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ABSTRACT

Embedded processors often need to be programmed in situations where JTAG cannot be used to program the target device. In these cases, the engineer needs to rely on serial programming designs. C2000™ devices aid in this endeavor through the inclusion of several program loading utilities in ROM. These utilities are useful, but only solve half of the programming problem because the utilities only allow loading application code into RAM. This application note builds on these ROM loaders by using a flash kernel. A flash kernel is loaded to RAM using a ROM loader - the flash kernel is then executed and used to program the on-chip flash memory of the target device with the end application. This document details one possible implementation for C2000 devices and provides PC utilities to evaluate the design.

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1 Introduction

As applications grow in complexity, the need to fix bugs, add features, and otherwise modify embedded firmware is increasingly critical in end applications. Enabling functionality like this can be easily and inexpensively accomplished through the use of bootloaders.

A bootloader, also referred to as a ROM loader or simply loader, is a small piece of code that resides in the boot-ROM memory of the target device that allows the loading and execution of code from an external host. In most cases, a communication peripheral such as Universal Asynchronous Receiver/Transmitter (UART) or Controller Area Network (CAN) is used to load code into the device rather than JTAG, which requires an expensive specialized tool.

Boot Pins are used to configure different boot modes using various peripherals that determine which ROM loader is invoked. In this report, the peripheral used is Serial Communications Interface (SCI, generally referred to as UART). The boot modes that are associated with the boot pins refer to the first instance of the peripheral - for SCI, the boot mode is associated with SCIA.

C2000 devices partially solve the problem of firmware updates by including some basic loading utilities in ROM. Depending on the device and the communications peripherals present, code can be loaded into on-chip RAM using UART, Serial Peripheral Interface (SPI), Inter-Integrated Circuit (I2C), Ethernet, CAN, and a parallel mode using General Purpose Input/Outputs (GPIOs). A subset of these loaders is present in every C2000 device and the loaders are very easy to use, but they can only load code into RAM. How does one bridge the gap and program the application code into non-volatile memory?

This application report aims to solve this problem by using a flash kernel. Flash kernels have been around for some time, but this document discusses the specifics of the kernels and the host application tool found in C2000Ware. While this implementation is targeted at C2000 devices using the SCI peripheral, the same principles apply to all devices in the C2000 product line and all communications options supported by the ROM loaders. A command line tool is provided to parse and transmit the application image from the host PC (Windows only) to the embedded device.

In summary, application programming to non-volatile memory like flash requires two steps:

1. Use the SCI ROM bootloader to download a flash kernel to RAM.
2. Run the flash kernel in RAM to download the application to flash.

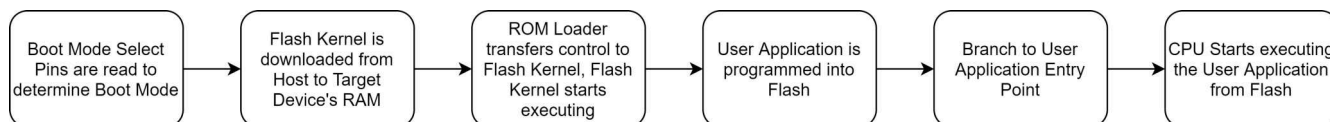


Figure 1-1. Flash Kernel Flow

2 Programming Fundamentals

Before programming a device, users must understand how the non-volatile memory of C2000 devices works. Flash is a non-volatile memory that allows users to easily erase and re-program the flash. Erase operations set all the bits in a sector to '1' while programming operations selectively clear bits to 0. Flash on certain devices can only be erased one sector at a time, but others have bank erase options. The term serial flash used in this report - serial flash kernels, serial flash programmer, and so forth only refers to the serial communication interface (SCI).

Flash operations on all C2000 devices are performed using the CPU. Algorithms are loaded into RAM and executed by the CPU to perform any flash operation. For example, erasing or programming the flash of a C2000 device with Code Composer Studio™ entails loading flash algorithms into RAM and letting the processor execute them. There are no special JTAG commands that are used. All flash operations are performed using the flash application programming interface (API). Because all flash operations are done using the CPU, there are many possibilities for device programming. Irrespective of how the kernels and application are brought into the device, flash is programmed using the CPU.

3 ROM Bootloader

At the beginning, the device boots and, based on the boot mode, decides if the device must execute code already programmed into the Flash memory or load in code using one of the ROM loaders. This application report focuses on the boot execution path when the emulator is not connected.

Note

This section is based on the TMS320F28004x device. Specific information for a particular device can be found in the *Boot ROM* section of the device-specific technical reference manual (TRM).

Table 3-1. Default Boot Modes for F28004x devices

Boot Mode	GPIO24 (default boot mode select pin 1)	GPIO32 (default boot mode select pin 0)
Parallel I/O	0	0
SCI/Wait boot	0	1
CAN	1	0
Flash	1	1

After the boot ROM readies the device for use, the boot ROM decides where the boot ROM can start executing. In the case of a standalone boot, the ROM does this by examining the state of two GPIOs (as seen in [Table 3-1](#), the default choices are GPIO 24 and 32). In some cases, two values programmed into one time programmable (OTP) memory can be examined. In the implementation described in this application report, the SCI loader is used, so at power up GPIO 32 must be forced high and GPIO 24 must be forced low. If this is the case when the device boots, the SCI loader in ROM begins executing and waits to autobaud lock with the host (for a character to be received to determine the baud rate at which the communications occur). At this point, the device is ready to receive code from the host.

The ROM loader requires data to be presented to it in a specific structure. The structure is common to all ROM loaders and is described in detail in the *Bootloader Data Stream Structure* section of [\[1\]](#). You can easily generate your application in this format by using the hex2000 utility included with the TI C2000 compiler. This file format can even be generated as part of the Code Composer Studio build process by adding a post-build step with the following options:

```
"${CG_TOOL_HEX}" "${BuildArtifactFileName}" -boot -sci8 -a -o "${BuildArtifactFileBaseName}.txt"
```

For the CM core in F2838x, the following command can be used:

```
"${CG_TOOL_HEX}" "${BuildArtifactFileName}" -boot -gpio8 -a -o "${BuildArtifactFileBaseName}.txt"
```

Alternatively, you can use the TI hex2000 utility to convert COFF and EABI .out files into the correct boot hex format. To do this, you need to enable the C2000 Hex Utility under Project Properties. The command is below:

```
hex2000.exe -boot -sci8 -a -o <file.txt> <file.out>
```

For the CM core in F2838x, the following command can be used:

```
armhex.exe -boot -gpio8 -a -o <file.txt> <file.out>
```

As stated before, ROM loaders can only load code into RAM, which is why they are used to load in flash kernels, which is described in [Section 4](#) and [Section 5](#).

4 Flash Kernel A

Flash Kernel A runs on:

- TMS320F2802x
- TMS320F2803x
- TMS320F2805x
- TMS320F2806x
- TMS320F2833x

To find the location of the flash kernel projects for these devices, see [Section 7](#).

4.1 Implementation

Flash Kernel A is based off SCI ROM loader sources. To enable this code to erase and program flash, flash APIs must be incorporated, which is done by linking the flash APIs. Before any application data is received, the flash kernel erases the flash of the device readying it for programming. A buffer is used to hold the received contiguous blocks of application code. When the buffer is full or a new block of noncontiguous data is detected, the code in the buffer is programmed. This continues until the entire application is received.

The protocol used to transfer the application data has been slightly modified from the SCI ROM loader protocol. This was done to improve the speed of programming while also ensuring robust communications. With the original SCI ROM loader protocol, most of the time is spent not transferring data, but waiting for the data to propagate through the different layers of the operating system. This problem is compounded by the fact that data must be sent a single byte at a time with the SCI ROM loader (due to the echo based flow control), so every byte incurs the OS transport delay. The flash kernel uses the same protocol but calculates a checksum that is sent after every block of data. This allows the PC side application to send many bytes at a time through the different layers of the operating system, substantially decreasing the latency of communications.

This flash kernel can be used with a CSM locked device. If the device is locked, the serial flash programmer can still be used by loading the flash kernel into unsecure RAM and modifying the kernel to unlock the device before the kernel erases and programs the flash. In that case, *CsmUnlock()* (present in `<device_name>_SysCtrl.c`) should be modified to write the correct CSM passwords to the CSM registers. This unlocks the device. If the user does not want to unlock CSM while programming the device, flash APIs will have to be in flash (not ROM) and be copied to Secure RAM from where they can program/erase secure flash sectors without unlocking the device.

4.1.1 Application Load

This section walks through the entire flow of programming an application into flash using the SCI boot mode. Make sure the device is ready for SCI communications by resetting the device while ensuring the boot mode pins are in the proper state to select SCI Boot mode. These are the steps that follow:

1. The device receives the autobaud character that determines the baud rate at which the load takes place. This happens soon after the host initiates a transfer command.
2. The flash kernel is transferred to the device, waiting for the character to be echoed before sending the next. Make sure the flash kernel is built and linked to RAM alone.
3. The ROM transfers control and the flash kernel begins to execute. There is a small delay in which the kernel must prepare the device for flash programming before the device is ready to begin communications, and in this time the kernel configures the PLL and flash wait states.
4. The kernel enters an autobaud mode and waits for the autobaud character to be received. This potentially allows the kernel to communicate at a higher speed than was used for the ROM loader because the PLL is configured for a higher speed by the kernel. SCI has an autobaud lock that allows the host to send any baud rate the user prefers - a single baud rate does not need to be agreed on for both sides.
5. Once the baud rate is locked, the application can be downloaded using the same format as the flash kernel. At the beginning of the download process, a key, a few reserved fields, and the application entry point are transferred before the actual application code.
6. After the entry point is received, the kernel begins to erase the flash. Erasing flash can take a few seconds, so note that while erasing flash looks like the application load has failed, the flash is just being erased.
7. Once the flash is erased, the application load continues by transferring each block of application code and programming the code to flash.
8. After a block of data is programmed into flash, a checksum is sent back to the host PC to make sure that all of the data was correctly received by the embedded device. This process continues until the entire application has been programmed into flash.

Now that the application is programmed into flash, the flash kernel attempts to run the application by branching to the entry point that was transferred to the application at the start of the application load process. A device reset is needed for this.

5 Flash Kernel B

Flash Kernel B runs on:

- TMS320F2807x
- TMS320F2837xD
- TMS320F2837xS
- TMS320F28004x
- TMS320F2838x
- TMS320F28002x
- TMS320F28003x
- TMS320F280013x
- TMS320F280015x
- TMS320F28P65x
- TMS320F28P55x
- TMS320F28E12x

To find the location of the flash kernel projects for these devices, see [Section 7](#).

5.1 Implementation

Flash Kernel B is more robust than Kernel A. Flash Kernel B communicates with the host PC application provided in C2000Ware (*C2000Ware_x_xx_xx_xx > utilities > flash_programmers > serial_flash_programmer*) and provides feedback to the host on the receiving of packets and completion of commands given to it.

After loading the kernel into RAM and executing the program through the SCI ROM bootloader, the kernel first initializes the PLLs of the device, initializes SCIA, and takes control of the flash pump, if necessary. The program then waits for an 'a' or 'A' from the host to perform an auto baud lock with the host. After this, the kernel begins a while loop, which waits on commands from the host, executes the commands, and sends a status packet back to the host. This while loop breaks when a Run or Reset command is sent.

Commands are sent in a packet described in [Table 5-1](#) and each packet is either acknowledged or not-acknowledged. All commands, except for Run and Reset, send a packet after completion with the status of the operation. The status packet sends a 16-bit status code and 32-bit address. In case of an error, the address in the data specifies the address of the first error. In case of NO_COMMAND_ERROR, the address is 0x12345678.

In the case of a Device Firmware Upgrade (DFU) command, the following steps take place:

Note

These steps do not apply to F28P55x. For details on the F28P55x device, see [F28P55x SCI Flash Kernel](#).

1. The kernel receives a file in the hex boot format byte-by-byte from the SCI module and calculates a checksum over the block size. After receiving the block of data, the kernel sends back the checksum.
2. After receiving a block of data and storing it in a buffer, the kernel erases the sector if it has not been previously erased, and programs the data into flash at the correct address along with ECC using the flash API library.

Note

To get more information on the blocks of data and how block size is determined, see the *Bootloader Data Stream Structure* section of the device-specific TRM. Note that the block and block size mentioned here are not to be confused with the command packet mentioned earlier.

3. Afterwards, the kernel verifies that the data and ECC were programmed correctly into flash.

Note

This kernel only erases sectors that are needed to program the application and data into flash. This is different from Flash Kernel A that erases the entire flash at the start of kernel execution. However, Flash Kernel B also supports an erase command independent of the DFU command, which gives the user the ability to erase specific sectors or the entire flash of the device.

Similarly, the verify command receives a file in the hex boot format and in place of erasing and programming the flash, the kernel only verifies the contents of the flash.

5.1.1 Packet Format

Packets are sent in a standard format between the host and device. The packet allows for a variable amount of data to be sent while making sure there is correct transmission and reception of the packet. The header, footer and checksum fields help to make sure that the data was not corrupted during transmission. The checksum is the summation of the bytes in the command and data fields.

Table 5-1. Packet Format

Header	Data Length	Command	Data	Checksum	Footer
2 Bytes	2 Bytes	2 Bytes	Length Bytes	2 Bytes	2 Bytes
0x1BE4	Length of Data in Bytes	Command	Data	Checksum of Command and Data	0xE41B

The host and the device both send packets one word at a time (16-bits), the LSB followed by the MSB. Both the host and device respond to a packet with an ACK or NAK.

Table 5-2. ACK/NAK Values

ACK	NAK
0x2D	0xA5

5.1.2 CPU1 Kernel Commands

CPU1 commands for the dual core F2837xD are acceptable for the F2807x, F28004x, and F2837xS single core device kernels excluding the *Run CPU1 Boot CPU2* and *Reset CPU1 Boot CPU2*. A brief description of the command codes are provided in [Table 5-3](#).

Table 5-3. CPU1 Kernel Commands

Kernel Commands	Command Code	Description
DFU CPU1	0x0100	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Receive the flash application byte-by-byte in boot hex format 3. Selective Erase, Program, and Verify 4. Send status packet <p>If successful, the address sent in the status packet is the entry point address of the programmed flash application</p>
Erase CPU1	0x0300	<ol style="list-style-type: none"> 1. Receive the packet with 32-bit data (described in Section 5.1.4) 2. Erase the sectors specified in the data 3. Send status packet
Verify CPU1	0x0500	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Receive the flash application byte-by-byte in boot hex format 3. Verify flash contents 4. Send status packet
Unlock CPU1 – Zone 1	0x000A	<ol style="list-style-type: none"> 1. Receive the packet with 128-bit data (described in Section 5.1.4) 2. Write the password to the DCSM Key Registers 3. Check to see if Zone 1 is unlocked 4. Send status packet
Unlock CPU1 – Zone 2	0x000B	<ol style="list-style-type: none"> 1. Receive the packet with 128-bit data (described in Section 5.1.4) 2. Write the password to the DCSM Key Registers 3. Check to see if Zone 2 is unlocked 4. Send status packet
Run CPU1	0x000E	<ol style="list-style-type: none"> 1. Receive the packet with a 32-bit address (described in Section 5.1.4) 2. Branch to the 32-bit address
Reset CPU1	0x000F	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Break the while loop and enable WatchDog Timer to time-out and reset
Run CPU1 Boot CPU2 ⁽¹⁾	0x0004	<ol style="list-style-type: none"> 1. Receive the packet with 32-bit address 2. Release the flash pump, boot CPU2 by IPC to SCI boot mode, give CPU2 control of SCI and shared RAM, and then wait for CPU2 to signal. 3. Branch to the address
Reset CPU1 Boot CPU2 ⁽¹⁾	0x0007	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Release the flash pump, boot CPU2 by IPC to SCI boot mode, give CPU2 control of SCI and shared RAM, and then wait for CPU2 to signal. 3. Break the while loop and enable WatchDog Timer to time-out and reset.

(1) This command is not available to F2807x, F2837xS, and F28004x single core device kernels.

5.1.3 CPU2 Kernel Commands

Table 5-4 shows the functions, command codes, and descriptions for the CPU2 commands used on dual core F2837xD device kernel.

Table 5-4. CPU2 Kernel Commands

Kernel Commands	Command Code	Description
DFU CPU2	0x0200	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Receive the flash application byte-by-byte in boot hex format 3. Selective Erase, Program, and Verify 4. Send status packet <p>If successful, the address sent in the status packet is the entry point address of the programmed flash application</p>
Erase CPU2	0x0400	<ol style="list-style-type: none"> 1. Receive the packet with 32-bit data (described in Section 5.1.4) 2. Selective erase the sectors specified in the data 3. Send status packet
Verify CPU2	0x0600	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Receive the flash application byte-by-byte in boot hex format 3. Verify flash contents 4. Send status packet
Unlock CPU2 – Zone 1	0x000C	<ol style="list-style-type: none"> 1. Receive the packet with 128-bit data (described in Section 5.1.4) 2. Write the password to the DCSM Key Registers 3. Check to see if Zone 1 is unlocked 4. Send status packet
Unlock CPU2 – Zone 2	0x000D	<ol style="list-style-type: none"> 1. Receive the packet with 128-bit data (described in Section 5.1.4) 2. Write the password to the DCSM Key Registers 3. Check to see if Zone 2 is unlocked 4. Send status packet
Run CPU2	0x0010	<ol style="list-style-type: none"> 1. Receive the packet with a 32-bit address (described in Section 5.1.4) 2. Branch to the 32-bit address
Reset CPU2	0x000F	<ol style="list-style-type: none"> 1. Receive the packet with no data 2. Break the while loop and enable WatchDog Timer to time-out and reset

5.1.4 Packet Data

This section describes the data expected for the commands that require data to be sent to the device.

- **Erase**

Each bit of the 32-bit data sent with the erase command corresponds to a sector.

- Data Bit 0 – Sector A
- Data Bit 1 – Sector B
- And, so forth

Table 5-5. Erase Packet

Header	Data Length	Command	Data	Checksum	Footer
0x1BE4	6 (bytes)	0x0300 CPU1 0x0400 CPU2	32-bit Data (1 means erase, 0 means do not erase)	Checksum of Command and Data	0xE41B

- **Unlock**

- 1st 32 bits is Key 1
- 2nd 32 bits is Key 2
- 3rd 32 bits is Key 3
- 4th 32 bits is Key 4

Table 5-6. Unlock Packet

Header	Data Length	Command	Data	Checksum	Footer
0x1BE4	4 (bytes)	0x000A CPU1 Z1 0x000B CPU1 Z2 0x000C CPU2 Z1 0x000D CPU2 Z2	128-bit Data	Checksum of Command and Data	0xE41B

- **Run**

- 32-bit address

Table 5-7. Run Packet

Header	Data Length	Command	Data	Checksum	Footer
0x1BE4	4 (bytes)	0x000E CPU1 0x0020 CPU2	32-bit Data	Checksum of Command and Data	0xE41B

5.1.5 Status Codes

After a command is completed, the kernel sends a status packet to the host with the same format as the host-to-device packet. This lets the host know if an error occurred, what type of error, and where the error occurred. The command field is the command last completed. The data field consists of a 16-bit status code followed by a 32-bit address where the error occurs. If there is no error the address is 0x12345678 unless the address is responding to a DFU command in which case the address is the entry point address of the hex boot format file of the application just programmed into flash. This address can then be used for the RUN command, which tells the CPU which address to branch to and begin executing code.

Table 5-8 displays the status codes.

Table 5-8. Status Codes

Status Code	Value	Description
NO_COMMAND_ERROR	0x1000	Return on Success
BLANK_ERROR	0x2000	Return on Erase Error
VERIFY_ERROR	0x3000	Return on Verify Error
PROGRAM_ERROR	0x4000	Return on Programming Error
COMMAND_ERROR	0x5000	Return on Invalid Command Error

Table 5-8. Status Codes (continued)

Status Code	Value	Description
UNLOCK_ERROR	0x6000	Return on Unsuccessful Unlock

For Program, Erase and Verify commands, if a Flash API error is detected, the error is displayed on the console. If an FMSTAT error is detected, the FMSTAT register contents is displayed.

Status Code	Value
INCORRECT_DATA_BUFFER_LENGTH	0x7000
INCORRECT_ECC_BUFFER_LENGTH	0x8000
DATA_ECC_BUFFER_LENGTH_MISMATCH	0x9000
FLASH_REGS_NOT_WRITABLE	0xA000
FEATURE_NOT_AVAILABLE	0xB000
INVALID_ADDRESS	0xC000
INVALID_CPUID	0xD000
FAILURE	0xE000

For more details on the errors, see the device-specific Flash API guide.

The following section gives an overview of the F2838x SCI Flash kernels and how to use them.

5.2.1 CPU1-CPU2 Kernels

The F2838x CPU1-CPU2 kernel projects utilize the SCI ROM Bootloader in CPU1 to download the CPU1 application image and a modified bootloader to download the CPU2 application image. The CPU1 and CPU2 kernel and application files are entered as parameters to the serial_flash_programmer utility, and the CPU1 kernel is downloaded once the host has completed the autobaud lock with the CPU1 SCI ROM Bootloader. Once the CPU1 kernel has been downloaded, normal kernel operations can start such as DFU, Erase, etc.

Once the CPU1 operations are completed, the CPU2 kernel can be downloaded by selecting either the "Run CPU1 Load CPU2" or "Reset CPU1 Load CPU2" commands. For F2838x, there is not a SCI ROM Bootloader for CPU2, so CPU1 writes the CPU2 kernel into shared RAM for CPU2. There is also an instruction to branch to the CPU2 entry point placed in CPU1TOCPU2MSGRAM that is copied into M1RAM during the CPU2 boot sequence. After the branch instruction is written to M1RAM and the CPU2 boot sequence is complete, CPU2 starts execution from M1RAM and branches to the kernel entry point. Once the CPU2 kernel has been downloaded, normal kernel operations can start. The CPU1 kernel waits for CPU2 to finish its kernel commands before proceeding to either the application address or a reset based on if "Run CPU1 Load CPU2" or "Reset CPU1 Load CPU2" was selected.

CPU1 has 9 Options

1. DFU
2. Erase
3. Verify
4. Unlock Zone 1
5. Unlock Zone 2
6. Run
7. Reset
8. Run CPU1 Load CPU2
9. Reset CPU1 Load CPU2

CPU2 has 7 Options

1. DFU
2. Erase
3. Verify
4. Unlock Zone 1
5. Unlock Zone 2
6. Run
7. Reset

5.2.1.1 Kernel Commands

Most of the commands are the same as previous devices, there are two new commands for CPU1 : Run CPU1 Load CPU2 and Reset CPU1 Load CPU2.

Table 5-9 describes how each command works.

Table 5-9. Kernel Commands

Kernel Command	Command Code	Description
Run CPU1 Load CPU2	0x0004	<ol style="list-style-type: none"> 1. Receive the packet with 32 bit address. 2. Load the CPU2 kernel into GSRAM sections as specified by the CPU2 kernel linker command file. 3. Transfer control of SCI and shared RAM to CPU2. 4. Release Flash pump and set boot mode via IPC for CPU2. 5. Wait for CPU2 signal. 6. Branch to address.
Reset CPU1 Load CPU2	0x0007	<ol style="list-style-type: none"> 1. Receive the packet with no address. 2. Load the CPU2 kernel into GSRAM sections as specified by the CPU2 kernel linker command file. 3. Transfer control of SCI and shared RAM to CPU2. 4. Release Flash pump and set boot mode via IPC for CPU2. 5. Wait for CPU2 signal. 6. Break the while loop and enable WatchDog Timer to time-out and reset.

5.2.2 CPU1-CM Kernels

The F2838x CPU1-CM kernel projects utilize the SCI Bootloader to download the CPU1 application image and a modified bootloader to download the CM application image. The CPU1 and CM kernel and application files are entered as parameters to the serial_flash_programmer utility, and the CPU1 kernel is downloaded once the host has completed the autobaud lock with the CPU1 SCI ROM Bootloader. Once the CPU1 kernel has been downloaded, normal kernel operations can start such as DFU, Erase, etc.

Once the CPU1 operations are completed, the CM kernel can be downloaded by selecting either "Run CPU1 Load CM" or "Reset CPU1 Load CM". CPU1 first writes the CM boot mode needed to download the kernel. After setting the boot mode for CM, CPU1 jumps to a copy function where the CPU1 takes in the CM kernel being sent through SCI from the host and copies the CM kernel over to a buffer in CPU1 to CM IPC Message RAM. Once the CM kernel has filled up the buffer, it signals CM which then copies over the contents of the buffer into the intended address in CM RAM. A copy function for the CM side that communicates with the CPU1 copy function is written into S0RAM during the CM boot sequence. This function was compiled using an ARM compiler and is stored as a const array in CPU1 to CM message RAM. The CPU1 and CM copy functions work together to copy over the CM kernel until all of it has been written. CPU1 then sends the CM kernel entry address to CM which then jumps to this address to start kernel execution. The user can then perform any desired CM commands.

CPU1 keeps control of the SCI peripheral and sends over the data CM needs for its kernel functions when requested by CM. The CM kernel can signal the CPU1 kernel that it needs a certain function executed, for example sciaGetWordData. CPU1 will get the result of executing the function and place it into Message RAM for CM to copy over and use for any of its commands.

CPU1 has 9 Options

1. DFU
2. Erase
3. Verify
4. Unlock Zone 1
5. Unlock Zone 2
6. Run

CM has 7 Options

1. DFU
2. Erase
3. Verify
4. Unlock Zone 1
5. Unlock Zone 2
6. Run

- 7. Reset
- 8. Run CPU1 Load CM
- 9. Reset CPU1 Load CM

7. Reset

5.2.2.1 Kernel Commands

CPU1 has two new commands for the F2838x SCI Flash Kernels. The F2838x SCI Flash Kernels are listed in [Table 5-10](#).

Table 5-10. CPU1 Kernel Commands

Kernel Command	Command Code	Description
Run CPU1 Load CM	0x0030	<ol style="list-style-type: none"> 1. Receive the packet with 32 bit address. 2. Release Flash Pump and set boot mode via IPC for CM. 3. Write CM kernel to CM RAM via CPU1 to CM IPC Message RAM. 4. Wait for CM signal and perform SCI function for CM when requested. 5. Branch to address.
Reset CPU1 Load CM	0x0040	<ol style="list-style-type: none"> 1. Receive the packet with 32 bit address. 2. Release Flash Pump and set boot mode via IPC for CM. 3. Write CM kernel to CM RAM via CPU1 to CM IPC Message RAM. 4. Wait for CM signal and perform SCI function for CM when requested. 5. Break the while loop and enable WatchDog Timer to time-out and reset.

The CM commands are as listed in [Table 5-11](#).

Table 5-11. CM Kernel Commands

Kernel Command	Command Code	Description
DFU CM	0x0050	<ol style="list-style-type: none"> 1. Receive the packet with no data. 2. Receive the flash application byte-by-byte in boot hex format. 3. Selective Erase, Program, and Verify. 4. Send status packet. <p>If successful, the address sent in the status packet is the entry point address of the programmed flash application.</p>
Erase CM	0x0060	<ol style="list-style-type: none"> 1. Receive the packet with 32-bit data. 2. Selective erase the sectors specified in the data. 3. Send status packet.
Verify CM	0x0070	<ol style="list-style-type: none"> 1. Receive the packet with no data. 2. Receive the flash application byte-by-byte in boot hex format. 3. Receive the flash application byte-by-byte in boot hex format. 4. Send status packet.

Table 5-11. CM Kernel Commands (continued)

Kernel Command	Command Code	Description
CM Unlock Zone 1	0x0080	<ol style="list-style-type: none"> 1. Receive the packet with 128-bit data. 2. Write the password to the DCSM Key Registers. 3. Check to see if Zone 1 is unlocked. 4. Send status packet.
CM Unlock Zone 2	0x0090	<ol style="list-style-type: none"> 1. Receive the packet with 128-bit data. 2. Write the password to the DCSM Key Registers. 3. Check to see if Zone 2 is unlocked. 4. Send status packet.
Run CM	0x00A0	<ol style="list-style-type: none"> 1. Receive the packet with a 32-bit address. 2. Branch to the 32-bit address.
Reset CM	0x00B0	<ol style="list-style-type: none"> 1. Receive the packet with no data. 2. Break the while loop and enable WatchDog Timer to time-out and reset.

5.2.3 Using the Projects With SCI Bootloader

This section details the steps needed to run the F2838x kernels on the controlCard.

5.2.3.1 CPU1-CPU2

1. Set controlCard S1:A position 1 to OFF (left). This turns off JTAG communication.
2. Set controlCard S1:A position 2 to ON (right). This turns on UART communication.
3. Set S2 position 1 to OFF (left) and position 2 to ON (right). This sets the controlCard to SCI Boot mode.
4. Open up a command window and navigate to where serial_flash_programmer.exe is.
5. Enter a command with parameters as described below:

```
Example: serial_flash_programmer.exe -d f2838x -k flash_kernel_c28x_dual_ex1_c28x1.txt
-a led_ex1_c28x_dual_blinky_cpu1.txt -m flash_kernel_c28x_dual_ex1_c28x2.txt -n
led_ex1_c28x_dual_blinky_cpu2.txt -b 9600 -p COM10 -v
```

6. When the kernel is downloaded and the menu pops up, perform all CPU1 operations before proceeding with CPU2. Restarting the serial_flash_programmer application gives control back to CPU1, so CPU1 and CPU2 actions can be performed within one run of the serial_flash_programmer application.

5.2.3.2 CPU1-CM

1. Set controlCard S1:A position 1 to OFF (left). This turns off JTAG communication.
2. Set controlCard S1:A position 2 to ON (right). This turns on UART communication.
3. Set S2 position 1 to OFF (left) and position 2 to ON (right). This sets the controlCard to SCI Boot mode.
4. Open up a command window and navigate to where serial_flash_programmer.exe is.
5. Enter a command with parameters as described below:

```
Example: serial_flash_programmer.exe -d f2838x -k flash_kernel_c28x_cm_ex1_c28x1.txt -a
led_ex1_c28x_cm_blinky_cpu1.txt -o flash_kernel_c28x_cm_ex1_cm.txt -r led_ex1_c28x_cm_blinky_cm.txt
-b 9600 -p COM10 -v
```

6. When the kernel is downloaded and the menu pops up, perform all CPU1 operations before proceeding with CM. Exit the application once CM actions are performed. Restarting the serial_flash_programmer application gives control back to CPU1, so CPU1 and CM actions can be performed within one run of the serial_flash_programmer application.

5.2.4 Using the Projects With Code Composer Studio (CCS) Software

5.2.4.1 CPU1-CPU2

1. Set controlCard S1:A position 1 to ON (right). This turns on JTAG communication.
2. Set controlCard S1:A position 2 to ON (right). This turns on UART communication.
3. In Code Composer Studio™ IDE, import and build the CPU1 and CPU2 kernel projects.
4. Launch the target configuration file.

5. Connect to CPU1.
6. Load the gel file provided in the project folder to the project. Right click on CPU1 in the target configuration and select "Open GEL Files View".
7. In the "GEL Files" tab, click on GEL Files. Right click in the "Script" window and select "Load GEL...". Navigate to the project folder and load the gel file.
8. Connect to CPU2.
9. Click "Reset" for CPU1. CPU2 is now in wait boot.
10. Click "Resume" for CPU2.
11. For CPU1, click "Load Program".
12. Load the .out file for the CPU1 kernel. Click "Resume" after the file has loaded.
13. Open up a command window and navigate to where serial_flash_programmer_appln.exe is.
14. Enter a command with parameters as described below:

```
Example: serial_flash_programmer_appln.exe -d f2838x -d f2838x -k flash_kernel_c28x_dual_ex1_c28x1.txt  
-a led_ex1_c28x_dual_blinky_cpu1.txt -m flash_kernel_c28x_dual_ex1_c28x2.txt -n  
led_ex1_c28x_dual_blinky_cpu2.txt -b 9600 -p COM10 -v
```

15. When the menu pops up, perform all CPU1 operations before proceeding with CPU2.

5.2.4.2 CPU1-CM

1. Set controlCard S1:A position 1 to ON (right). This turns on JTAG communication.
2. Set controlCard S1:A position 2 to ON (right). This turns on UART communication.
3. In CCS, import and build the CPU1 and CM kernel projects.
4. Launch the target configuration file.
5. Connect to CPU1.
6. Load the gel file provided in the project folder to the project. Right click on CPU1 in the target configuration and select "Open GEL Files View".
7. In the "GEL Files" tab, click on GEL Files. Right click in the "Script" window and select "Load GEL...". Navigate to the project folder and load the gel file.
8. Connect to CM.
9. Click "Reset" for CPU1. CM is now in wait boot.
10. Click "Resume" for CM.
11. For CPU1, click "Load Program".
12. Load the .out file for the CPU1 kernel. Click "Resume" after the file has loaded.
13. Open up a command window and navigate to where serial_flash_programmer_appln.exe is.
14. Enter a command with parameters as described below.

```
Ex: serial_flash_programmer_appln.exe -d f2838x -k flash_kernel_c28x_cm_ex1_c28x1.txt -a  
led_ex1_c28x_cm_blinky_cpu1.txt -o flash_kernel_c28x_cm_ex1_cm.txt -r led_ex1_c28x_cm_blinky_cm.txt  
-b 9600 -p COM10 -v
```

15. When the menu pops up, perform all CPU1 operations before proceeding with CM. Exit the application once CM actions are performed. Restarting the serial_flash_programmer application gives control back to CPU1, so CPU1 and CM actions must be performed within one run of the serial_flash_programmer application.

The following section gives an overview of the F28P65x SCI Flash kernel and how to use the SCI flash kernel.

5.3.1 CPU1 Kernel

The F28P65x CPU1 kernel project utilizes the SCI ROM Bootloader in CPU1 to download the CPU1 application image and CPU2 application image. The CPU1 kernel and application files are entered as parameters to the serial_flash_programmer utility, and the CPU1 kernel is downloaded once the host has completed the autobaud lock with the CPU1 SCI ROM Bootloader. Once the CPU1 kernel has been downloaded, normal kernel operations can start such as DFU, Erase, and so forth.

Once the CPU1 operations are completed, the CPU2 application can be downloaded by selecting the "DFU CPU2" command. The CPU1 kernel waits for CPU2 application to finish the download before proceeding to either the CPU1 application image address with "Run CPU1" or a reset based on if *Reset CPU1* was selected. For F28P65x, there is not a SCI ROM Bootloader for CPU2, hence, the CPU2 application image must be downloaded through CPU1 kernel. CPU1 application image must set the GSxRAM, Flash Banks and device boot mode for CPU2. Once the CPU2 image has been downloaded, normal kernel operations can continue.

5.3.1.1 Host-Kernel Communication: ControlCard

The host-kernel communication for the F28P65x device requires a change to the boot define settings for SCI. The device assigns by default GPIO12/13 pins for SCI communication. The default boot values used for SCITX/ SCIRX are not the same as what is used by the FTDI chip on the board, so the user must change the boot definition values to match what is seen by the USB-to-UART SCI lines. The USB-to-UART SCI lines share communication with SCI through GPIO 28/29 for the ControlCard. Therefore, setting the emulation boot mode is necessary to use GPIO28/29 for SCI communication.

5.3.1.2 Host-Kernel Communication: LaunchPad™ Development Kit

The host-kernel communication for the F28P65x device requires a change to the boot define settings for SCI. The device assigns by default GPIO12/13 pins for SCI communication. The default boot values used for SCITX/ SCIRX are not the same as what is used by the FTDI chip on the board, so the user must change the boot definition values to match what is seen by the USB-to-UART SCI lines. The USB-to-UART SCI lines share communication with SCI through GPIO 42/43 for the LaunchPad. Therefore, setting the emulation boot mode is necessary to use GPIO42/43 for SCI communication.

5.3.1.3 Kernel Commands

Most of the commands are the same as previous devices. There are some new feature changes in the commands for CPU1: Erase CPU1, Erase CPU2.

[Table 5-12](#) describes how each command works.

Table 5-12. Kernel Commands

Kernel Command	Command Code	Description
Erase CPU1	0x0300	<ol style="list-style-type: none"> 1. Receive the packet with 32-bit data 2. Erase the bank specified in the data 3. Send status packet
Erase CPU2	0x0400	<ol style="list-style-type: none"> 1. Receive the packet with 32-bit data 2. Erase the bank specified in the data 3. Send status packet

5.3.2 Using the Projects With SCI Bootloader

This section details the steps needed to run the F28P65x kernel on the controlCard.

5.3.2.1 CPU1

1. Set controlCard S1 position 1 to OFF (left). This turns off JTAG communication.
2. Set controlCard S1 position 2 to ON (right). This turns on UART communication.
3. Set S3 position 1 to OFF (left) and position 2 to ON (right). This sets the controlCard to SCI Boot mode.
4. Open up a command window and navigate to where serial_flash_programmer.exe is.
5. Enter a command with parameters as described below:
 - Example: serial_flash_programmer.exe -d f28p65x -k flash_kernel_c28x_dual_ex1_c28x1.txt -a led_ex1_c28x_dual_blinky_cpu1.txt -n led_ex1_c28x_dual_blinky_cpu2.txt -b 9600 -p COM34 -v.

6. When the kernel is downloaded and the menu pops up, perform all CPU1 operations before proceeding with CPU2. Restarting the `serial_flash_programmer` application gives control back to CPU1, so CPU1 and CPU2 actions can be performed within one run of the `serial_flash_programmer` application.

5.3.3 Using the Projects With CCS

5.3.3.1 CPU1

1. Set controlCard S1 position 1 to ON (right). This turns on JTAG communication.
2. Set controlCard S1 position 2 to ON (right). This turns on UART communication.
3. In CCS, import and build the CPU1 and CPU2 kernel projects.
4. Launch the target configuration file.
5. Connect to CPU1.
6. Load the gel file provided in the project folder to the project. Right click on CPU1 in the target configuration and select "Open GEL Files View".
7. In the "GEL Files" tab, click on GEL Files. Right click in the "Script" window and select "Load GEL...". Navigate to the project folder and load the gel file.
8. Connect to CPU2.
9. Click "Reset" for CPU1. CPU2 is now in wait boot.
10. Click "Resume" for CPU2.
11. For CPU1, click "Load Program".
12. Load the .out file for the CPU1 kernel. Click "Resume" after the file has loaded.
13. Open up a command window and navigate to where serial_flash_programmer_appln.exe is.
14. Enter a command with parameters as described below:

Example: `serial_flash_programmer_appln.exe -d f28p65x -k flash_kernel_c28x_dual_ex1_c28x1.txt -a led_ex1_c28x_dual_blinky_cpu1.txt -n led_ex1_c28x_dual_blinky_cpu2.txt -b 9600 -p COM34 -v`

15. When the menu pops up, perform all CPU1 operations before proceeding with CPU2.

5.4 F28P55x SCI Flash Kernel

This section gives an overview and instructions for using the F28P55x SCI Flash kernel.

5.4.1 Implementation

The F28P55x implementation of SCI Flash Kernel B is similar to what is described in [the previous Implementation section](#), but differs in how flash is erased during the DFU command.

In the case of a Device Firmware Upgrade (DFU) command on the F28P55x, the following steps take place:

1. The host programmer checks to see if a text file specifying the flash banks and sectors to erase was included (see [Specifying the Flash Banks and Sectors of the Application](#))
2. If so, the specified flash banks and sectors are erased. If not, all flash banks and sectors are erased to prepare for programming
3. The kernel receives a file in the hex boot format byte-by-byte from the SCI module and calculates a checksum over the block size. After receiving the block of data, the kernel sends back the checksum.
4. After receiving a block of data and storing the data in a buffer, the kernel programs the data into flash at the correct address along with ECC using the flash API library. Keep in mind that this kernel uses the 512-bit programming feature of the flash API, so the application must be aligned to 512-bit boundaries. See [the Troubleshooting section](#) for more details.

Note

To get more information on the blocks of data and how block size is determined, see the *Bootloader Data Stream Structure* section of the device-specific TRM. Note that the block and block size mentioned here are not to be confused with the command packet mentioned earlier.

5. Afterwards, the kernel verifies that the data and ECC were programmed correctly into flash.

Similarly, the verify command receives a file in the hex boot format and in place of erasing and programming the flash, the kernel only verifies the contents of the flash.

5.4.1.1 Specifying the Flash Banks and Sectors of the Application

To specify which flash banks and sectors are erased during the DFU command, the [-t] option must be used when executing the host programmer. Follow the [-t] option with a text file in the format shown below:

```
00 FFFFFFFF FFFFFFFF 01 FFFFFFFF FFFFFFFF 02 FFFFFFFF FFFFFFFF 03 FFFFFFFF FFFFFFFF 04 FFFFFFFF
00000000 05 00000000
```

The first two characters, 00, indicate that the following 64 bits are applicable to flash bank 0. This is referred to as the flash bank identifier. The first 32 bits following the flash bank identifier, 0xFFFFFFFF, indicate that sectors 0-31 are used by the application and must be erased. The following 32 bits, 0xFFFFFFFF, indicate that sectors 32-127 are used by the application and must be erased. In the second 32-bit value, each bit corresponds to eight flash sectors. For example, the LSB, or bit 0, corresponds to flash sectors 32-39 while bit 1 corresponds to sectors 40-47. In the 64-bits following a flash bank identifier, a one marks the appropriate sectors for erase, a zero does not mark the sectors for erase. For example, if only erasing flash sectors 0-31 in flash bank 0 is desired, the second 32-bit value must be changed to 0x00000000.

This format continues for flash banks 1-4. The second 32 bit values following the flash bank 4 identifier need to always remain 0x00000000. Unlike flash banks 0-3, flash bank 4 has 32 sectors. Additionally, the final identifier and 32-bit value, 05 and 0x00000000, are unused.

5.4.2 Kernel

The F28P55x kernel project utilizes the SCI ROM Bootloader in CPU1 to download the application image. The CPU1 kernel and application file are entered as parameters to the serial_flash_programmer utility, and the CPU1 kernel is downloaded once the host has completed the autobaud lock with the CPU1 SCI ROM bootloader. Once the CPU1 kernel is downloaded, normal kernel operations can start such as DFU, Erase, and so forth. [Section 5.1.2](#) shows the kernel commands for CPU1.

5.4.3 Using the Project With SCI Bootloader

1. Set controlCard S4 position 1 to OFF (left). This turns off JTAG communication.

2. Set controlCard S4 position 2 to ON (right). This turns on UART communication.
3. Set S1 position 1 to OFF (left) and position 2 to ON (right). This sets the controlCard to SCI Boot mode.
4. Open up a command window and navigate to where serial_flash_programmer.exe is.
5. Enter a command with parameters as described below:
 - Example: `serial_flash_programmer.exe -d f28p55x -k flash_kernel_c28x_dual_ex1_c28x1.txt -a led_ex1_c28x_dual_blinky_cpu1.txt -n led_ex1_c28x_dual_blinky_cpu2.txt -b 9600 -p COM34 -v -t app_flash_banks_and_sectors.txt`
6. When the kernel is downloaded and the menu pops up, perform all desired operations.

5.4.4 Using the Project with CCS

1. Set controlCard S4 position 1 to ON (right). This turns on JTAG communication.
2. Set controlCard S4 position 2 to ON (right). This turns on UART communication.
3. In CCS, import and build the CPU1 kernel project.
4. Launch the target configuration file.
5. Connect to CPU1.
6. Click "Load Program".
7. Load the .out file for the CPU1 kernel. Click "Resume" after the file has loaded.
8. Open up a command window and navigate to where serial_flash_programmer_appln.exe is.
9. Enter a command with parameters as described below:

Example: `serial_flash_programmer_appln.exe -d f28p55x -k flash_kernel_ex3_sci_flash_kernel.txt -a led_ex1_blinky.txt -b 9600 -p COM34 -v -t app_flash_banks_and_sectors.txt`
10. When the menu pops up, perform all desired CPU1 operations.

6 Example Implementation

The kernels described above are available in C2000Ware under examples folder for the specific device within the examples directory. For example, the flash kernel for F2837x is found at `C2000Ware_x_x_xx_xx > device_support > f2837xd > examples > dual > F2837xD_sci_flash_kernels > cpu01`. The host application is found in C2000Ware (`C2000Ware_x_x_xx_xx > utilities > flash_programmers > serial_flash_programmer`). The source and executable are found in the `serial_flash_programmer` folder. This section details the `serial_flash_programmer`: how to build, run and use the programmer with Flash Kernel A and B.

Note

The flash kernel of the appropriate device must be supplied to the host application tool being used to program the flash. The `serial_flash_programmer` starts the same way independent of the kernel or device. The `serial_flash_programmer` first loads the kernel to the device through the SCI ROM bootloader. After this, the tool's functionality differs depending on the device and kernel being used.

6.1 Device Setup

6.1.1 Flash Kernels

Flash kernel source and project files for Code Composer Studio (CCS) are provided in C2000Ware, in the corresponding device's examples directory. Load the project into CCS and build the project. These projects have a post-build step in which the compiled and linked .out file is converted into the correct boot hex format needed by the SCI ROM bootloader and is saved as the example name with a .txt extension.

6.1.2 Hardware

After building the kernels in CCS, setting up the device correctly to be able to communicate with the host PC running the `serial_flash_programmer` is important. The first thing to do is make sure the boot mode select pins are configured properly to boot the device to SCI boot mode. Next, connect the appropriate SCI boot loader GPIO pins to the Rx and Tx pins that are connected to the host PC COM port. A transceiver is often needed to convert a Virtual COM port from the PC to GPIO pins that can connect to the device. On some systems, like the controlCARD, an FTDI chip is used to interface the GPIO pins used for SCI communication to a USB Virtual COM port. Refer to the user guide for the controlCARD to get information on the switch configuration needed to enable SCI communication. In this case, the PC must connect to the mini-USB on the controlCARD and use channel B of the FTDI chip to connect to the GPIO pins on the device. After the hardware is setup correctly to communicate with the host, reset the device. This boots the device to SCI boot mode.

6.2 Host Application: serial_flash_programmer

6.2.1 Overview

The command line PC utility is a programming design that can easily be incorporated into scripting environments for applications such as production line programming. The command line PC utility was written using Microsoft Visual Studio® in C++. The project and the source can be found in C2000Ware (C2000Ware_x_xx_xx_xx > utilities > flash_programmers > serial_flash_programmer).

To use this tool to program the C2000 device, make sure that the target board has been reset and is currently in the SCI boot mode and connected to the PC COM port. The command line usage of the tool is described below:

```
serial_flash_programmer.exe -d <device> -k <kernel file> -a <app file> -p COM <num>
[-m] <kernel2 name> [-n] <app2 name> [-o] <kernel3 name> [-r] <app3 name> [-b] <baudrate> [-q] [-w]
[-v] [-t]
```

-d <device>	The name of the device to connect and load to: F2802x, F2803x, F2805x, F2806x, F2807x, F2833x, F2837xD, F2837xS, F28004x, F2838x, F28002x, F28003x, F280013x, F280015x, F28P65x, F28P55x or F28E12x
-k <file>	The file name for the CPU1 flash kernel. This file must be in the ASCII SCI boot format.
-a <file>	The application file name to download or verify to CPU1 This file must be in the ASCII SCI boot format.
-m <file>	The file name for the CPU2 flash kernel. This file must be in the ASCII SCI boot format.
-n <file>	The application file name to download or verify to CPU2. This file must be in the ASCII SCI boot format.
-o <file>	The file name for the CM flash kernel. This file must be in the ASCII GPIO boot format.
-r <file>	The application file name to download or verify to CM. This file must be in the ASCII GPIO boot format.
-p COM<num>	Set the COM port to be used for communications
-b <num>	Set the baud rate for the COM port
-? or -h	Show help
-q	Quiet mode. Disable output to stdout
-w	Wait for a key press before exiting
-v	Enable verbose output
-t	This option is only applicable to the F28P55x device. The file name for the custom flash bank and sector erase configuration. Make this file in the format detailed in Specifying the Flash Banks and Sectors of the Application .

-d, -k, -a, -p are mandatory parameters. If the baud rate is omitted, the baud rate is set to 9600 by default.

Note

Both the flash kernels and flash application MUST be in the SCI8 boot format. For F2838x CM, the flash kernel and flash application file MUST be in the GPIO8 boot format. This was discussed earlier in [Section 3](#) and can be generated from the OUT file using the hex2000 utility.

6.2.2 Building and Running serial_flash_programmer Using Visual Studio

Serial_flash_programmer.cpp can be compiled using Visual Studio.

1. Navigate to the serial_flash_programmer directory.
2. Double click the serial_flash_programmer.sln to open the Visual Studio project.
3. When Visual Studio opens, select Build → BuildSolution.
4. After Visual Studio completes the build, select Debug → serial_flash_programmer properties.
5. Select Configuration Properties → Debugging.
6. Select the input box next to the CommandArguments.
7. Type the arguments in the following format. The arguments are described in [Section 6.2.1](#).

- Format:


```
-d <device> -k <file> -a <file> -p COM<num> -b <baudrate>
```
- Example:


```
-d f2807x -k C:\Documents\flash_kernel.txt -a C:\Documents\Test.txt -p COM7 -b 9600
```

8. Click Apply and OK.
9. Select Debug → Start Debugging to begin running the project.

6.2.3 Running serial_flash_programmer for F2806x (Flash Kernel A)

Note

TI recommends resetting the device before running serial_flash_programmer so that Autobaud completes correctly.

1. Navigate to the folder containing the compiled serial_flash_programmer executable.
2. Run the executable serial_flash_programmer.exe with the following command:

```
:> serial_flash_programmer.exe -d f2806x -k <~\f28069_flash_kernel.txt> -a <file> -p COM<num>
```

This first loads the f28069_flash_kernel into RAM of the device using the bootloader. Then, the kernel executes and loads and program flashes with the file specified by the '-a' command line argument.

6.2.4 Running serial_flash_programmer for F2837xD (Flash Kernel B)

Note

TI recommends resetting the device before running serial_flash_programmer so that auto baud completes correctly.

1. Navigate to the folder containing the compiled serial_flash_programmer executable.
2. Run the executable serial_flash_programmer.exe with the following command:

```
:> serial_flash_programmer.exe -d f2837xD -k <~\F2837xD_sci_flash_kernels_cpu01.txt>
-a <file> -m <~\F2837xD_sci_flash_kernels_cpu02.txt> -n <file> -p COM<num> -v
```

This automatically connects to the device, perform an auto baud lock, and download the CPU1 kernel into RAM and execute the CPU1 kernel. Now, the CPU1 kernel is running and waiting for a packet from the host.

3. The serial_flash_programmer prints the options to the screen to choose from that is sent to the device kernel (see [Figure 6-1](#)). Select the appropriate number and then provide any necessary information when asked for that command (described in [Section 5.1](#)). In the case of DFU or Verify, the original command already specified the Application file, so no additional information is required at this point. [Figure 6-2](#) shows what the window looks like after the execution of command 1- DFU CPU1.


```
C:\Windows\System32\cmd.exe - serial_flash_programmer.exe -d f2837xD -k F2837xD_sci_flash_kernels_cpu01_alt.txt -a blinky_dc_cpu01.txt -b 9600 -p ...  
6f==6f  
2==2  
9a==9a  
6==6  
0==0  
0==0  
0==0  
Bit rate /s of transfer was: 500.011139  
Kernel loaded! Booting kernel...  
Done waiting for kernel boot...  
Attempting autobaud to send function message...  
What operation do you want to perform?  
1-DFU CPU1  
2-DFU CPU2  
3-Erase CPU1  
4-Erase CPU2  
5-Verify CPU1  
6-Verify CPU2  
7-Unlock CPU1 Zone 1  
8-Unlock CPU1 Zone 2  
9-Unlock CPU2 Zone 1  
10-Unlock CPU2 Zone 2  
11-Run CPU1  
12-Reset CPU1  
13-Run CPU1 and Boot CPU2  
14-Reset CPU1 and Boot CPU2  
15-Run CPU2  
16-Reset CPU2  
0-DONE
```

Figure 6-1. Serial Flash Programmer Prompt for Next Command After Downloading Flash Kernel to RAM

```
C:\Windows\System32\cmd.exe - serial_flash_programmer.exe -d f2837xD -k F2837xD_sci_flash_kernels_cpu01_alt.txt -a blinky_dc_cpu01.txt -b 9600 -p ...  
0  
0  
0  
0  
0  
Bit rate /s of transfer was: 6819.310059  
Application load successful!  
Done waiting for application to download and boot...  
SUCCESS of Command  
Entry Point Address is: 0x00002e7d  
What operation do you want to perform?  
1-DFU CPU1  
2-DFU CPU2  
3-Erase CPU1  
4-Erase CPU2  
5-Verify CPU1  
6-Verify CPU2  
7-Unlock CPU1 Zone 1  
8-Unlock CPU1 Zone 2  
9-Unlock CPU2 Zone 1  
10-Unlock CPU2 Zone 2  
11-Run CPU1  
12-Reset CPU1  
13-Run CPU1 and Boot CPU2  
14-Reset CPU1 and Boot CPU2  
15-Run CPU2  
16-Reset CPU2  
0-DONE
```

Figure 6-2. Serial Flash Programmer After Downloading Application to Flash

6.3 Host Application: Firmware Updates on F28004x With SCI Flash Kernel

6.3.1 Overview

As explained, the SCI Flash Kernel enables firmware updates. This section explains one possible method of doing so using SCI boot and flash boot modes. For this scenario, the device boots from flash by default, and use SCI boot for firmware updates.

One thing worth noting is what exactly booting from flash entails. As noted earlier, a bootloader is used by a device to load and run code from an external source. The SCI flash kernel is loaded to RAM and then the application is loaded to flash. In the case of booting from flash, the device is already equipped with the application, either through Uniflash, CCS or a custom bootloader.

In this scenario, once the device boots from flash, through the flash entry point, the application runs. For firmware updates, the device can boot up in SCI boot mode, where the serial flash programmer downloads the SCI flash kernel to RAM which allows the download of the new application to flash - this allows the firmware upgrade to happen without putting the SCI flash kernel in flash, thus saving flash space.

6.3.2 Boot Pin Configurations

To have both of the boot modes for flash Boot and SCI boot, the boot mode needs to be configured. The boot control GPIO Pins determine the boot mode configuration - for F28004x devices, the Boot control Pins are GPIO 24 and GPIO 32. To boot from flash, both GPIO 24 and GPIO 32 have to be pulled up to 1, and for SCI Boot, GPIO 24 needs to be pulled down to 0.

How a user pulls down the GPIO pin depends on the implementation - one possible example is that the device sets the GPIO pin low prior to a firmware upgrade - more details can be found in [10].

6.3.3 Using Three Boot Modes

Suppose that a user wants to switch between 3 boot modes - SCI, flash and I2C. Three boot mode pins must be used, since the pins do not fall into the 4 device default boot modes.

To have further customization of boot modes as desired here, the user needs to use the BOOTPIN_CONFIG location of the user configurable DCSM OTP. This allows the user to select up to 3 GPIO pins to have up to 8 total boot modes.

The BOOTDEF register of the user configurable DCSM OTP also allows the user to configure boot modes beyond the default boot modes.

To switch between SCI, flash, and I2C Boot, the following steps need to be taken:

1. Set BOOTPIN_CONFIG appropriately – bits 7-0, 15-8, 23-16 all to indicate which GPIOs is used to represent the boot mode. Bits 31-24 have the key 0x5A to validate the earlier bits.
2. Set BOOTDEF1 to 0x01 to indicate SCI boot with boot mode 1 (when boot mode select GPIOs = 001) and the SCI GPIOs are GPIO29 and GPIO28.
3. Set BOOTDEF3 to 0x03 to indicate Flash boot with boot mode 3 (when boot mode select GPIOs = 011). The Flash entry point is 0x80000 from Flash Bank 0, sector 0.
4. Set BOOTDEF7 to 0x07 to indicate I2C boot with boot mode 7 (when boot mode select GPIOs = 111), and the I2C GPIOs are GPIO32 and GPIO33.

For experimentation with boot mode options, users can use the EMU_BOOTPIN_CONFIG register before writing to OTP_BOOTPIN_CONFIG. OTP_BOOTDEF also has a EMU_BOOTDEF for experimentation.

The equivalent of the BOOTPIN_CONFIG registers on the F2837x is the BOOTCTRL register.

6.3.4 Performing Live Firmware Updates

It has been shown how the flash kernel is downloaded to RAM, and facilitates downloading the application to flash. By storing the flash kernel in flash, the user does not need to download the flash kernel to RAM, thus saving time. The flash kernel is available in flash to directly download the application to flash. The flash kernel takes up some flash space. This is a tradeoff that certain users can decide to use. It is especially useful to enable certain features, such as Live Firmware Updates (LFU). In LFU, the application only uses flash boot mode, and when the application is running, a user can choose to update firmware. The application will pass control to the flash kernel in flash, which will facilitate updating the application in Flash. On a single-bank flash, this typically requires a device reset. But if the device contains multiple flash banks, a device reset can be avoided with LFU, allowing a seamless transition to new firmware.

For further details on how to perform Live Firmware Updates, see [6] and [7].

7 Troubleshooting

Below are designs to some common issues encountered by users when utilizing the SCI flash kernel.

7.1 General

Question: I cannot find the SCI flash kernel projects, where are the projects?

Answer:

Device	Build Configurations	Location
F2802x	RAM	C2000Ware_x_xx_xx_xx > device_support > f2802x > examples > structs > f28027_flash_kernel
F2803x	RAM	C2000Ware_x_xx_xx_xx > device_support > f2803x > examples > c28 > f2803x_flash_kernel
F2805x	RAM	C2000Ware_x_xx_xx_xx > device_support > f2805x > examples > c28 > f28055_flash_kernel
F2806x	RAM	C2000Ware_x_xx_xx_xx > device_support > f2806x > examples > c28 > f28069_sci_flash_kernel
F2807x	RAM	C2000Ware_x_xx_xx_xx > device_support > f2807x > examples > cpu1 > F2807x_sci_flash_kernel
F2833x	RAM	C2000Ware_x_xx_xx_xx > device_support > f2833x > examples > f28335_flash_kernel
F2837xS	RAM	C2000Ware_x_xx_xx_xx > device_support > f2837xs > examples > cpu1 > F2837xS_sci_flash_kernel > cpu01
F2837xD	RAM	C2000Ware_x_xx_xx_xx > device_support > f2837xd > examples > dual > F2837xD_sci_flash_kernels
F28004x	RAM, Flash with LDFU, Flash without LDFU	C2000Ware_x_xx_xx_xx > driverlib > f28004x > examples > flash, select flashapi_ex2_sci_kernel
F2838x	RAM	CPU1-CPU2 C2000Ware_x_x_xx_xx > driverlib > f2838x>examples>c28x_dual>flash_kernel CPU1-CM C2000Ware_x_x_xx_xx > driverlib > f2838x>examples>c28x_cm>flash_kernel
F28002x	RAM, Flash with LDFU	C2000Ware_x_xx_xx_xx > driverlib > f28002x > examples > flash, select flash_kernel_ex3_sci_flash_kernel
F28003x	RAM, Flash with LDFU	C2000Ware_x_xx_xx_xx > driverlib > f28003x > examples > flash, select flash_kernel_ex3_sci_flash_kernel
F280013x	RAM	C2000Ware_x_xx_xx_xx > driverlib > f280013x > examples > flash, select flash_kernel_ex3_sci_flash_kernel
F280015x	RAM	C2000Ware_x_xx_xx_xx > driverlib > f280015x > examples > flash, select flash_kernel_ex3_sci_flash_kernel
F28P65x	RAM	C2000Ware_x_xx_xx_xx > driverlib > f28p65x > examples > c28x_dual > flash_kernel
F28P55x	RAM	C2000Ware_x_xx_xx_xx > driverlib > f28p55x > examples > flash,select f28p55x_flash_ex3_sci_flash_kernel
F28E12x	RAM	C2000Ware_x_xx_xx_xx > driverlib > f28e12x > examples > flash, select flash_kernel_ex3_sci_flash_kernel

Question: What is the difference between Flash Kernel A and Flash Kernel B?

Answer: Type A flash kernels erase the entirety of flash before streaming any data in, whereas Type B flash kernels erase only the required sectors as data is being streamed in. Type B kernels also provide users the choice to erase all or chosen sectors as desired, as a standalone operation. In addition, Type B kernels support a variety of user commands as opposed to Type A kernels which only support an application load command.

Question: What are the first things I must check if the SCI flash kernel does not download?

Answer:

- One area of the program to check is the linker command file - make sure all flash sections are aligned to 128-bit boundaries. In SECTIONS, add a comma and "ALIGN(8)" after each line where a section is allocated to flash. If using the F28P55x SCI flash kernel, align the flash sections to 512-bit boundaries. Instead of "ALIGN(8)" as mentioned above, modify this to "ALIGN(32)".
- One other common issue users encounter is that the correct boot pins for SCI boot mode are not used. For example, on the F28004x devices, SCI boot has 4 options for GPIO pins to use. Make sure that the pins for the default option are not being used for something else. If the pins are already used, make sure that another SCI boot option is used, so that the SCI boot can be connected to another set of pins. Make sure that the SCI kernel project uses this SCI boot GPIO option as the parameter for SCI_GetFunction() as well.
- When using long cables, use a lower baud rate to get rid of noise.
- For baud rate and connection issues, try running SCI loopback and echoback examples for the device (you can find these in C2000Ware in the device_support or driverlib folders for your device).

7.2 SCI Boot

Question: I cannot download the SCI kernel to RAM in SCI boot mode, what course of action do I take?

Answer: Make sure to use the correct GPIO pins to use SCI boot mode. Refer to the previous question for a detailed explanation.

7.3 F2837x

7.3.1 F2837xS

Question: The SCI Kernel is downloaded to RAM and Application is downloaded to Flash, but no command window appears, and once that is done, Flash seems to be unwritten to?

Answer: To address the issue where no command window appears after the Flash kernel is downloaded to RAM - SCI Flash Kernel project contains 2 possible SCIA Boot options:

- SCIA Boot option 2 (GPIO 28, 29)
- SCIA Boot option 1 (GPIO 84, 85)

Use the right pins for your hardware configuration. To address the issue where Flash does not get written properly - Align all Flash sections to 128-bit boundaries in the linker command file.

7.3.2 F2837xD

Question: I want to boot from Flash and SCI, how do I switch between the two? Flash Boot is used for normal operation, SCI Boot for firmware update.

Answer:

There are a few options here. A few are mentioned in [Section 6.3](#) - the device can boot up in Flash boot mode for normal operation, and in SCI Boot mode for firmware upgrades. The user needs to design a scheme that allows changing the boot mode select pins settings. Alternately, the user can decide to only use the Flash boot mode, and then in software, branch to the SCI Boot function. This can be through an IO trigger or host command, that serves as a cue to call the SCI_Boot() function. The advantage of this approach is that the user does not need to change the boot mode select pins settings. Note that in this case, the SCI ROM Bootloader is not invoked.

Question: Using SCI Boot mode to upgrade firmware works, however using Flash boot and branching to SCI Boot in software by calling SCI_Boot() does not work. What must I look at to fix this?

Answer:

- Make sure the correct GPIO pins are being used for SCI boot mode.
- Also, disabling the watchdog and interrupts prior to the SCI_Boot() call in your program is necessary, since Flash is being updated.

Question: With the ControlCARD, I cannot download the SCI Flash Kernel to RAM in SCI Boot, what steps must I take to do so?

Answer:

1. The controlCARD requires that option 2 of SCI Boot be used for the controlCARD to work on the device. For more details, see the *Warnings/Notes/Errata* section of [12]. To do this, make sure the SCI Flash Kernel project builds with SCI_BOOT_ALTERNATE as the parameter for SCI_GetFunction.
2. Next, set the SW1:A position 1 to ON on the controlCARD. This allows the emulator to be connected. Set the Boot mode to SCI by setting SW1 Position 1 to 0, and SW1 Position 2 to 1.
3. After that, make sure that SW1:A position 2 is also ON. GPIO28 (and pin 76 of the 180-pin controlCARD connector) is coupled to the FTDI's USB-to-Serial adapter. This allows UART communication to a computer through the FTDI chip.
4. After this, connect the emulator via CCS. Launch the target configuration file for the controlCard and connect to CPU1. Open up a Memory Window (View > Memory Window) and look up the location 0xD00 in memory. Change 0xD00 to 0x815A. To use Alternate GPIOs (28, 29) for SCI Boot mode, we need to set the BMODE field (bits 15:8) of the corresponding BOOTCTRL register (either EMUBOOTCTRL (0xD00) or Z1-BOOTCTRL (0x7801E which is in User configurable DCSM OTP) to 0x81).
5. If you wish to run the flash kernel on CPU2 as well, connect to the flash kernel in CCS. Click "Reset CPU", followed by "Resume". The program hits ESTOP. Click "Resume" again.
6. In CCS, for CPU1, click "Reset CPU", followed by "Resume" (F8).
7. Now, run the command serial_flash_programmer.exe with the appropriate command. The kernel is downloaded to RAM. When the menu pops up, select the desired operation to proceed. To see what the command window looks like at this stage, see [Figure 6-1](#).

7.3.3 F2837xD LaunchPad™

Question: I cannot get the SCI Flash Kernel to load into RAM, is there a reason why?

Answer: The F2837xD LaunchPad does not support SCI Boot Mode, so this board cannot be used with the SCI Flash Kernel (see the *Revision* section of [11]).

7.4 F28P65x

Question: With the ControlCARD, I cannot download the SCI Flash Kernel to RAM in SCI Boot, what steps must I take to do so?

Answer:

1. Check the revision for the controlCard. Only Revision A has the ability to use the SCI Flash Kernel project as the SCIRX/SCITX communication lines are properly connected to GPIO28/29 for SCI Autobaud. Versions below Revision A does not work with the project. For more details, see the *Warnings/Notes/Errata* section of [13].
2. The FTDI Chip interface for the device by default uses GPIO12/13 for SCI communication. The controlCARD requires that option 5 of SCI Boot be used in order for the controlCARD to work on the device.
3. Next, set the S1 position 1 to ON on the controlCARD. This allows the emulator to be connected. Set the Boot mode to SCI by setting S3 Position 1 to 0, and SW1 Position 2 to 1.
4. After that, make sure that S1 position 2 is also ON. GPIO28 (and pin 76 of the 180-pin controlCARD connector) is coupled to the FTDI's USB-to-Serial adapter. This allows UART communication to a computer via the FTDI chip.
5. After this, connect the emulator via CCS. Launch the target configuration file for the controlCard and connect to CPU1. Open up a Memory Window (View > Memory Window) and look up the location 0xD00 in memory. To use Alternate GPIOs (28, 29) for SCI Boot mode, we need to set the EMU-BOOTDEF-LOW field (bits 15:0) or Z1-OTP-BOOTDEF-LOW (0x7800C which is in User configurable DCSM OTP) to 0xA1. Change the following values at the respective register locations: 0xFFFF at 0xD00, 0x5AFF at 0xD01, 0x00A1 at 0xD04.
6. If you wish to run CPU2 as well, connect to the CPU2 in CCS. Click *Reset CPU*, followed by *Resume*. The program hits ESTOP. Click *Resume* again.
7. In CCS, for CPU1, click *Reset CPU* followed by *Resume* (F8).

- Now, run the command `serial_flash_programmer.exe` with the appropriate command. The kernel is downloaded to RAM. When the menu pops up, select the desired operation to proceed.

Question: With the LaunchPad, I cannot download the SCI Flash Kernel to RAM in SCI Boot, what steps must I take to do so?

Answer:

- The FTDI Chip interface for the device by default uses GPIO12/13 for SCI communication. The LaunchPad requires that option 3 of SCI Boot be used in order for it to work on the device. Within the device header file for the SCI Flash Kernel project, there is a symbol for utilizing the LaunchPad (`_LAUNCHXL_F28P65X`) that must be added to the list of predefined symbols under project properties. Also within the project make sure that the boot mode value given to `sciGetFunction` within the main source file is set to `SCI_BOOT_ALT3`. Rebuild the project for the changes to take place.
- Next, set the S2 position 1 to OFF on the LaunchPad. This allows UART communication to a computer via the FTDI Chip. Set the Boot mode to SCI by setting S3 Position 1 to 0, and S3 Position 2 to 1.
- After this, connect the emulator via CCS. Launch the target configuration file for the controlCard and connect to CPU1. Open up a Memory Window (View > Memory Window) and look up the location 0xD00 in memory. To use Alternate GPIOs (42, 43) for SCI Boot mode, we need to set the EMU-BOOTDEF-LOW field (bits 15:0) or Z1-OTP-BOOTDEF-LOW (0x7800C which is in User configurable DCSM OTP) to 0x61. Change the following values at the respective register locations: 0xFFFF at 0xD00, 0x5AFF at 0xD01, 0x0061 at 0xD04.
- If you wish to run CPU2 as well, connect to CPU2 in CCS. Click "Reset CPU", followed by "Resume". The program hits ESTOP. Click "Resume" again. In CCS, for CPU1, click "Reset CPU", followed by "Resume" (F8). Now, run the command `serial_flash_programmer.exe` with the appropriate command. The kernel is downloaded to RAM. When the menu pops up, select the desired operation to proceed.

8 References

- Texas Instruments, [TMS32028004x Piccolo Microcontrollers Technical Reference Manual](#), technical reference manual.
- Texas Instruments: *ROM Code and Peripheral Booting* section from the [TMS320F2837xD Dual-Core Delfino Microcontrollers Technical Reference Manual](#), technical reference manual.
- Piccolo Flash API User's Guide - located within controlSUITE at: (`/controlSUITE/libs/utilities/flash_api/DEVICE/VERSION/doc`)
- Texas Instruments [TMS320F28M35x and TMS320F28M36x Flash API Reference Guide](#), reference guide.
- Texas Instruments: [TMS320C28x Assembly Language Tools User's Guide](#), user's guide.
- Texas Instruments: [Live Firmware Update With Device Reset on C2000 MCUs](#), application note.
- Texas Instruments: [Live Firmware Update Without Device Reset on C2000 MCUs](#), application note.
- Texas Instruments: [USB Flash Programming of C2000 Microcontrollers](#), application note.
- Texas Instruments: [TMS320F28004x Boot Features and Configurations](#), application note.
- Texas Instruments: [C2000 Software Controlled Firmware Update Process](#), application note.
- Texas Instruments: [LAUNCHXL-F28379D Overview User's Guide](#), user's guide.
- Texas Instruments: [TMS320F28379D controlCARD User's Guide](#), user's guide.
- Texas Instruments: [TMS320F28P65 controlCARD User's Guide](#), user's guide.

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