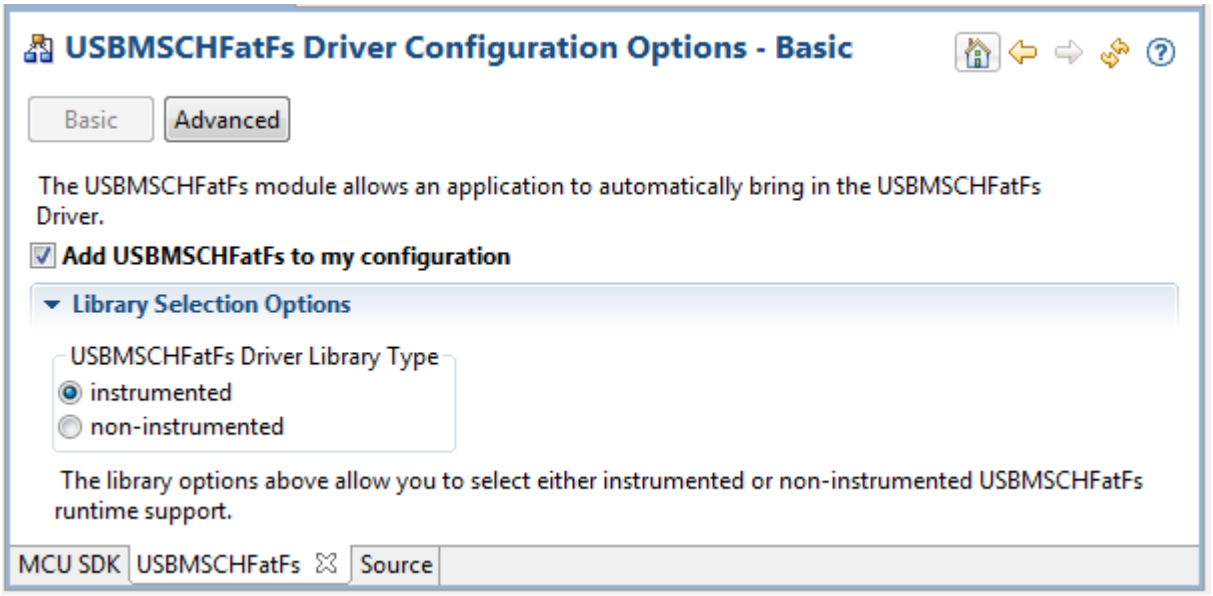
Tasks that make FatFs calls can be preempted only by higher priority tasks, Swis, and Hwis.

6.8.1 Static Configuration

To use the USB driver, the application needs to include the USBMSCHFatFs and FatFS modules into the application's configuration file (.cfg). This can be accomplished textually:

```
var FatFs = xdc.useModule('ti.sysbios.fatfs.FatFS');
var USBMSCHFatFs = xdc.useModule('ti.drivers.USBMSCHFatFs');
```

or graphically:



6.8.2 Runtime Configuration

As the overview in Section 6.2.2 indicates, the USBMSCHFatFs driver requires the application to initialize board-specific portions of the USBMSCHFatFs and provide the USBMSCHFatFs driver with the USBMSCHFatFs_config structure.

6.8.2.1 Board-Specific Configuration

The <board>.c files contain a <*board*>_initUSBMSCHFatFs() function that must be called to initialize the board-specific USBMSCHFatFs peripheral settings. This function also calls the USBMSCHFatFs_init() to initialize the USBMSCHFatFs driver.

6.8.2.2 USBMSCHFatFs_config Structure

The <*board*>.c file also declare the USBMSCHFatFs_config structure. This structure must be provided to the USBMSCHFatFs driver. It must be initialized before the USBMSCHFatFs_init() function is called and cannot be changed afterwards.

For details about the individual fields of this structure, see the Doxygen help by opening <*mcu_sdk_install*>\docs\doxygen\html\index.html. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.8.3 APIs

In order to use the USBMSCHFatFs module APIs, the USBMSCHFatFs header file should be included in an application as follows:

```
#include <ti/drivers/USBMSCHFatFs.h>
```

The following are the USBMSCHFatFs APIs:

- **USBMSCHFatFs_init()** initializes the USBMSCHFatFs data objects pointed by the driver's config structure.
- **USBMSCHFatFs_open()** registers the USBMSCHFatFs driver with FatFs and mounts the FatFs file system.
- **USBMSCHFatFs_close()** unmounts the file system and unregisters the USBMSCHFatFs driver from FatFs.
- **USBMSCHFatFs_Params_init()** initializes a USBMSCHFatFs_Params structure to its defaults.
- **USBMSCHFatFs_waitForConnect()** blocks a task's execution until a USB flash drive was detected.

For details, see the Doxygen help by opening <*mcu_sdk_install*>\docs\doxygen\html\index.html. (The CDOC help available from within CCS provides information about configuring the driver, but no information about the APIs.)

6.8.4 Usage

Before the FatFs APIs can be used, the application needs to open the USBMSCHFatFs driver. The USBMSCHFatFs_open() function ensures that the USBMSCHFatFs disk functions get registered with the FatFs module. The FatFs module then mounts the FatFs volume to that particular drive.

Internally, opening the USBMSCHFatFs driver creates a high-priority Task to service the USB library. The default priority for this task is 15 and runs every 10 SYS/BIOS system ticks. You can change the priority of this task using the USBMSCHFatFs_Params structure.

```
USBMSCHFatFs_Handle usbmschfatfsHandle;
USBMSCHFatFs_Params usbmschfatfsParams;
UInt peripheralNum = 0; /* Such as USB0 */
UInt FatFsDriveNum = 0;

USBMSCHFatFs_Params_init(&usbmschfatfsParams);
usbmschfatfsHandle =
              USBMSCHFatFs_open(peripheralNum, FatFsDriveNum, &usbmschfatfsParams);
if (usbmschfatfsHandle == NULL) {
    System_abort("Error opening USBMSCHFatFs\n");
}
```

Similarly, the close() function unmounts the FatFs volume and unregisters the USBMSCHFatFs disk functions.

```
USBMSCHFatFs_close(usbmschfatfsHandle);
```

The application must ensure the no FatFs or C I/O APIs are called before the USBMSCHFatFs driver has been opened or after the USBMSCHFatFs driver has been closed.

Although the USBMSCHFatFs driver may have been opened, there is a possibility that a USB flash drive may not be present. To ensure that a Task will wait for a USB drive to be present, the USBMSCHFatFs driver provides the USBMSCHFatFs_waitForConnect() function to block the Task's execution until a USB flash drive is detected.

6.8.5 Instrumentation

The USBMSCHFatFs driver logs the following actions using the Log_print() APIs provided by SYS/BIOS:

- USB MSC device connected or disconnected.
- USB drive initialized.
- USB drive read or failed to read.
- USB drive written to or failed to write.
- USB status OK or error.

Logging is controlled by the Diags_USER1 and Diags_USER2 masks. Diags_USER1 is for general information and Diags_USER2 is for more detailed information.

The USBMSCHFatFs driver does not provide any information to the ROV tool.

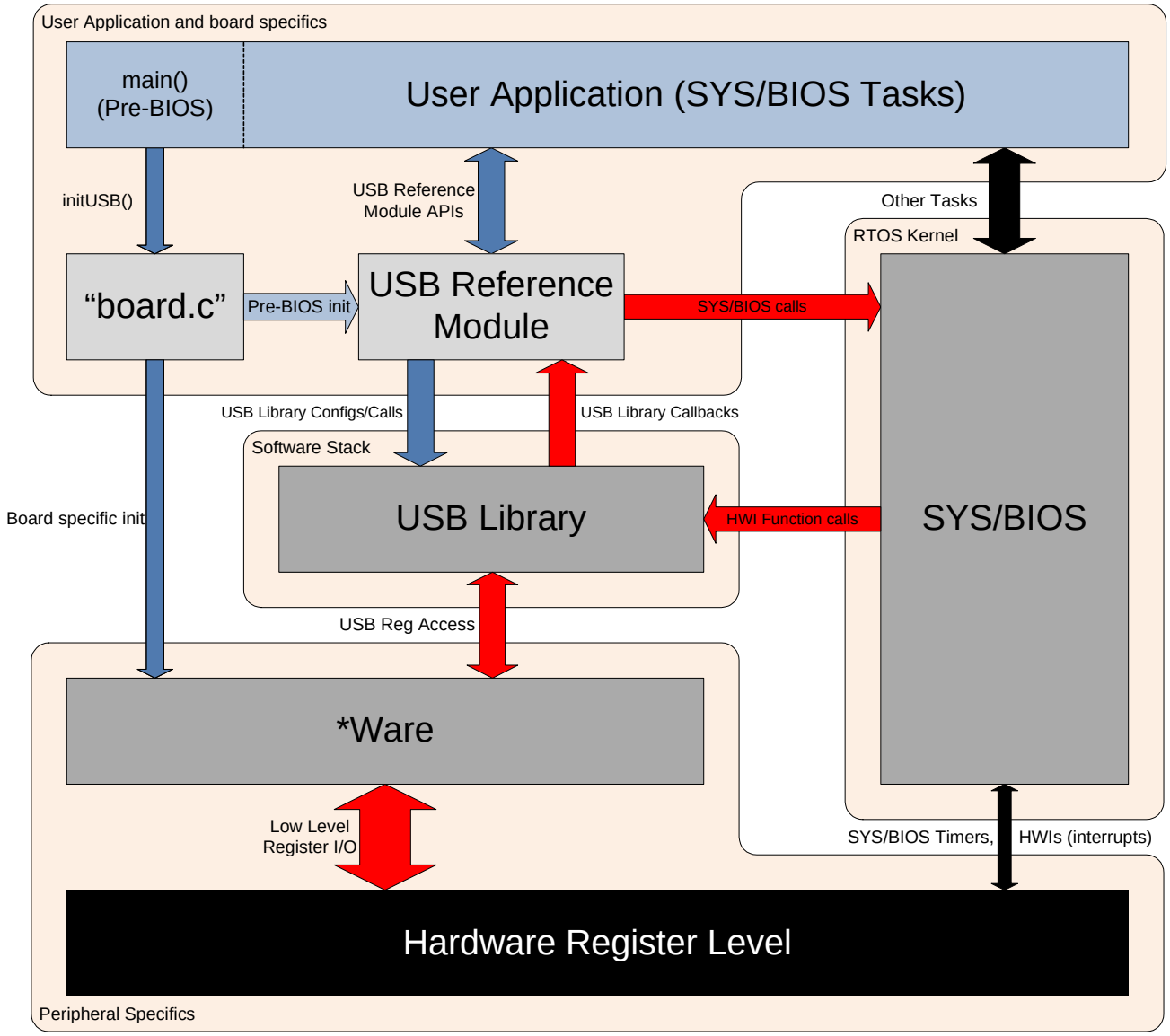
6.8.6 Examples

The FatSD USB Copy example (Section 2.2.9) included with the MCU SDK uses this driver.

6.9 USB Reference Modules

This section provides general guidelines for integrating TI's USB Library into an RTOS environment such as SYS/BIOS. The USB Library incorporated with MCU SDK is a released version of StellarisWare's USB library. This document does not explain StellarisWare's usblib in detail. Instead, it points out important design considerations to consider in application development.

The USB library is highly customizable. The USB library uses StellarisWare's driverlib software to access physical registers on the device, in particular those of the USB controller. To avoid limiting its capabilities by providing a driver that uses the library in a particular way, the MCU SDK USB examples are structured as reference modules.



Reference modules are examples that give developers full access, so they can make changes and modifications as needed. The goal of these modules is to provide a starting point for integrating the USB library into a SYS/BIOS application.

6.9.1 USB Reference Modules in the MCU SDK

Each module handles the following items:

- Initializes the USB library and provides the necessary memory allocation, data structures, and callback functions.
- Installs the associated USB interrupt service routine provided with the USB library as a SYS/BIOS HWI object.
- Provides a set of thread-safe APIs that can be used by one or more SYS/BIOS Tasks.
- Creates the necessary RTOS primitives to protect critical regions and allows Tasks to block when possible.
- For USB Host examples, it also creates separate Task that services the USB stack.

6.9.1.1 Reference module APIs

All of the reference modules include the following APIs. Each module also includes specific APIs unique to that particular module.

- *Module*`_init()` – This function initializes the USB library, creates RTOS primitives, and installs the proper interrupt handler. For the host examples, it also creates a Task to service the USB controller.
- *Module*`_waitForConnect()` – This function causes a Task to block when the USB controller is not connected.

6.9.1.2 USB Examples

The MCU SDK has six USB reference examples and one USB FatFs (MSC host) driver. (On-the-go (OTG) examples are not available with the MCU SDK.) The reference examples and driver are as follows:

- **HID Host Keyboard** – Allows a USB keyboard to be connected to the MCU. Keys pressed on the keyboard are registered on the MCU.
- **HID Host Mouse** – Allows a USB mouse to be connected to the MCU. The MCU registers the overall mouse movements and button presses.
- **HID Device Keyboard** – Causes the MCU to emulate a USB keyboard. When connected to a workstation, the MCU functions as another USB keyboard.
- **HID Device Mouse** – Causes the MCU to emulate a USB mouse when connected to a workstation.
- **CDC Device (Serial)** – The MCU enumerates a virtual serial COM port on a workstation. This method of communication is commonly used to replace older RS-232 serial adapters.
- **HID Mouse and CDC composite device** – This example enumerates two different USB devices—a HID mouse and a CDC serial virtual COM port.
- **MSC Host** (Mass Storage) – This example uses an actual driver instead of a USB reference module. This driver is modeled after the FatFs driver APIs. This driver allows external mass storage devices such a USB flash drives to be used with FatFs.

6.9.2 USB Reference Module Design Guidelines

This section discusses the structure of the USB reference examples.

Design considerations involved in creating these examples included:

- **USB Device Specifics.** Each module contains memory, data structures, and a callback function needed to function properly with the USB library. In device mode, the reference module also includes device descriptors that need to be sent to the USB host controller upon request.
- **OS Primitives.** OS primitives that implement gates, mutexes, and semaphores are used to guard data against race-conditions and reduce unwanted processing time by blocking Tasks when needed.
- **Memory Allocation.** The USB library is designed so that the user application performs all required memory allocation. In a multi-tasked / preempted environment such as SYS/BIOS, it is necessary to protect this memory from other threads. In the reference examples, this is done using the GateMutex module.
- **Callback Functions.** The USB library requires user-provided callback functions to notify the application of events. The USB reference modules provide a set of callback functions to notify the module of status updates. The callback functions update an internal state variable and in some cases post Semaphores to unblock pending Tasks.
- **Interrupts.** Some of the events that trigger callback functions are hardware notifications about the device being connected or disconnected from a USB host controller.

6.9.2.1 Device Mode

USB Device mode examples are rather straightforward. In device mode, the job of the USB library is to respond to the USB host controller with its current state/status. By making USB library API calls in device mode, the example updates information stored in the USB controller's endpoints. This information can be queried by the USB host controller.

6.9.2.2 Host Mode

All USB Host mode examples install a high-priority Task to service the USB controller. This Task calls the USB library's HCDMain() function, which maintains the USB library's internal state machine. This state machine performs actions that include enumerating devices and performing callbacks as described in the Stellaris USB library documentation.

To protect the USB library from race conditions between the service Task and other Tasks making calls to the module's APIs, a GateMutex is used.

6.9.2.3 On-The-Go Mode

OTG is not currently used by a USB reference module.

6.10 USB Device and Host Modules

See the USB examples for reference modules that provide support for the Human Interface Device (HID) class (mouse and keyboard) and the Communications Device Class (CDC). This code is provided as part of the examples, not as a separate driver.

The code for the HID keyboard device is in USBKBD.c in the USB Keyboard Device example (Section 2.2.10). This file provides the following functions:

- USBKBD_init()
- USBKBD_waitForConnect()
- USBKBD_getState()
- USBKBD_putChar()
- USBKBD_putString()

The code for the HID keyboard host is in USBKBH.c in the USB Keyboard Host example (Section 2.2.11). This file provides the following functions:

- USBKBH_init()
- USBKBH_waitForConnect()
- USBKBH_getState()
- USBKBH_setState()
- USBKBH_putChar()
- USBKBH_putString()

The code for the HID mouse device is in USBMD.c in the USB Mouse Device example (Section 2.2.12). This file provides the following functions:

- USBMD_init()
- USBMD_waitForConnect()
- USBMD_setState()

The code for the HID mouse host is in USBMH.c in the USB Mouse Host example (Section 2.2.13). This file provides the following functions:

- USBMH_init()
- USBMH_waitForConnect()
- USBMH_getState()

The code for the CDC device is in USBCDCD.c in the Demo example (Section 2.2.2), the USB Serial Device example (Section 2.2.14), and the UART Console example (Section 2.2.7). This file provides the following functions:

- USBCDCD_init()
- USBCDCD_waitForConnect()
- USBCDCD_sendData()
- USBCDCD_receiveData()

The code for the CDC mouse is in USBCDCMOUSE.c in the USB CDC Mouse Device example (Section 2.2.15). This file provides the following functions:

- USBCDCMOUSE_init()
- USBCDCMOUSE_receiveData()
- USBCDCMOUSE_sendData()
- USBCDCMOUSE_waitForConnect()

MCU SDK Utilities

This chapter provides information about utilities provided by the MCU SDK.

Topic **Page**

7.1 Overview

Utilities for use with the MCU SDK are provided in the `<mcusdk_install>\packages\ti\mcusdk\utils` directory. This chapter describes such modules.

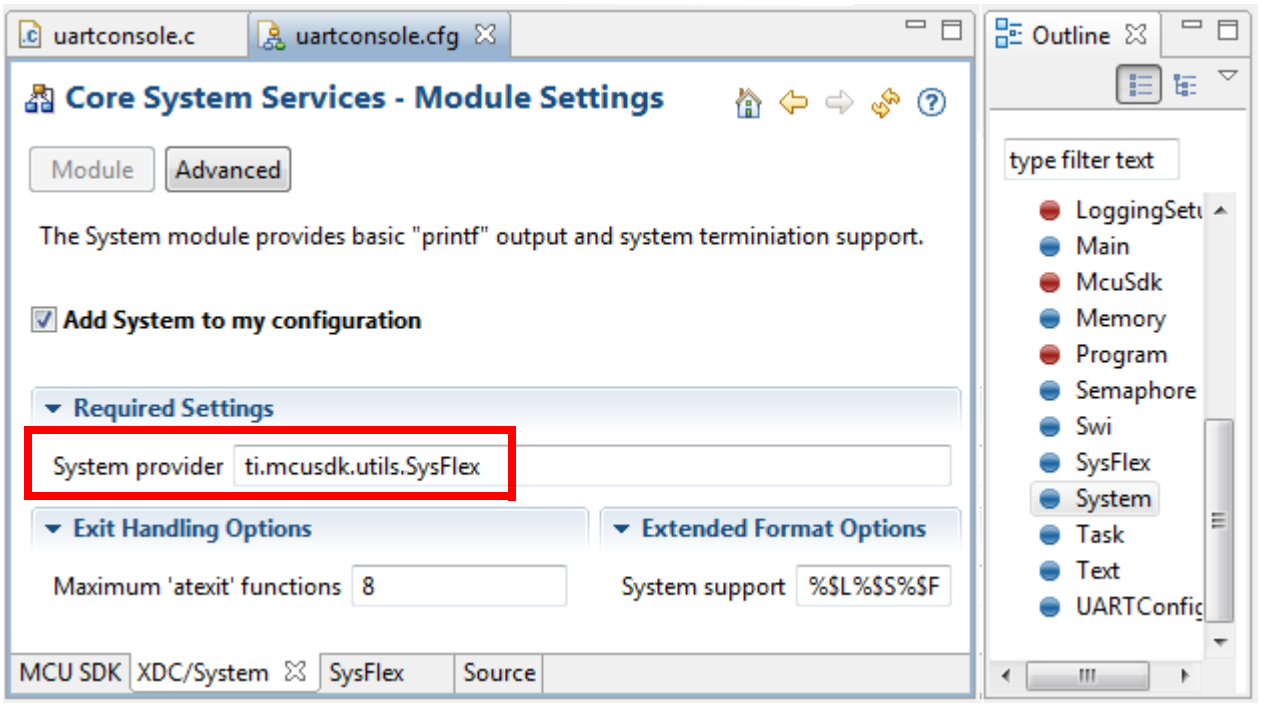
7.2 SysFlex Module

The SysFlex module plugs into the xdc.runtime.System module. It is one of the three System Support implementations that are supplied by the MCU SDK and its XDCtools component. See “Using CCS Debugging Tools” on page 29 for comparisons of SysFlex with the other System Support implementations.

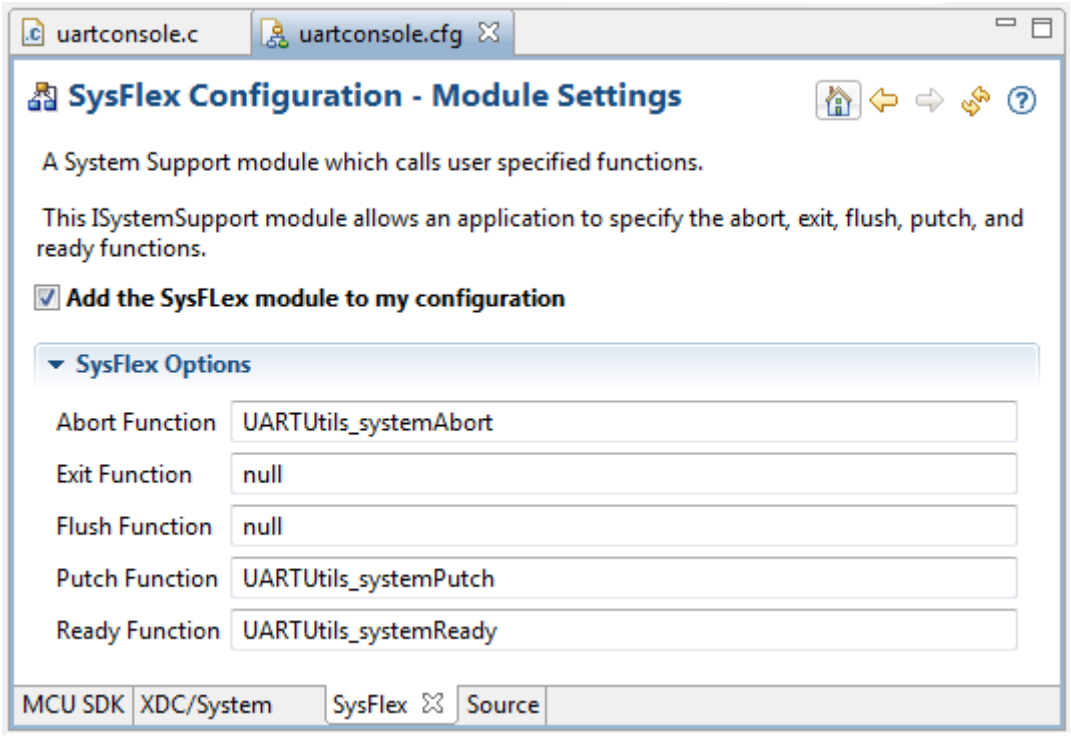
You can write your own System Support implementations and plug them into System module, however this is non-trivial. The SysFlex module provided by the MCU SDK simplifies this process and makes it more flexible (thus the name). SysFlex has five C function pointers you can configure. The five functions are:

- **abortFxn.** Last function called in System_abort(). This function should return and let System_abort() call abort.
- **exitFxn.** Last function called in System_exit(). This function should return and let System_exit() call exit.
- **flushFxn.** Last function called in System_flush(). This function should return.
- **putchFxn.** Called as part of any System function that outputs characters. The readyFxn is called before the putchFxn is called. putchFxn is only called if readyFxn returns TRUE.
- **readyFxn.** Called at various times within the System module. If the putchFxn is not ready to be called (for example, you have not initialized UART yet), the readyFxn should return FALSE. Once the putchFxn can be called, the readyFxn should return TRUE. If no readyFxn is supplied, TRUE is assumed.

To configure the SysFlex module, open the application's *.cfg file with the XGCONF Configuration Editor. In the Outline area, select the System module. Configure the System Provider to use SysFlex as follows:



Then, find the SysFlex module, and configure the plug-in functions as needed. For example, here are the settings used by the UART Console example provided with the MCU SDK:



After checking the box to enable the module, specify functions to run for each state that may occur. The default for all the SysFlex functions is "null".

The SysFlex module is an implementation of the ISystemSupport module. In other words, it plugs into the xdc.runtime.System module. When System_printf() is called, the SysFlex putch function is called.

The `UARTUtils.c` file in the UART Console example provides the functions shown in the previous figure for use as the Abort function (UARTUtils_systemAbort), the Putch function (UARTUtils_systemPutch), and the Ready function (UARTUtils_systemReady). In these functions, the SysFlex System Support module is configured to use UART0. In the UARTUtils_systemPutch() function, the character is sent out to the UART via the UART_writePolling() API.

See the MCU SDK online help in CCS for more details about the SysFlex module.

7.3 UART Example Implementation

The `UARTUtils.c` file provides an example implementation using a UART. Three of the SysFlex functions are initialized (the others default to NULL) in the `uartconsole.cfg` file. The configuration source is as follows:

```
var System = xdc.useModule('xdc.runtime.System');
var SysFlex = xdc.useModule('ti.mcusdk.utils.SysFlex');
SysFlex.abortFxn = "&UARTUtils_systemAbort";
SysFlex.putchFxn = "&UARTUtils_systemPutch";
SysFlex.readyFxn = "&UARTUtils_systemReady";
System.SupportProxy = SysFlex;
```

In `uartconsole.c`, main() does the following

1. Calls the board-specific setupUART() function to initialize the UART peripheral.
2. Calls UARTUtils_systemInit() as follows to initialize the UART 0 software. After the UARTUtils_systemInit function is called, any System_printf output will be directed to UART 0.

```
/* Send System_printf to the UART 0 also */
UARTUtils_systemInit(0);
```

Using the FatFs File System Drivers

This chapter provides an overview of FatFs and discusses how FatFs is interconnected and used with MCU SDK and SYS/BIOS.

Topic **Page**

8.1 Overview

FatFs is a free, 3rd party, generic File Allocation Table (FAT) file system module designed for embedded systems. The module is available for download at http://elm-chan.org/fsw/ff/00index_e.html along with API documentation explaining how to use the module. Details about the FatFs API are not discussed here. Instead, this section gives a high-level explanation about how it is integrated with MCU SDK and SYS/BIOS.

The FatFs drivers provided by the MCU SDK enable you to store data on removable storage media such as Secure Digital (SD) cards and USB flash drives (Mass Storage Class). Such storage may be a convenient way to transfer data between embedded devices and conventional PC workstations.

8.2 FatFs, SYS/BIOS, and MCU SDK

SYS/BIOS provides a FatFS module. The MCU SDK extends this feature by supplying "FatFs" drivers that link into the SYS/BIOS FatFs implementation. The FatFS module in SYS/BIOS is aware of the multi-threaded environment and protects itself with OS primitives supplied by SYS/BIOS.

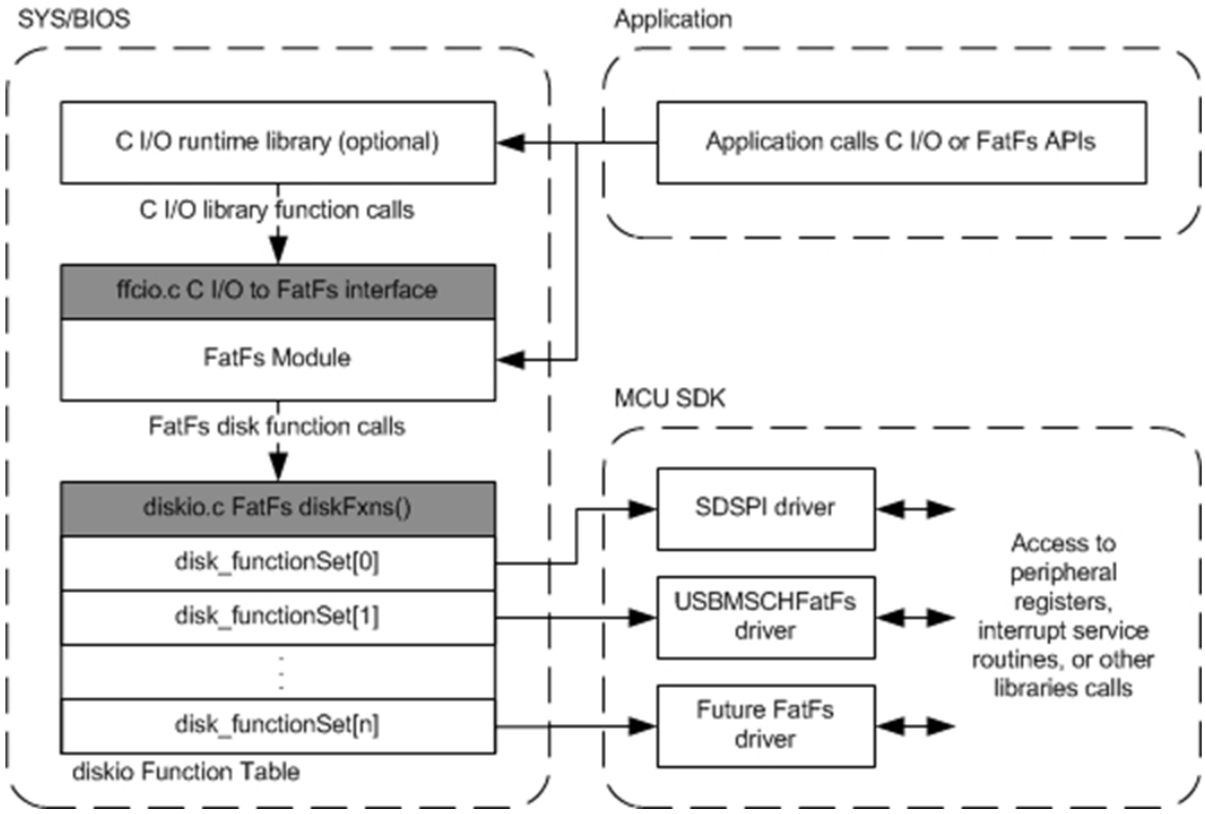


Figure 8-1 FatFs data flow

From the start of this data flow to the end, the components involved behave as follows:

- **Application.** The top application layer calls the basic open, close, read, and write functions. Users who are familiar with FatFs can easily use the FatFs API, which is documented at the module's download site. Alternatively, SYS/BIOS also connects the C input/output (C I/O) runtime support library in TI's Code Generation Tools to FatFs. You can call familiar functions such as fopen(), fclose(), fread(), and fwrite(). Functionally, the C I/O interface and the FatFs APIs perform the same operations (with a few exceptions described in Section 8.3).
- **FatFS module.** The next layer, the ti.sysbios.fatfs.FatFS module, is provided as part of SYS/BIOS. This module handles the details needed to manage and use the FAT file system, including the media's boot sector, FAT tables, root directories, and data regions. It also protects its functions in a multi-threaded environment. Internally, the FatFS module makes low-level data transfer requests to the Disk IO functions described on the FatFs product web page. Implementations of this set of functions are called "FatFs drivers" in this document.
- **diskIO Function table.** To allow products to provide multiple FatFs drivers, the SYS/BIOS FatFS module contains a simple driver table. You can use this to register multiple FatFs drivers at runtime. Based on the drive number passed through FatFs, the driver table routes FatFs calls to a particular FatFs driver.

- **FatFs drivers.** The last layer in Figure 8-1 is the FatFs drivers. MCU SDK comes with pre-built FatFs drivers that plug into the FatFS module provided by SYS/BIOS. A FatFs driver has no knowledge of the internal workings of FatFs. Its only task is to perform disk-specific operations such as initialization, reading, and writing. The FatFs driver performs read and write operations in data block units called sectors (commonly 512 bytes). Details about writing data to the device are left to the particular FatFs driver, which typically accesses a peripheral's hardware registers or uses a driver library.

8.3 Using FatFs

The subsections that follow show how to configure FatFs statically, how to prepare the FatFs drivers for use in your application, and how to open files. For details about performing other file-based actions once you have opened a file, see the FatFs APIs described on http://elm-chan.org/fsw/ff/00index_e.html in the "Application Interface" section or the standard C I/O functions.

The MCU SDK Demo example (Section 2.2.2) and all 3 FatFs File Copy examples (Section 2.2.4, Section 2.2.5, and Section 2.2.9) use FatFs with the SDSPI driver.

The FatSD USB Copy example (Section 2.2.9) uses the USBMSCHFatFs driver.

8.3.1 Static FatFS Module Configuration

To incorporate the SYS/BIOS FatFS module into an application, simply "use" this module in a configuration (.cfg) file. You can do this by searching the **Available Products** list in XGCONF for FatFS, selecting the SYS/BIOS FatFS module, and checking the **Enable FAT File System in My Application** box. Or, you can add the following statement to the .cfg file.

```
var FatFS = xdc.useModule('ti.sysbios.fatfs.FatFS');
```

Note: The name of the product and the drivers is "FatFs" with a lowercase "s". The name of the SYS/BIOS module is "FatFS" with an uppercase "S". If you are using a text editor to write configuration statements, be sure to use the uppercase "S". If you are using XGCONF to edit your configuration graphically, the correct capitalization is used automatically.

By default, the prefix string used in C I/O fopen() calls that uses this module is "fat" and no RAM disk is created. You can these defaults by modifying the FatFS module properties.

For example, you can change the C I/O prefix string used in fopen() calls by adding this line to the .cfg file:

```
FatFS.fatfsPrefix = "newPrefix";
```

The application would then need to use the prefix in C I/O fopen() calls as follows:

```
src = fopen("newPrefix:0:signal.dat", "w");
```

See the online help for the module for more details about FatFS configuration.

You will also need to configure the FatFs driver or drivers you want to use. See Section 6.7, *SDSPI Driver* and Section 6.8, *USBMSCHFatFs Driver* for details.

8.3.2 Defining Drive Numbers

Calls to the open() functions of individual FatFs drivers—for example, SDSPI_open()—require a drive number argument. Calls to the C I/O fopen() function and the FatFs APIs also use the drive number in the string that specifies the file path. The following C code defines driver numbers to be used in such functions:

```
/* Drive number used for FatFs */
#define SD_DRIVE_NUM           0
#define USB_DRIVE_NUM          1
```

Here are some statements from the FatSD USB Copy example (Section 2.2.9) that use these drive number definitions. Note that STR(SD_DRIVE_NUM) uses a MACRO that expands SD_DRIVE_NUM to 0.

```
SDSPI_Handle sdspiHandle;
SDSPI_Params sdspiParams;
FILE *src;
const Char  inputfilesd[]  = "fat:"STR(SD_DRIVE_NUM)":input.txt";

/* Mount and register the SD Card */
SDSPI_Params_init(&sdspiParams);
sdspiHandle = SDSPI_open(Board_SDSPI, SD_DRIVE_NUM, &sdspiParams);

/* Open the source file */
src = fopen(inputfilesd, "r");
```

8.3.3 Preparing FatFs Drivers

In order to use a FatFs driver in an application, you must do the following:

- **Include the header file for the driver.** For example:

  ```
  #include <ti/drivers/SDSPI.h>
  ```

- **Run the initialization function for the driver.** All drivers have init() functions—for example, SDSPI_init()—that need to be run in order to set up the hardware used by the driver. Typically, these functions are run from main(). In the MCU SDK examples, a board-specific initialization function for the driver is run instead of running the driver's initialization function directly. For example:

  ```
  Board_initSDSPI();
  ```

- **Open the driver.** The application must open the driver before the FatFs can access the drive and its FAT file system. Similarly, once the drive has been closed, no other FatFs calls shall be made. All drivers have open() functions—for example, SDSPI_open()—that require a drive number to be passed in as an argument. For example:

  ```
  sdspiHandle = SDSPI_open(Board_SDSPI0, SD_DRIVE_NUM, NULL);
  ```

See Section 6.7, *SDSPI Driver* and Section 6.8, *USBMSCHFatFs Driver* for details about the FatFs driver APIs.

8.3.4 Opening Files Using FatFs APIs

Details on the FatFs APIs can be found at http://elm-chan.org/fsw/ff/00index_e.html in the "Application Interface" section.

The drive number needs to be included as a prefix in the filename string when you call f_open() to open a file. The drive number used in this string needs to match the drive number used to open the FatFs driver. For example:

```
res = f_open(&fsrc, "SD_DRIVE_NUM:source.dat", FA_OPEN_EXISTING | FA_READ);

res = f_open(&fdst, "USB_DRIVE_NUM:destination.dat", FA_CREATE_ALWAYS | FA_WRITE);
```

A number of other FatFs APIs require a path string that should include the drive number. For example, f_opendir(), f_mkdir(), f_unlink(), and f_chmod().

Although FatFs supports up to 10 (0-9) drive numbers, the SYS/BIOS diskIO function table supports only up to 4 (0-3) drives. You can modify this default by changing the definition of _VOLUMES in the ffconf.h file in the SYS/BIOS FatFS module. You will then need to rebuild SYS/BIOS as described in the *SYS/BIOS User's Guide* (SPRUEX3).

It is important to use either the FatFs APIs or the C I/O APIs for file operations. Mixing the APIs in the same application can have unforeseen consequences.

8.3.5 Opening Files Using C I/O APIs

The C input/output runtime implementation for FatFs works similarly to the FatFs API. However, you must add the file name prefix configured for the FatFS module ("fat" by default) and the logical drive number as prefixes to the filename. The file name prefix is extracted from the filename before it gets passed to the FatFs API.

In this example, the default file name prefix is used and the drive number is 0:

```
fopen("fat:0:input.txt", "r");
```

It is important to use either the FatFs APIs or the C I/O APIs for file operations. Mixing the APIs in the same application can have unforeseen consequences.

8.4 Cautionary Notes

FatFs drivers perform data block transfers to and from physical media. Depending on the FatFs driver, writing to and reading from the disk could prevent lower-priority tasks from running during that time. If the FatFs driver blocks for the entire transfer time, only higher-priority SYS/BIOS Tasks, Swis or Hwis can interrupt the Task making FatFs calls. In such cases, the application developer should consider how often and how much data needs to be read from or written to the media.

By default the SYS/BIOS FatFS module keeps a complete sector buffered for each opened file. While this requires additional RAM, it helps mitigate frequent disk operations when operating on more than one file simultaneously.

The SYS/BIOS FatFS implementation allows up to four unique volumes (or drives) to be registered and mounted.

Rebuilding the MCU SDK

This chapter describes how and when to rebuild the MCU SDK.

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9.1 Rebuilding the MCU SDK

In most cases, you will not need to rebuild the MCU SDK libraries. Pre-built libraries are provided when you install the MCU SDK. However, if you want to change the compiler or linker options, you may need to rebuild the libraries.

The MCU SDK can be rebuilt from a top-level make file called `mcusdk.mak`.

If MCU SDK is installed in `c:\ti`, you can rebuild the drivers and examples by running the following command from a command shell window:

```
%cd <mcusdk_install_dir>

% products/<xdctools>/gmake -f mcusdk.mak
```

If you installed somewhere else, you can edit the `mcusdk.mak` file in the top-level MCU SDK directory. Adjust the directory names as needed, or pass in the necessary names. For example to use a different location for XDCtools do the following:

```
% products/<xdctools>/gmake -f mcusdk.mak XDCTOOLS_INSTALLATION_DIR=c:/ti/xdctools_version
```

The following list shows items you can change and sample values. The version numbers in your copy of the `mcusdk.mak` file will match the versions of the components installed with MCU SDK.

```
CODEGEN_INSTALLATION_DIR := c:/ti/ccsv5/tools/compiler
ti.targets.C28_float      ?= $(CODEGEN_INSTALLATION_DIR)/c2000_6.1.0
ti.targets.arm.elf.M3     ?= $(CODEGEN_INSTALLATION_DIR)/tms470_4.9.1
ti.targets.arm.elf.M4F    ?= $(CODEGEN_INSTALLATION_DIR)/tms470_4.9.1

MCUSDK_INSTALLATION_DIR   := c:/ti/mcusdk_1_00_00_68
XDCTOOLS_INSTALLATION_DIR ?= $(MCUSDK_INSTALLATION_DIR)/products/xdctools_3_23_04_60
BIOS_INSTALLATION_DIR     ?= $(MCUSDK_INSTALLATION_DIR)/products/bios_6_33_04_39
IPC_INSTALLATION_DIR      ?= $(MCUSDK_INSTALLATION_DIR)/products/ipc_1_24_02_27
UIA_INSTALLATION_DIR      ?= $(MCUSDK_INSTALLATION_DIR)/products/uia_1_01_01_15
NDK_INSTALLATION_DIR      ?= $(MCUSDK_INSTALLATION_DIR)/products/ndk_2_21_01_38
MWARE_INSTALLATION_DIR    ?= $(MCUSDK_INSTALLATION_DIR)/products/MWare_v140x/MWare
STELLARISWARE_INSTALLATION_DIR  ?= $(MCUSDK_INSTALLATION_DIR)/products/StellarisWare_9107
```

If you are rebuilding on Linux, you will need to change all of these Windows paths in the `mcusdk.mak` file to Linux paths.

9.2 Rebuilding Individual Components

The SYS/BIOS, IPC, NDK, and UIA products all have similar rebuilding mechanisms. Refer to the documentation for these products for details.

The MWare and StellarisWare rebuilding mechanism is substantially different. See the documentation for these products for details.

The driverlib in the version of MWare distributed with MCU SDK has been rebuilt with the following compiler option: `--define=RTOS_SUPPLIED_INTERRUPTS`. In addition, the example projects provided with MWare for use in CCS have also been modified to use this compiler option.

Memory Usage with MCU SDK

This chapter provides links to information about memory usage.

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10.1 Memory Footprints

See MCU SDK Memory Footprints on the TI Embedded Processors Wiki for details about the memory footprint of the MCU SDK drivers:

10.2 Networking Stack Memory Usage

See MCU SDK Networking Stack Memory Usage on the TI Embedded Processors Wiki for details about to adjusting memory usage of the networking stack (NDK).

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