I²C Bootloader Datasheet BootLdrI2CV 3.00

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Resources	PSoC® Blocks			API Memory (Bytes)		Pins (per External I/O)
	Digital	Analog CT	Analog SC	Flash	RAM	
CY7C603xx, CY7C64215, CY8C20x24, CY8C20x34, CY8C21x12, CY8C21x34, CY8C21x45, CY8C22x45/H, CY8C23x33, CY8C24x23A/33/94, CY8C27x43, CY8C28xxx, CY8C29x66, CY8CLEDxx, CY8CPLC20, CY8CTMA120, CY8CTMG120, CYWUSB6953						
Slave (full API support)	0	0	0	2560	6-128	2
Slave (no API support)	0	0	0	2144	6-128	2

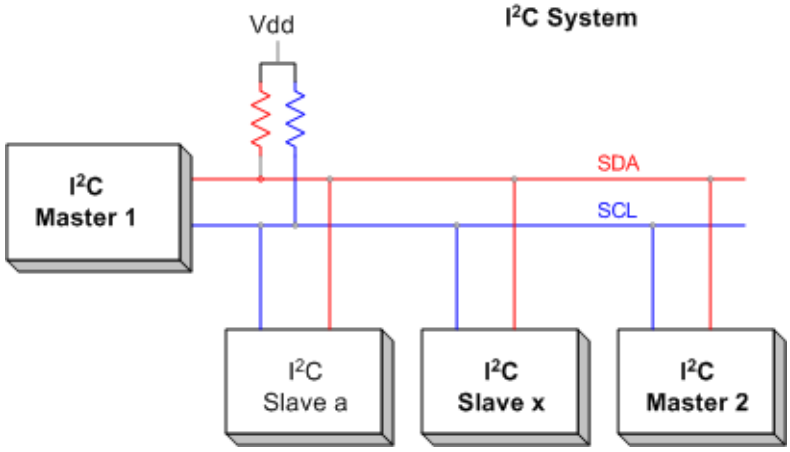
Features and Overview

- Industry standard Philips I²C-bus compatible interface
- Enables you to reprogram a PSoC device using the I²C system bus instead of in-system programming pins

The BootLdrI2C User Module implements a bootloader that can reprogram the PSoC device over the I²C interface. The PSoC device already gives an in-system serial programming interface (ISSP) that allows downloading new code into the device. However, the bootloader allows a code update to occur through an industry standard communication interface, such as I²C. This user module can be useful for any device that has to be reprogrammed in the field. The bootloading information can be sent through an I²C master device, such as a CY3240 (USB to I²C bridge) or an in-system host processor.

The I²C bootloader requires the I²C Hardware User Module. It does not preclude the use of the I²C bus for other functions within the PSoC device. The I²C bootloader uses a separate I²C address for its associated functions. All of the code for the I²C bootloader is programmed in a protected area of EEPROM and cannot be accidentally overwritten.

Figure 1. I²C Block Diagram



Quick Start

1. Review this user module datasheet. A successful implementation of a bootloader project requires an understanding of this information.
2. Add the user module to a project.
3. Place the user module, selecting either I²C for Bootloader Only or Full I²C API Support with Bootloader.
4. In the menu bar, open **Project > Settings**dialog box and click **OK**to save project parameters.
5. Right-click the user module icon and select Boot Loader Tools.
6. Click Get Files. The files *boot.tpl*, *custom.lkp*, and *flashsecurity.example* files are placed in the project root directory.
7. Close the **BootLoader Tools** wizard.
8. Generate the source code and compile the project.
9. Review the output file *<project>.mp* and *<project>.hex* to see how the project has been built.
10. After creating a project that compiles without errors, go to the Sample Firmware Code section. Modify and adapt the code given in the sample.
11. A detailed tutorial is available in PSoC Designer™. To access the Bootloader tutorial, go to the menu bar, and click **Help > Documentation > Supporting Documents**.

Functional Description

The bootloader is located in a section of Flash memory defined by you (using user module parameters). This memory space is (must be) write-protected to prevent any accidental modification or corruption. The reset vector is modified so that when the processor is reset, the bootloader is executed.

The following operations are carried out by the bootloader:

1. When reset, the bootloader calculates a checksum for the Flash user code and verifies it with a checksum written to the last two bytes of Flash memory. If the checksum matches, the previous programming attempt has been successful and the bootloader branches to the beginning of the user code and the user code can execute.
2. If the checksum does not match, the bootloader executes customizable user code to perform system critical tasks (such as turning on a fan) and then enters the bootloader mode, where it waits for a 8-byte bootloader key from the master. If the previous bootloading has failed (for example, if there was a power transient), the program enters the bootloader mode due to a checksum mismatch.
3. When the bootloader receives a valid bootloader key from the master, it responds with a status byte informing the master that it is ready to receive the Flash image.
4. The master sends the updated user code in 64-byte packets with some encoding bytes.
5. The bootloader writes the user code to the Flash. When all the Flash pages are written successfully, the bootloader performs a Flash verify operation and then a software reset to start the user code.

   Note The I^2C master must wait 100 ms after each block write, before reading the block status byte to allow the Flash block write operation.

The bootloader portion of the user module gives a method to organize the memory map and major code functional blocks into areas that are compatible with device reprogramming. The memory organization of the project is considerably different from that of a conventional PSoC Designer project. Modifications to the memory map are necessary to meet the minimum device functionality requirements while the device application is being reprogrammed. Effectively, a project incorporating a bootloader contains two independent programs supporting different functions. Figure 2 shows the Bootloader memory organization.

After a project incorporating a bootloader is deployed, the memory locations highlighted in gray are never reprogrammed. The memory locations highlighted in green may be altered by running the bootloader.

I2C and Sleep

Special care must be taken when using I2C with a project that goes to a sleep state. Before the project enters a sleep state, follow these steps for proper sleep entry and I2C handling:

1. Ensure that all I2C traffic is complete.
2. Disable the I2C by calling the Stop API.
3. Configure the I2C pins to a analog High-Z drive mode.

Follow these steps when the part wakes from sleep:

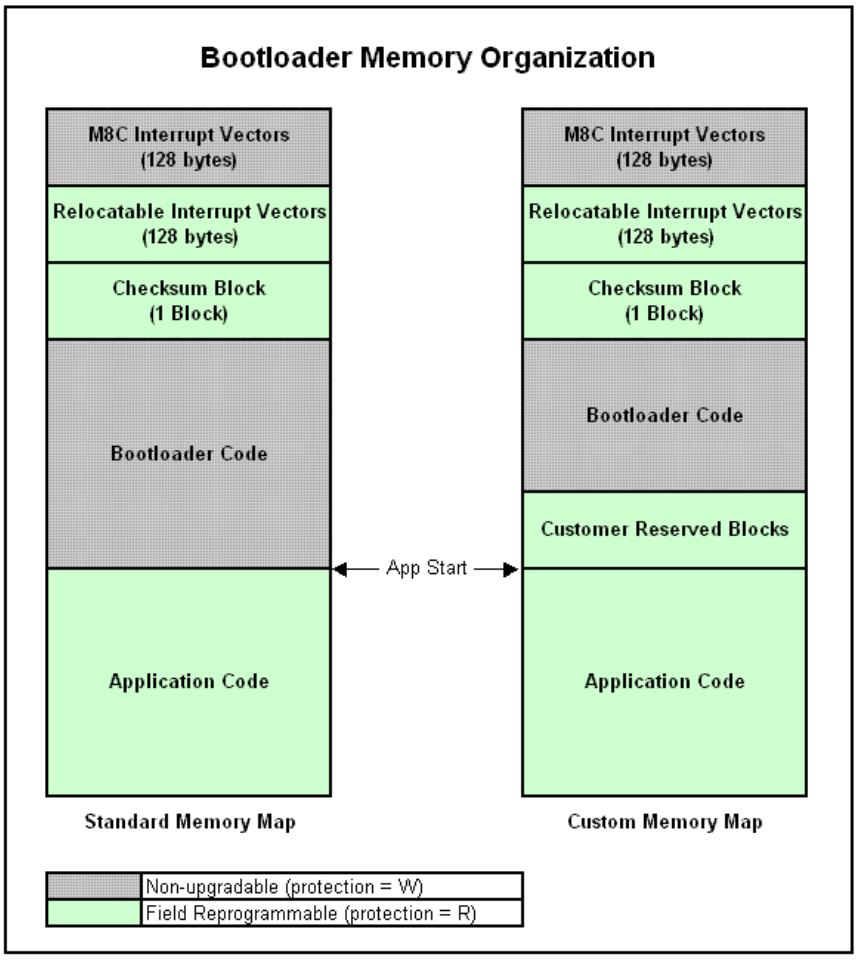
1. Ensure that there is no active I2C traffic.
2. Enable the I2C by calling the Start API.
3. Configure the I2C pins to Open-Drain Drives Low drive mode.
4. Enable Interrupts.

Theory of Operation

Creating a project with a bootloader requires several nonstandard modifications to the PSoC Designer standard model. To facilitate this, the BootLdrI2C User Module gives customized files and specialized tools to assist you in bootloader project development. The special tools are accessed by switching to the Device Editor view and right-clicking the BootLdrI2C User Module icon. In addition to the tools and files given as part of the user module, a host application example is given as part of the user module installation that can demonstrate the basic capability of the bootloader. This PC-based application and source code for Microsoft Visual Studio® 2005 is contained in a .zip file in the installation directory of PSoC Programmer 3:

[Install path]\Cypress\Programmer\3.xx\Bootloaders\BootLdrI2C\BootLoaderHostApp\…

Figure 2. Bootloader Memory Organization



Overview

PSoC Designer uses standardized files, built-in data about the part family, and attributes of specific devices to create compilable projects and correct API definitions. A project with a bootloader requires a memory map that is considerably different from that of a standard PSoC Designer project. Selection of the memory areas represents a core design decision that is maintained throughout the life of the design. While a project without the requirements of a bootloader simply allows the compiler and linker to allocate RAM and ROM, a bootloader must group RAM and ROM in specific areas so that the program does not crash while a new application is being loaded.

In the memory layout, there are six key areas of ROM that are managed:

- The first is blocks 0 and 1 of ROM. These blocks contain critical interrupt vectors and restart vectors. Because it is nearly impossible to control read access to these blocks by any operating device, they are never erased and reprogrammed. The first two blocks of ROM must not be modified and cannot be placed in any other location.
- The second memory area is the relocatable interrupt table. This table may consist of one or two blocks depending on the architecture of the device. This area contains interrupt and general purpose vectors to give a jump table for interrupts or code entries that may be altered when a new application is loaded using the bootloader. For example, this area contains the application start address. The bootloader is able to use this address to start the new application after the checksum has been validated at power up. This area is placed at block 2 and 3. After the application and bootloader are deployed, the contents in this area may be rewritten, but its location must not be modified. The characteristics of this area are similar to the checksum area described in the next section.
- The third area of ROM defined is the checksum area. This area is placed at block 4 and it contains important data that the bootloader software uses to download and verify the foreground application. The checksum area contains the start address and size in blocks of the foreground application. The first two bytes of the checksum block are a checksum of the checksum block itself. The last two bytes are the checksum of the runtime application. The structure of the checksum block contains space for you to define your own data in addition to that used by the bootloader. This structure is exposed as a C-structure definition and may be modified as long as data used by the bootloader utility is not changed or repositioned within the block.
- The fourth area of memory to be defined is the area containing the bootloader code itself. This area is started at block 5. After the project or device containing the bootloader is deployed, this area is not reprogrammable and cannot be field upgraded.
- The fifth area is reserved for customer's data. This may contain configuration data that must persist through an upgrade using bootload. As shown in the memory map, this area is optional. You can use the Standard Memory Map if there is no custom data.
- The sixth memory area is the application area. This area holds the application image. Because the code size of the "Bootloader Code" area is expandable, the starting address of this area is adjustable. The "Appliaction_Start_Block" parameter (in properties window) allows users to set the application starting address accordingly. This area should occupy all remaining memory.

If your application has code that must always be operational, including during a bootload process, the design of the BootLdrI2C User Module can allow sufficient customization to accommodate this. The best way to accomplish this is to add this code to the bootloader ROM area using the assembler AREA directive. Any RAM used by your code during the bootload process needs to be added to the RAM area defined for the bootloader.

Definition of Memory Areas in the User Module Parameters

The BootLdrI2C User Module parameters enable you to customize where major program elements are placed in ROM. The defaults in the user module should give a working initial setup. Use these settings until a complete project is successfully compiled. After you have a compiled project, you can see the program memory map and .hex output file to determine how to optimize your program structure. If you reconfigure the parameters and accidentally create memory area conflicts, it may be difficult to determine the correct locations without a valid memory map to look at.

Bootloader Utility

The BootLdrI2C User Module gives a complete utility that coexists with a foreground (primary) application. When the device is started or reset, the bootloader utility is always invoked. Once invoked at system startup, the bootloader validates the foreground application by calculating a checksum on the foreground application ROM area. The calculated checksum is compared to the one stored in the checksum block

(which is created with the application). If the two checksums are equal, the bootloader utility allows the foreground application to execute. If the two checksums are not equal, the bootloader enters a wait loop for a host application to download a valid application. It also enables its own I^2C subsystem to allow the host to transmit data. When the host system observes this interface enabled, it may choose to execute its own set of applications. Two download file formats for downloading an application to a target are automatically supported by the user module tools. The first is an output file named <project_name>.txt and the second is an output file named <project_name>.dld. Each of these download file formats is supported by a different demonstration tool.

Download Methods

1. The .txt and .dld files can be downloaded by using the Bridge Control Panel GUI. This method is also discussed in the knowledge base article, Programming PSoC 1 using an I2C Bootloader.

2. A second method of downloading an application is also supported. This method is more complicated than the previous method, but may give more information on developing a custom I2C download application for the finished product. A brief discussion of this host application is given here. An example application and source code is given in the installation directory of PSoC Programmer 3:

[Install path]\Cypress\Programmer\3.xx\Bootloaders\BootLoaderI2c\...

Two applications are given for demonstrating the I^2C bootloader. The first is a PSoC 27000 based application (a complete PSoC project is included) that is capable of translating RS-232 communication containing embedded bootloader download records to I^2C packets sent to the Bootloader application. Source code is given for this PSoC project. It can be easily adapted to other PSoC Device architectures.

The second application is a Microsoft Visual Studio application, I^2C Bootloader Host, given with an installer and source code for modification. It can read and parse the download file *<fiilename>.dld* and transmit it to the PSoC project mentioned earlier in this section. Source code for this application is also given for use with Microsoft Visual Studio 2005. This application is for demonstration purposes only and is not intended for production use or resale.

Note In some cases, you may need to install the file *mscomm32.ocx* in your computer. Download this file from the Microsoft website and install it using the Windows/ accessories/command prompt window and the command:

```
> regsvr32 mscomm32.ocx
```

The file *regsvr32.exe* is in the Windows installation folder windows/system32 (winXP).

The file *mscomm32.ocx* is available for download from the Microsoft website by searching for the filename “*mscomm32.ocx*".

Bootloader Tools

Several tools are available from the shortcut menu accessed by right-clicking on the user module icon. Select BootLoader Tools from the dropdown menu.

The “Get Files" selections add special versions of boot.tpl, custom.lkp, and HTLinkOpts.lkp that can be placed in the project or removed. From the main menu, select Tools Restore Default Boot files to remove these. If the BootLdrI2C User Module is removed, the option to restore the default boot files is no longer available from the user module icon and can be accessed from the tools tab in the main menu of PSoC Designer.

Generate Checksum – After your project builds correctly, you can use the bootloader tools to create and autovalidate checksums. When the bootloader tools selection screen is accessed, the project code is generated and a complete compile of the entire project is executed. Next, a checksum calculation is

performed on the resulting hex file, which is compared to a checksum stored by the user module. If the checksums do not match, a message is displayed. You can recalculate and store a new checksum if you want. If build or compile errors occur in the automated generate and build invoked by the Bootloader Tools and no hex file is successfully created, an error is reported but no error debug information is displayed in the build dialog of PSoC Designer. Error reporting is suppressed when the generate and build is invoked from the automation interface. To debug build errors, it is necessary to use the conventional build and generate process external to the bootloader tools menu.

Generate dld file – This tool item derives a download file from the hex project output file. This file contains only the hex blocks that are reprogrammed by the bootloader including the checksum block. The Host Demonstration application is capable of reading this file and downloading it to a working project incorporating a bootloader. This download file can be deployed to a field application to upgrade a PSoC device.

The dld and txt download files are generated by the BootLdrI2C User Module tool and listed in “Output Files” in Workspace Explorer.

Checksum Semiautomatic Generation

After your project is built and compiled without errors, the application checksum must be generated. The application checksum is created using one of the utilities accessed by right-clicking on the BootLdrI2C User Module icon in the Device Editor view and selecting **Bootloader Tools**. An application checksum (previously calculated or default) is stored as a hidden user module parameter. When the Bootloader Tools menu page is invoked, any previous checksum is validated against the one calculated on the current output\<prj_name>.hex file. Necessarily the checksum cannot be generated before a successful compile. After a checksum is created, it must be integrated into the compiled files. This requires a second compile.

Special Files Given

You can access several important files by opening the **Bootloader Tools** menu and selecting **Get Files**. A device specific boot.tpl file is placed in the main project directory along with a file called custom.lkp (ImageCraft), HTLinkOpts.lkp (Hi Tech) and a predefined flashsecurity.txt file. The original versions of these files are placed in the project backup directory. The purpose of each file is briefly described:

Boot.tpl. – This file contains a relocatable and nonrelocatable definition of interrupt vector tables and device specific boot setup, which is specified in a relocatable area of the ROM instead of the fixed location specified in the standard boot.tpl file.

Custom.lkp – When source generation takes place, the custom.lkp file is populated with autogenerated ROM areas for major code blocks as defined in the user module parameters. Do not modify the following code blocks in the custom.lkp file:

- -bSSCParmBlk: Contains specified critical RAM used during flash operations.
- -bBootloader
- -bBLChecksum
- -bUserAPP: Changes to any of the last three lines result in an error dialog indicating the inability of the project to detect the correct custom.lkp file.

During code generation, each of the last three lines of the custom.lkp file are rewritten under control of the code generation software. Changes made within or below the last three lines either cause an error or are simply lost. You can make changes to the rest of the custom.lkp file. To debug the memory allocation of the project, comment out all three lines mentioned earlier by inserting a semicolon in the first space. This allows the linker to place code automatically and can be helpful in determining application code size requirements.

HTLinkOpts.lkp – When source generation takes place, the HTLinkOpts.lkp file is populated with autogenerated ROM areas for major code blocks as defined in the user module parameters. Do not modify the code blocks in the HTLinkOpts.lkp file:

- -L-ACODE... & -L-AROM... Lines contain data giving the overall ROM size.
- -L-PPD_startup... contains linker directives to locate bootloader specific ROM areas
- -L-P
- -L-Pbss0= Changes to any of the last several lines result in an error dialog indicating the inability of the project to detect the correct HTLinkOpts.lkp file.

During code generation, several of the last lines of the HTLinkOpts.lkp file are rewritten under the control of the code generation software. Changes made within or below the last three lines either cause an error or are simply lost.

Flashsecurity.example – This is a default file that is laid out according to the default memory map specified by the default user module parameters. To create the final project, you may have to manually modify this file according the final memory map and application size for the deployed device and firmware. This is not the file that is directly used by PSoC Designer. If for some reason the project is updated or tagged for out of data files, it is inconvenient to have the flashsecurity file overwritten. This would then require repeated modification by the developer. The given file flashsecurity.example may be edited and renamed as necessary.

Flashsecurity.txt – This is a default file given by PSoC Designer. The data in this file is added to the .hex file and instructs the device how to manage access to the internal ROM memory. If memory blocks are protected in from Write access, the bootloader does not work. Because read and write protection is built into the programmed PSoC, this file must be correctly configured before the first deployment of the bootloader.

I^2C Interrupt Processing

The standard BootLdrI2C User Module optionally gives a foreground copy of the I^2C interrupt processing module. This code is placed in upgradable memory along with APIs to operate a fully featured I^2C slave. The bootloader itself maintains an internal utility that processes I^2C data that is addressed to the bootloader. This is to overcome the problem of executing code that is being rewritten (this is not a good programming practice).

Block Entry of Parameters

All memory parameters are entered in the bootloader in Blocks numbered from 0x00 through 0xFF for 16K devices, 0x00 through 0x7F for 8K devices and 0x00 through 0x1FF for 32K devices. Although this is not the most convenient format to enter memory addressees, it prevents accidental assignment of partial block addresses to different sections of the memory map. The PSoC devices in question are only capable of storing 64 byte flash blocks (128 byte for some device families), and this is a simple way to correctly maintain the boundaries between different sections of the project code.

Most PSoC parts have 64 byte block sizes. Some new PSoC devices have 128 byte blocks. Two key facts are:

1. Any Bootloader must write to Flash.
2. PSoC can only write to flash “Block" by “Block.

So for bootloader applications, it is more useful to think of memory as a group of “Blocks" to be written.

To translate from Blocks to absolute addresses, multiply: Abs_addr = block_number X Block Size. Block_0 starts at addr 0, Block_n starts at address n x Block_size. All blocks are delimited in hex for the bootloader

parameters, so a hex address can be obtained by multiplying by 0x40 (64-byte blocks) or 0x80 (128-byte blocks).

Hex output files contain an absolute address for each line. Regardless of the block size of the device in question (0x40/0x80), the hex output file breaks the code into lines of 64(d)/0x40 bytes per line. As a result, for a 64 byte block device each line represents a block of code. For a 128 byte block device, two lines from the hex file go into a block (because block 0 starts at address 0, 128 byte blocks must be ALWAYS considered to have an “even" half representing the lower (address) half and an “odd" half representing the upper (address) half).

See a hex file and become familiar with the flash block size for the part that you are working with.

Placement

The I2CHW User Module allows two choices of SCL and SDA P1[5]/P1[7] or P1[0]/P1[1] and does not require any digital or analog PSoC blocks. There are no placement restrictions. Placement of multiple I^2C modules is not possible because the I^2C module uses a dedicated PSoC resource block and interrupt.

Parameters and Resources

Default parameters are for informational purposes only. Defaults in your project may be tailored to the block size of the part in use, or may have been adjusted to give adequate sizes of code areas. After your project is compiled and tested, you can adjust block sizes to optimize memory use.

Figure 3. Default Parameters - Full API

Slave_Addr_HEX	0x0
Boot_Loader_Addr_HEX	0x0
Read_Buffer_Types	RAM ONLY
Communication_Service_Ty	Interrupt
ApplicationCode_Start_Bloc	0x29
BootLoaderKey	0001020304050607
Flash_Program_Temperature	-20C
Ignore_N_I2C_Prefix_Bytes	2
BootLdrI2C_ver	0x1000
I2C Clock	100K Standard
I2C_Pin	P[1]5-P[1]7

Figure 4. Default Parameters - I2C Bootloader only

Boot_Loader_Addr_HEX	0x0
Communication_Service_Ty	Interrupt
ApplicationCode_Start_Bloc	0x29
BootLoaderKey	0001020304050607
Flash_Program_Temperature	-20C
Ignore_N_I2C_Prefix_Bytes	2
BootLdrI2C_ver	0x1000
I2C Clock	100K Standard
I2C_Pin	P[1]5-P[1]7

Figure 3 shows the default user module parameters. Periodically, these parameters may be updated in the source code of the user module, and may differ from the given example.

All buffer names are written to describe their use by an I^2C master. For example, the I2Cs_pRead_Buf refers to the location in RAM containing data to be read by the I^2C master.

Slave_Addr_HEX

This is a Slave and MultiMasterSlave parameter. It selects the 7-bit slave address that is used by the I^2C master to address the slave or the MultiMasterSlave when it is in slave mode. Valid selections are

from 0x00-0x7F. Because this is the upper 7 bits of the address, the actual address appears to be doubled inside the code.

Boot_Loader_Addr_HEX

Selects the 7-bit slave address that is used by the I2C master to address the I2C BootLoader slave device. Valid selections are from 0 - 7Fh. Because this is the upper 7 bits of the address, the actual address appears to be doubled inside the code. The parameter value must differ from the Slave_Addr_HEX parameter value.

Read_Buffer_Types

Selects what types of buffers are supported for data reads. Two selections are available: RAM ONLY or RAM OR FLASH. Selection of RAM ONLY removes code and variables required to support direct Flash-ROM reads. Select RAM OR FLASH to give code and variable support for reading either RAM buffers or Flash-ROM buffers to transmit data to the master. Select RAM OR FLASH to enable support for API calls to select whether a RAM- or Flash-read buffer is used.

Communication_Service_Type

This parameter enables you to select between an interrupt based data processing strategy and a polled strategy. In the interrupt based strategy, a transfer is initiated against a predefined buffer. Data is then moved in or out of the buffer as quickly as possible in the background. An ISR routine is included which handles data movement. When you select the polled data processing strategy, you are in control of when data movement takes place. To implement a polled strategy, you must periodically call the function BootLdrI2C_Poll() (see the I2C.h files for the exact instance name). Each time the polling function is called, a single byte is transferred. Other I^2C functions are used identically. The polled communication strategy may be used in a situation where interrupt latency is critically important (and asynchronous communication interrupts may cause problems). Another use is when you want absolute control of when data is transferred. A drawback of polling is that when the I^2C state machine is enabled, the bus is stalled automatically after each byte until the polling function is called.

The polling function is available only for the Slave and MultiMasterSlave implementations of I^2C. The Single Master implementation offers API functions to support byte-wise data transfers.

Using the polling function from an interrupt is not recommended. The definition of a timed interrupt to call the poll function may call the function so often that no other data processing can take place. The poll service is not re-entrant and the function cannot be called until it completes its processing.

I2C Clock

Specifies the desired clock speed at which to run the I^2C interface. There are three I2C_Clock speeds available:

- 50K Standard
- 100K Standard
- 400K Fast (when CPU_Clk_speed is greater than 6 MHz)

I2C_Pin

Selects the pins from Port 1 to be used for I^2C signals. PSoC Designer automatically selects the proper drive mode for these pins. Note that all pins on Port 1 other than SCL, SDA and the optional interrupt pin are set to HI-Z analog mode during bootloading.

ApplicationCode_Start_Block

This is the first block of code assigned to the User Application. This code must be bootloadable/writeable. This parameter is also used by the Bootloader Tools to determine which blocks of code should be processed for a .dld file and which blocks of code to calculate checksums on. This variable is prop-

agated into the checksum block for use when the bootloader utility automatically verifies the application checksum.

The default address specified by the parameter block default may be calculated by multiplying the device block size (0x40 or 0x80) times the block in the parameter.

Bootloader_Key

This is the key value prepended to the transactions sent to the bootloader application, representing an extra verification step. This step ensures that the bootloader upgrade utility is not accidentally invoked.

The default value "0001020304050607".

Flash_Program_Temperature_Deg_C

This is the typical programming temperature expected when the device is reprogrammed. Programming the device at a different temperature than that specified in this parameter may adversely effect program retention.

Matching the program temperature parameter to the actual temperature during bootload impacts memory retention and the maximum number of write cycles. PSoC implements a stronger flash write at colder temperatures. Bootloading at significantly lower temperatures than the parameter setting may result in reduced memory retention. For this reason, you must take precautions to ensure that the bootloader is never operated more than 20°C from the value in this parameter. See the Cypress device specification for more information.

Ignore_N_I2C_Prefix_Bytes

Note The RS-232 to I^2C translator project sends 2 prefix bytes to the device. As a result, the correct setting for this parameter when using the given demonstration applications is 2. This is also used for certain SM-bus protocols based on I^2C. This parameter enables you to configure the Bootloader to ignore a variable number of prefix bytes.

BootLdrI2C_ver

This is the version of the bootloader. It is currently not used by the internal firmware, but is available as part of the Checksum block. You can set it up and use it to verify the correct version of bootloader executable code.

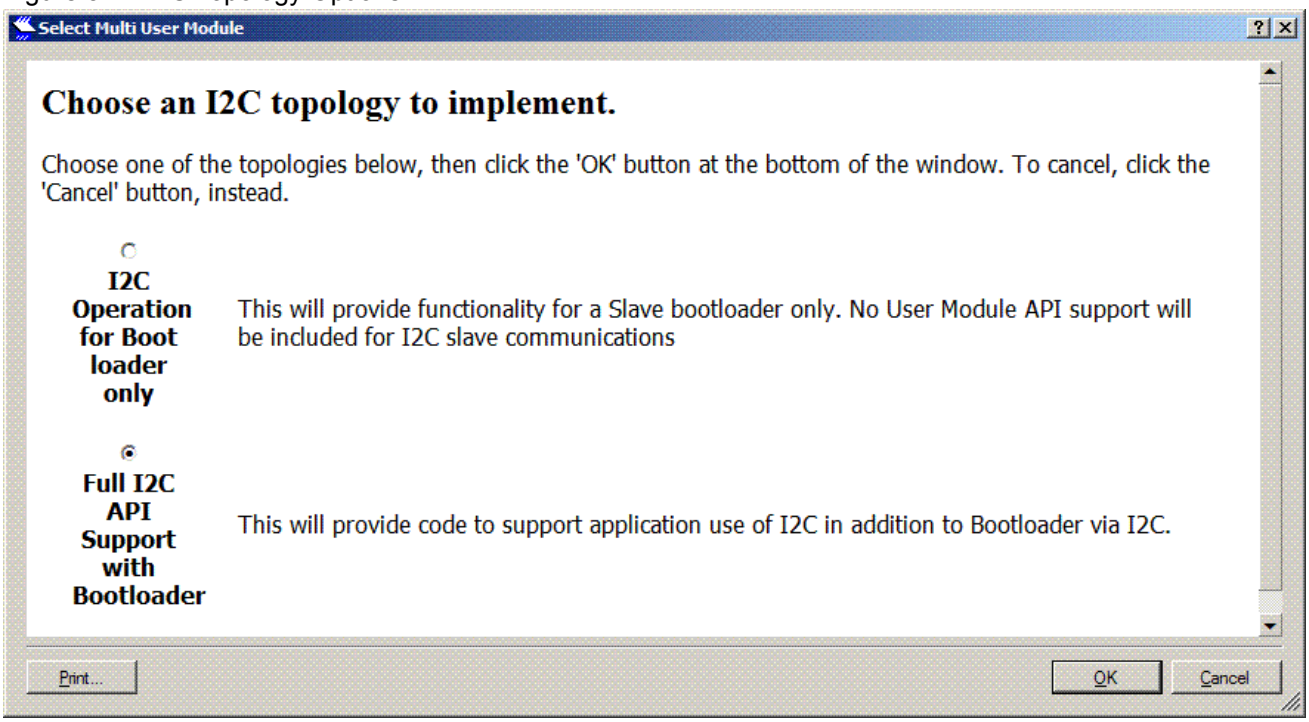
I2C Topology Selection Options

When placing a BootLdrI2C User Module, you must decide which I2C topology to implement for the bootloader project.

I2C Operation for Bootloader only: This option gives I2C communication for the bootloader only. No user module API support is included for I2C slave communications. Select this option if your application uses I2C communication for bootloading only.

Full I2C API Support with Bootloader: This option gives code to support the application use of I2C in addition to Bootloader through I2C. Select this option if you plan to use I2C communication in your application for other purposes besides bootloading.

Figure 5. I2C Topology Options



Common Problems

Updating Bootloader Projects, Service Pack Upgrades, and Compilers

Avoid changes to the PSoC Developer environment when using a bootloader application. This includes not updating PSoC Designer, not updating the BootLdrI2C User Module, and not changing the compiler.

The reason behind this is that initially the bootloader and application are compiled together, but after a bootloadable system is deployed, only the application section is reprogrammed. A new or revised application must be compiled with the identical version of the BootLdrI2C User Module, so that the new application matches the bootloader from the original deployment. Ideally, all versions of the elements in the development environment are compatible. However, in the case of a bootloader, it is essential to maintain that compatibility. By not changing the development environment compatibility, risks can be eliminated.

Although multiple compilers are supported by PSoC Designer, a bootloader compiled under one compiler may not be compatible with an application compiled under another. Also, the implementation of RAM paging may differ from one compiler to the other. Another difficulty is that, because a bootloader and application are compiled together, it is not possible debug a bootloader/application pair that had mismatches in the development tools used.

RAM Allocation Problems With the HI-TECH Compiler

Some user modules use the memory in large arrays or use a large amount of RAM on page 0.

- The default location for user module memory is page 0.
- The bootloader demands memory at the lowest locations of page 0.

- The default for HI-TECH local variables and for InterruptRAM is page 0.

With these items competing for space on RAM page 0, it is possible to run out of memory on page 0. If this is a problem, select Project -> Settings -> Compiler, and add a line to the Options box for HI-TECH:

```
--AUTOBANK=1
```

This option moves automatic C variables to memory page 1. You can choose any memory page up to the maximum available for the device in use. See the HI-TECH manual for further information about the --AUTOBANK option.

Internal Use of the Watch Dog Timer

Coordination with the watchdog timer is linked to the global parameter: WATCHDOG_ENABLE contained in the file globalparams.inc. If the project uses a watchdog timer, conditionally compiled code linked to the global parameter automatically sets the watchdog during bootload checksum and download operations. The CPU clock speed effects how fast the watchdog timer is updated. A practical minimum setting for the watchdog timer is about 0.125s.

Improper Settings in Flashsecurity.txt

The default settings for this file are set when the project is created. An example configuration is given in the file “Flashsecurity.example". Flashsecurity.example is given with the BootLoader Tools - Get Files user module menu item. The map must allow flash write at all the locations that are eventually bootloaded. One strategy is to make all blocks writeable. Another is to take a moment to layout your memory map now and edit this file accordingly. No matter which strategy is chosen, taking action at the beginning of the project is quicker than debugging it later. You must write-protect the areas of code used by the bootloader executable. Failure to correctly map flash security can be a contributing factor in a broken system and an extremely difficult debug task.

For development and debugging purposes, a flash security of 'U' (unprotected) is recommended for the application area. For final production, a flash security setting of 'R' (read protected) is recommended on the application area to prevent external reads and writes from occurring.

Incorrect Relocatable Code Start Address (Linker Parameter ImageCraft Compiler Only)

The memory map for a bootloader project is considerably different than that for a conventional project. As a result, the relocatable code start address usually needs to be altered. This is a common source of the errors generated by the linker when it attempts to write more than one block code to the same address. This parameter can be changed in the Relocate code start address filed in the Project > Settings > Linker tab. Calculate the absolute hex start address as a little more than the highest block used by the bootloader code, or to occupy an unused area of ROM. For the I^2C version of the bootloader setting, this value to 0xA40 should be adequate (if the default values of the other parameters are used).

Note When unplacing the BootLdrI2C User Module, the Relocatable Code Start Address does not reset to its original value. You must change it back manually to save ROM space.

Memory Overlap

To correct the relocatable code start address (see previous section), use a leading semicolon to comment out the last three lines of the custom.lkp file, attempt to build the file again, and examine the resulting memory map. Memory overlap problems are difficult to diagnose, because they prevent output files from being generated. Modifying the custom.lkp file may allow the linker to place object blocks, which then gives a starting point to correct the memory overlap root cause.

Power Stability

Power noise, glitches, brownout, slow power ramp, and poor connections can cause difficult to diagnose problems with flash programming. Program execution is rapid in comparison to power ramps, and in some cases, a part may still have changing power levels when flash programming takes place. One example is a status write to flash at power up. You must evaluate your use model and the potential for changing power supply conditions during flash operations. Poor power stability may contribute to nonfunctional parts and may cause poor flash retention.

Downloading a New File Causes the Device to Stop Working

It is possible to unintentionally construct applications with no facility to enter the bootloader utility. For example, a main{} function with a simple while(1); loop never returns and never enters the bootloader. As a result, it cannot be reprogrammed after it begins executing (as long as it has a correct checksum). There are multiple strategies to address this problem. No default method is included in this user module. A few suggestions are:

1. Apply a reset condition that allows a period of time when the bootloader is enabled when the device first powers up. By setting timeout parameters, the device could be configured to enter the bootloader upon reset, and exit to the foreground application when the timeout expires.
2. Set a test at some point in the code that causes the device to enter the bootloader. This could be switch closure or holding a port pin low/high.
3. Enable the I^2C application resource and create an I^2C command that causes the device to enter the bootloader. Generally, if I^2C is enabled by the main routine, the bootloader address can be used to cause the device to enter the bootloader.
4. Use the Watch Dog Timer to reset the device if it is not serviced regularly. This could be combined with one of the previous strategies to allow a WDT interrupt to initiate a bootloadable state. When reset from a watch dog timer reset condition, it is possible to monitor a status bit associated with the watch-dog timer to detect that this is the cause of the reset condition (see the Technical Reference Manual).
5. Two projects have been developed and the bootloader in each is different in some subtle way. Remember that bootloading implies that programming part of a device is taking place. This implies that the implementation of the bootloader for each of two mutually reprogrammable applications must be identical. All bootloader parameters and relocatable code start addresses must be identical (that is, different from first application block). Debug strategies for this problem include comparison of the two hex files in question, paying particular attention to the areas of hex code used by the bootloader. Another method is to compare the <project>.lst files. The bootloader uses some redirect vectors to allow certain application address parameters to change. All these jump vectors must match for an application and a bootloader. After a bootloader is deployed to a field application, there is no way to alter the code within it. A future application must still ‘agree’ about where mutually used jump vectors are stored.
6. The PSoC based translator app hangs when a bootload operation fails. There is an if-def based timeout that can be configured to allow the PSoC base translator to drop a communication attempt after a variable software loop. For debugging purposes, you can turn this software switch on or off. Examine the source code of the project for the timeout switch.
7. Power Stability. Power noise, glitching, brownout, slow power ramp poor connections. All of these power problems can cause difficult to diagnose problems with flash programming. Program execution is rapid with respect to power ramps, and in some cases, a part may still have changing power levels when flash programming takes place. One example is a status write to flash at power up. You must evaluate your use model and the potential for changing power supply conditions during flash operations. Poor power stability may contribute to non functional parts and may appear to be the result of poor flash retention.

Application Programming Interface

The Application Programming Interface (API) firmware gives high level commands that support sending and receiving multi-byte transfers. Read buffers may be set up in RAM or Flash memory. Write buffers can only be set up in the RAM memory.

Note

In this, as in all user module APIs, the values of the A and X register may be altered by calling an API function. It is the responsibility of the calling function to preserve the values of A and X before the call if those values are required after the call. This “registers are volatile" policy was selected for efficiency reasons and has been in force since version 1.0 of PSoC Designer. The C compiler automatically takes care of this requirement. Assembly language programmers must ensure their code observes the policy, too. Though some user module API function may leave A and X unchanged, there is no guarantee they may do so in the future.

For Large Memory Model devices, it is also the caller's responsibility to preserve any value in the CUR_PP, IDX_PP, MVR_PP, and MVW_PP registers. Even though some of these registers may not be modified now, there is no guarantee that will remain the case in future releases.

ENTER_BOOTLOADER

Description:

Routine to completely setup the bootloader and prepare to download a new application program. After this routine is called, it does not return unless a timeout or reset occurs.

The GenericBootloaderEntry function name is always located at the same physical ROM address, so that an application compiled at a later date can still use this function call to enter the bootloader. All three of these routines represent the same address vector. The vector “GenericBootloaderEntry" is given so that there is an entry point that does not vary when the instance name of the user module is changed.

C Prototype:

```
void ENTER_BOOTLOADER(void);
```

Other API function names can be invoked using the names indicated earlier.

Assembler:

```
lcall ENTER_BOOTLOADER
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BL_SetTemp

Description:

This function is used to dynamically update the bootloader with the latest die temperature measurement. In this case, the application obtains a die temperature measurement and passes it to the bootloader using this function. Then, when a bootload event occurs, the bootloader programs the flash optimally based on the temperature passed to it using this function.

It is recommended that you periodically measure (or otherwise determine) the device's die temperature during run time. Every time the die temperature is measured, it should be passed to the bootloader using this function. The bootloader uses the die temperature passed to it to optimally vary the flash programming erase and write periods during a bootload. This optimizes the flash's retention and endurance. As a result, the time it takes to execute a bootload varies depending on the temperature value passed to the bootloader.

The die temperature can be measured using a user module that measures the device's on-chip temperature sensor. Or, by reading or measuring the temperature from some other external device or temperature sensor.

This function rewrites the Die Temperature value that is set by the "Flash_Program_Temperature_Deg_C" user module parameter.

C Prototype:

```
void BL_SetTemp (CHAR cTemp);
```

Assembler:

```
mov A, cTemp
lcall BL_SetTemp
```

Example Code:

```
void main(void)
{
CHAR cDieTemp = -20;  // Allocate a variable to hold the die temperature
// Use -20C as the default value
...
// Measure die temperature here and copy to cDieTemp variable
BL_SetTemp(cDieTemp); // Update Bootloader with real die temperature
ENTER_BOOTLOADER();  // Run the BootLoader
...
}
```

Parameters:

cTemp: Die Temperature in Celsius degrees.

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_Start

Description:

Empty routine given for compatibility.

C Prototype:

```
void  BootLdrI2C_Start(void);
```

Assembler:

```
lcall BootLdrI2C_Start
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_DisableInt

Description:

Disables the I^2C slave by disabling the SDA interrupt. Performs the same action as I2Cs_Stop.

C Prototype:

```
void  BootLdrI2C_DisableInt(void);
```

Assembler:

```
lcall BootLdrI2C_DisableInt
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_EnableInt

Description:

Enables I^2C interrupt allowing start condition detection. Call the global interrupt enable function by using the macro: M8C_EnableGInt.

C Prototype:

```
void  BootLdrI2C_EnableInt(void);
```

Assembler:

```
lcall BootLdrI2C_EnableInt
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_Poll() and BootLdrI2C_BootLdr_Poll()

Description:

Used when the Communication_ Service_Type parameter is set to Polled. This function gives a user controlled entry into the I/O processing routine. If Communication_Service_Type parameter is set to Interrupt, the function does nothing.

C Prototype:

```
void BootLdrI2C_Poll(void);
void BootLdrI2C_BootLdr_Poll(void);
```

Assembler:

```
lcall BootLdrI2C_Poll
lcall BootLdrI2C_BootLdr_Poll
```

Parameters:

None

Return Value:

None

Side Effects:

One I^2C event is processed each time this routine is called and status variables are updated. An event constitutes either an error condition, an I/O byte, or in certain cases, a stop condition. There are three possible results from calling this routine:

1. No action if no data is available.
2. Reception or transmission of an address or data byte if one is available.
3. Processing of a stop ‘event’ when an external master has completed its write operation. When a stop state is processed at the end of a write operation, only status variables are updated. If an I^2C byte is pending when a stop state is processed, the I2CHW_Poll function must be called again to process it.

   The I2CHW_Poll() function has no effect if Communication_Service_Type is set to Interrupt. When a start/restart condition and an address is detected on the bus the bus is stalled until the I2CHW_Poll()

function is called. If the address is NAK'ed, subsequent bytes transferred for that transaction are ignored until another start/restart and address is detected. Otherwise, the I^2C bus is stalled for each data byte until the I2CHW_Poll() function is called. The I^2C data is stalled by the I^2C hardware until this function is called if the Communication_Service_Type is set to Polled. For received data, the bus is stalled at the end of the byte and before an ACK/NAK is generated by holding the SCL (clock) line low. For transmitted data, the bus is stalled immediately after the ACK/NAK bit is generated externally.

These two functions are compatible with the following restrictions: If the Bootloader is active and can be entered by an external application I^2C command, the API BootLdrI2C_BootLdr_Poll() must be used. If an I^2C address that is not the Bootloader address is detected, this address is tested and passed on to the foreground I^2C interrupt process, which also tests the address. If the Bootloader is inactive, use of the BootLdrI2C_Poll() API does not give the I^2C address to the internal bootloader data process routine. The address and subsequent data is instead passed directly to the foreground routine.

BootLdrI2C_Stop

Description:

Disables the I2CHW by disabling the I^2C interrupt.

C Prototype:

```
void  BootLdrI2C_Stop(void);
```

Assembler:

```
lcall BootLdrI2C_Stop
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_EnableSlave

Description:

Enables the I^2C Slave function for the I^2C HW block by setting the Enable Slave bit in the I2C_CFG register.

C Prototype:

```
void  BootLdrI2C_EnableSlave(void);
```

Assembler:

```
lcall BootLdrI2C_EnableSlave
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_DisableSlave

Description:

Disables the I^2C Slave function by clearing the Enable Slave bit in the I2C_CFG register.

C Prototype:

```
void  BootLdrI2C_DisableSlave(void);
```

Assembler:

```
lcall BootLdrI2C_DisableSlave
```

Parameters:

None

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

The following API are available only for FullAPISupport:

BootLdrI2C_InitWrite

Description:

The BootLdrI2C_InitWrite routine initializes a data buffer pointer for the slave to use to deposit data, and zeroes the value of a count byte for the same buffer.

C Prototype:

```
void  BootLdrI2C_InitWrite(BYTE * pBootLdrI2C_WriteBuf, BYTE  BootLdrI2C_Write_Count);
```

Assembler:

```
mov A, Write_Count
push A
move A, >pWriteBuf
push A
mov A, <pWriteBuf
```

```
push A
lcall BootLdrI2C_InitWrite
```

Parameters:

pWriteBuf: A pointer to a RAM buffer location. Write_Count: The length of the write buffer.

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. The same is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_InitRamRead

Description:

The BootLdrI2C_InitRamRead routine initializes a data buffer pointer for the slave to use to retrieve data from, and zeroes the value of a count byte for the same buffer.

C Prototype:

```
void BootLdrI2C_InitRamRead(BYTE * pBootLdrI2C_ReadBuf, BYTE  BootLdrI2C_Read_Count);
```

Assembler:

```
mov A, Read_Count
push A
move A, >pReadBuf
push A
mov A, <pReadBuf
push A
lcall BootLdrI2C_InitRamRead
```

Parameters:

pReadBuf: A pointer to a RAM buffer location. Read_Count: The length of the read buffer.

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_InitFlashRead

Description:

The BootLdrI2C_InitFlashRead routine initializes a flash data buffer pointer for the slave to use to retrieve data from, and zeroes the value of a count byte for the same buffer.

C Prototype:

```
void  BootLdrI2C_InitFlashRead(const BYTE * pBootLdrI2C_flashaddr,  unsigned int
BootLdrI2C_Read_CountHI);
```

Assembler:

```
mov A, >Read_Count
push A
mov A, <Read_Count
push A
move A, >pflashaddr
push A
mov A, <pflashaddr
push A
lcall BootLdrI2C_InitFlashRead
```

Parameters:

pflashaddr: A pointer to a Flash data buffer location. Read_Count: The length of the read buffer.

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

Read status bits are cleared.

BootLdrI2C_bReadI2CStatus

Description:

Returns the value in the I2CStatus variable.

C Prototype:

```
BYTE  BootLdrI2C_bReadI2CStatus(void);
```

Assembler:

```
lcall BootLdrI2C_bReadI2CStatus ; Accumulator contains the status on return
```

Parameters:

None

Return Value:

bI2CStatus - status data

Constant	Value	Description
I2CHW_RD_NOERR	01h	Data is read by the master, normal ISR exit.
I2CHW_RD_ OVERFLOW	02h	More data bytes were read by the master than were available.
I2CHW_RD_ COMPLETE	04h	A read is initiated and is complete.
I2CHW_READFLASH	08h	The next read is from a Flash location.

Constant	Value	Description
I2CHW_WR_NOERR	10h	Data is successfully written by the master.
I2CHW_WR_OVERFLOW	20h	The master has written too many bytes for the write buffer.
I2CHW_WR_COMPLETE, I2CHW_ISR_NEW_ADDR	40h	A master write is completed by a new address or stop.
I2CHW_ISR_ACTIVE	80h	The I^2C ISR has not exited and is active.

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_ClrRdStatus

Description:

Clears the status bits in the Control/Status register, but does not alter buffer addresses, counts, or the Flash/Ram Read bit.

C Prototype:

```
void  BootLdrI2C_ClrRdStatus(void);
```

Assembler:

```
lcall BootLdrI2C_ClrRdStatus
```

Parameters:

None.

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

BootLdrI2C_ClrWrStatus

Description:

Clears the status bits in the Control/Status register, but does not alter buffer addresses, counts, or the Flash/Ram Read bit.

C Prototype:

```
void  BootLdrI2C_ClrWrStatus(void);
```

Assembler:

```
lcall BootLdrI2C_ClrWrStatus
```

Parameters:

None.

Return Value:

None

Side Effects:

The A and X registers may be modified by this or future implementations of this function. This is true for all RAM page pointer registers in the Large Memory Model (CY8C29xxx). When necessary, it is the calling function's responsibility to preserve the values across calls to fastcall16 functions.

Sample Firmware Source Code

Note: The instance name of the BootLdrI2C User Module is assumed to be BootLdrI2C_1.

Bootloader Only Configuration

In the sample code, the bootloader runs in the background.

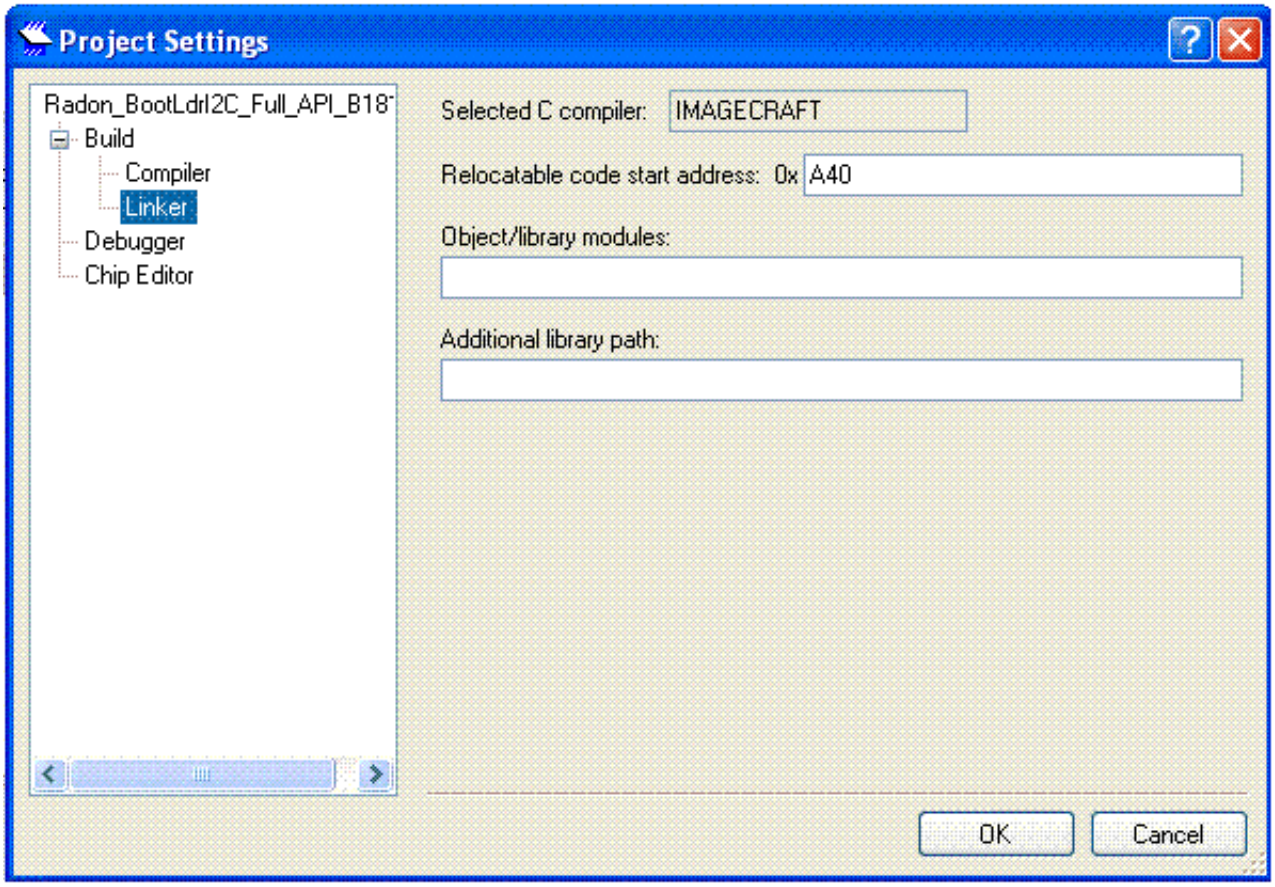
Configure the user module parameters as shown in Figure 6, for both the assembly language and C examples.

Figure 6. User Module Parameters - Bootloader Only

Boot_Loader_Addr_HEX	0x0
Communication_Service_Type	Interrupt
ApplicationCode_Start_Block	0x29
BootLoaderKey	0001020304050607
Flash_Program_Temperature_deg_	-20C
Ignore_N_I2C_Prefix_Bytes	2
BootLdrI2C_ver	0x1000
I2C Clock	100K Standard
I2C_Pin	P[1]0-P[1]1

Ensure that the code start address is set correctly.

Figure 7. Setting Code Start Address



Here is an implementation of an BootLdrI2C User Module written in C:

```
//-------------------------------------------------------------------------
// C main line
//-------------------------------------------------------------------------

#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules

void main(void)
{
    //start the bootloader running in the background
    BootLdrI2C_1_Start();
    BootLdrI2C_1_EnableSlave();
    BootLdrI2C_1_EnableInt();
    M8C_EnableGInt;
```

```
    // Insert your main routine code here
    while (1)
    {
    }
}
```

Here is an implementation of the BootLdrI2C User Module written in assembly language:

```
;-----------------------------------------------------------------------
; Assembly main line
;-----------------------------------------------------------------------

include "m8c.inc"       ; part specific constants and macros
include "memory.inc"    ; Constants & macros for SMM/LMM and Compiler
include "PSoCAPI.inc"   ; PSoC API definitions for all User Modules

export _main

_main:

    //start the bootloader running in the background
    lcall BootLdrI2C_1_Start
    lcall BootLdrI2C_1_EnableSlave
    lcall BootLdrI2C_1_EnableInt
    M8C_EnableGInt

    ; Insert your main assembly code here
.terminate
    jmp.terminate:
```

Full API Support Configuration

In the sample code, the following occur:

- The bootloader runs in the background
- I2C Slave writes and reads back echoed data from the buffer

Configure the user module parameters, as shown in Figure 8, for both the assembly language and C examples.

Figure 8. User Module Parameters - Full API

Slave_Addr_HEX	0x0
Boot_Loader_Addr_HEX	0x1
Read_Buffer_Types	RAM ONLY
Communication_Service_Type	Interrupt
ApplicationCode_Start_Block	0x29
BootLoaderKey	0001020304050607
Flash_Program_Temperature_deg_	-20C
Ignore_N_I2C_Prefix_Bytes	2
BootLdrI2C_ver	0x1000
I2C Clock	100K Standard
I2C_Pin	P[1]0-P[1]1

Ensure that the code start address is set correctly.

Here is an implementation of an BootLdrI2C User Module written in C:

```
//-----------------------------------------------------------------------
```

```
// C main line
//-----------------------------------------------------------------------------

#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules

/* Define buffer size */
#define BUFFERSIZE 8
/* Setup a 8 byte buffer */
BYTE txRxBuffer[BUFFERSIZE];
BYTE status;


void I2C_poll(void)
{
    status = BootLdrI2C_1_bReadI2CStatus();
    /* Wait to read data from the master */
    if( status & I2CHW_WR_COMPLETE )
    {
    /* Data received - clear the Write status */
        BootLdrI2C_1_ClrWrStatus();
        /* Reset the pointer for the next read data */
        BootLdrI2C_1_InitWrite(txRxBuffer,BUFFERSIZE);
    }
    /* wait until data is echoed */
    if( status & I2CHW_RD_COMPLETE )
    {
        /* Data echoed - clear the read status */
        BootLdrI2C_1_ClrRdStatus();
        /* Reset the pointer for the next data to echo */
        BootLdrI2C_1_InitRamRead(txRxBuffer,BUFFERSIZE);
    }
}


void main(void)
{
    //start the bootloader running in the background
    BootLdrI2C_1_Start();
    BootLdrI2C_1_EnableSlave();
    BootLdrI2C_1_EnableInt();
    M8C_EnableGInt;

    // Setup the Read and Write Buffer - set to the same buffer
    BootLdrI2C_1_InitRamRead(txRxBuffer,BUFFERSIZE);
    BootLdrI2C_1_InitWrite(txRxBuffer,BUFFERSIZE);
    /* Echo forever */
    while( 1 )
    {
        I2C_poll();

        // Place user code here to update and read structure data.
        // Please note that the I2C_poll() should be called often enough to properly
//serve I2C transactions
```

```
        // Thus if user code is large call the I2C_poll() multiple times during main
//loop execution
    }
}
```

Here is an implementation of the BootLdrI2C User Module written in assembly language:

```
;-----------------------------------------------------------------------------
; Assembly main line
;-----------------------------------------------------------------------------

include "m8c.inc"       ; part specific constants and macros
include "memory.inc"    ; Constants & macros for SMM/LMM and Compiler
include "PSoCAPI.inc"   ; PSoC API definitions for all User Modules

export _main

area bss (ram, rel)
; Define buffer size
BUFFERSIZE: equ 8
; Setup a 8 byte buffer
txRxBuffer: blk BUFFERSIZE
status:     blk 1

area text (rom, rel)
I2C_poll:

    lcall BootLdrI2C_1_bReadI2CStatus
    mov   [status], A

    ; Wait to read data from the master

    tst [status], I2CHW_WR_COMPLETE
    jz  CheckRdStatus

    ; Data received - clear the Write status
    lcall BootLdrI2C_1_ClrWrStatus

    ;Reset the pointer for the next read data
    mov  A, BUFFERSIZE
    push A
    mov  A, >txRxBuffer
    push A
    mov  A, <txRxBuffer
    push A
    lcall BootLdrI2C_1_InitWrite
    add  SP, -3

CheckRdStatus:
    ;wait until data is echoed
    tst [status],I2CHW_RD_COMPLETE
    jz   I2C_poll_exit

    ; Data echoed - clear the read status
    lcall BootLdrI2C_1_ClrRdStatus
```

```
    ; Reset the pointer for the next data to echo
    mov  A, BUFFERSIZE
    push A
    mov  A, >txRxBuffer
    push A
    mov  A, <txRxBuffer
    push A
    lcall BootLdrI2C_1_InitRamRead
    add  SP, -3

I2C_poll_exit:
    ret


_main:
    ; start the bootloader running in the background
    lcall BootLdrI2C_1_Start
    lcall BootLdrI2C_1_EnableSlave
    lcall BootLdrI2C_1_EnableInt
    M8C_EnableGInt

    ; Setup the Read and Write Buffer - set to the same buffer
    ; Setup the Read Buffer
    mov  A, BUFFERSIZE
    push A
    mov A, >txRxBuffer
    push A
    lcall BootLdrI2C_1_InitRamRead
    add  SP, -3

    ; Setup the Write Buffer
    mov  A, BUFFERSIZE
    push A
    mov A, >txRxBuffer
    push A
    mov  A, <txRxBuffer
    push A
    lcall BootLdrI2C_1_InitWrite
    add  SP, -3

loop:
    call I2C_poll

    ; Place user code here to update and read structure data.
    ; Please note that the I2C_poll() should be called often enough to properly
    ; Thus if user code is large call the I2C_poll() multiple times during main

    jmp loop
```

Configuration Registers

This section describes the PSoC Resource Registers used or modified by the BootLdrI2C User Module.

Table 1. Resource I2C_CFG: Bank 0 reg[D6] Configuration Register

Bit	7	6	5	4	3	2	1	0
Value	Reserved	PinSelect	Bus Error IE	Stop IE	Clock Rate[1]	Clock Rate[0]	Enable Master	Enable Slave

Pin Select: Selects either SCL and SDA as P1[5]/P1[7] or P1[0]/P1[1].

Bus Error Interrupt Enable: Enable I^2C interrupt generation on a Bus Error.

Stop Error Interrupt Enable: Enable an I^2C interrupt on an I^2C Stop condition.

Clock Rate[1,0]: Select from 3 valid Clock rates; 50, 100, and 400 Kbps (400 Kbps when CPU_Clk_speed is greater than 6 MHz).

Enable Master: Enable the I^2C HW block as a bus Master.

Enable Slave: Enable the I^2C HW block as a bus Slave.

Table 2. Resource I2C_SCR: Bank 0 reg[D7] Status Control Register

Bit	7	6	5	4	3	2	1	0
Value	Bus Error	Lost Arb	Stop Status	ACK out	Address	Transmit	Last Rec'd Bit (LRB)	Byte Complete

Bus Error: Indicates a Bus Error condition is detected.

Lost Arbitration: In MultiMaster mode indicates loss of arbitration for this device (the device does not control the bus).

Stop Status: An I^2C stop condition has been detected.

ACK out: direct the I^2C block to Acknowledge (1) or Not Acknowledge (0) a received byte.

Address: Received or transmitted byte is an address.

Last Received Bit (LRB): Value of last received bit (bit 9) in a transmit sequence, status of Ack/Nak from destination device.

Byte Complete: 8 data bits have been received. For Receive Mode, the bus is stalled waiting for an Ack/Nak. For Transmit Mode Ack Nak has also been received (see LRB) and the bus is stalled for the next action to be taken.

Table 3. Resource I2C_DR: Bank 0 reg[D8] Data Register

Bit	7	6	5	4	3	2	1	0
Value	Data							

Received or Transmitted data. To transmit data, this register must be loaded before a write to the I2C_SCR register. Received data is read from this register. It may contain an address or data.

Table 4. Resource I2C_MSCR: Bank 0 reg[D9] Master Status Control Register

Bit	7	6	5	4	3	2	1	0
Value	Reserved	Reserved	Reserved	Reserved	Bus Busy	Master Mode	Restart Gen	Start Gen

Bus Busy: Master Only, set when any bus Start condition is detected, cleared when a Stop condition is detected.

Master Mode: Indicates the device is currently operating as a bus Master.

Restart Gen: Master only, may be set to generate a repeat start for the I^2C bus.

Start Gen: Master Only, When bus becomes idle, generate an I^2C bus start and transmit an I^2C address using data in the data register (I2C_DR).

Appendix

The following section contains additional information that may be useful when creating an I2C bootloader.

Bootloader I^2C Download (.dld file) Format

This section briefly discusses the format of the file <project_name>.dld:

Two sample download records are shown in the following figures – the first, third, and the last. These records consist of actual data that would be transmitted between the I^2C master and a slave to be bootloaded. The format of the records is described in this section.

Figure 9. Sample Record

First Download Record

```
70 00 00 FF 38 00 01 02 03 04 05 06 07                  Enter bootloader FF, 38
71 20                                                   Master reads bootloader slave to acquire status
70 00 00 FF 39 00 01 02 03 04 05 06 07 00 02 40 40 40 40  No status request  or response
70 00 10 30 7E 30 30 7E 30 30 30 7E 30 30 30 7E 30 30 30
70 00 20 7E 30 30 30 7E 30 30 30 7D 0B 64 7E 7E 30 30 30
70 00 30 7E 30 30 30 7E 30 30 30 7E 30 30 30 7E 30 30 30
70 00 40 7E 30 30 30 7E 30 30 30 7E 30 30 30 2E B2
71 20                                                   Status request and response
```

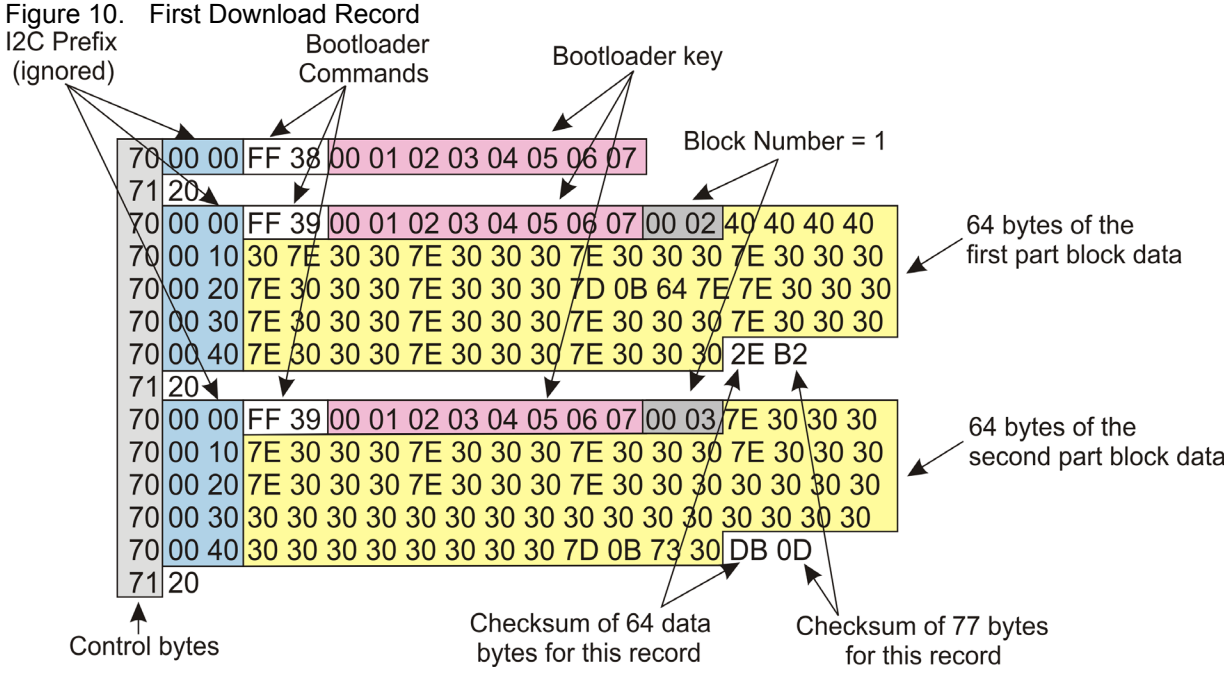
.....

Last Download Record

```
70 00 00 FF 39 00 01 02 03 04 05 06 07 01 FF 30 30 30 30  No status request  or response
70 00 10 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30
70 00 20 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30
70 00 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30 30
70 00 40 30 30 30 30 30 30 30 30 30 30 30 00 54
71 20                                                   Status request and response
70 00 00 FF 3B 00 01 02 03 04 05 06 07                  Exit bootloader FF, 3B
71 20*                                                  Status request and response
```

Figure 9 shows the format of the first record:

Figure 10. First Download Record



Every line begins with a control byte. The two control bytes used by the download protocol are:

- 70 – Slave address 38 write. The address is not considered part of the byte count.
- 71 – Slave address 38 read. The expected response to a slave address read is 0x20, success. Other possible responses are listed in Table 5:

Table 5. Slave Address Read Responses

Code	Meaning
0x20	Bootload mode (Success). Received 'Enter bootloader' command with valid bootLoader Key.
0x02	Image verify error. The checksum of application and relocatable interrupt vector areas calculated by the bootloader does not match the checksum received from the Host.
0x04	Flash checksum error. The flash block content does not match the data received from Host.
0x08	Flash protection error. Flash block cannot be rewritten because its flash protection level does not allow this.
0x10	Comm checksum error. Received a packet with incorrect checksum.
0x40	Invalid bootloader key. A packet with the incorrect bootLoaderKey value was received.
0x80	Invalid command error. Unknown command was received.

For details, see the BootLoader operation flowchart at the end of this document.

Slave address write commands do not require responses, so the next two bytes of each of the slave address write lines is an I^2C prefix that the bootloader ignores. Use the Ignore_N_I2C_Prefix_Bytes parameter to set the number of prefix bytes used in your application.

The first and third lines of the sample download record contain bootloader commands. The bootloader commands listed in Table 6 are used:

Table 6. Bootloader Commands

Command	Meaning
FF38	Enter bootloader
FF39	Write block
FF3B	Exit bootloader

All bootloader commands must be sent with the bootloader key. The bootloader ignores commands that are not sent with the proper key. You can set the bootloader key with the Bootloader_Key parameter.

Bootloader Write Block Command

Most of the commands sent to the bootloader are write block commands. The format of each of the write block commands is identical. The third block contains the checksum information. The format of the checksum block is discussed in this section. Each of the other write block command transmits a 64-byte hex record to the bootloader in five packets totalling 78 bytes (neglecting addresses and discarded prefixes).

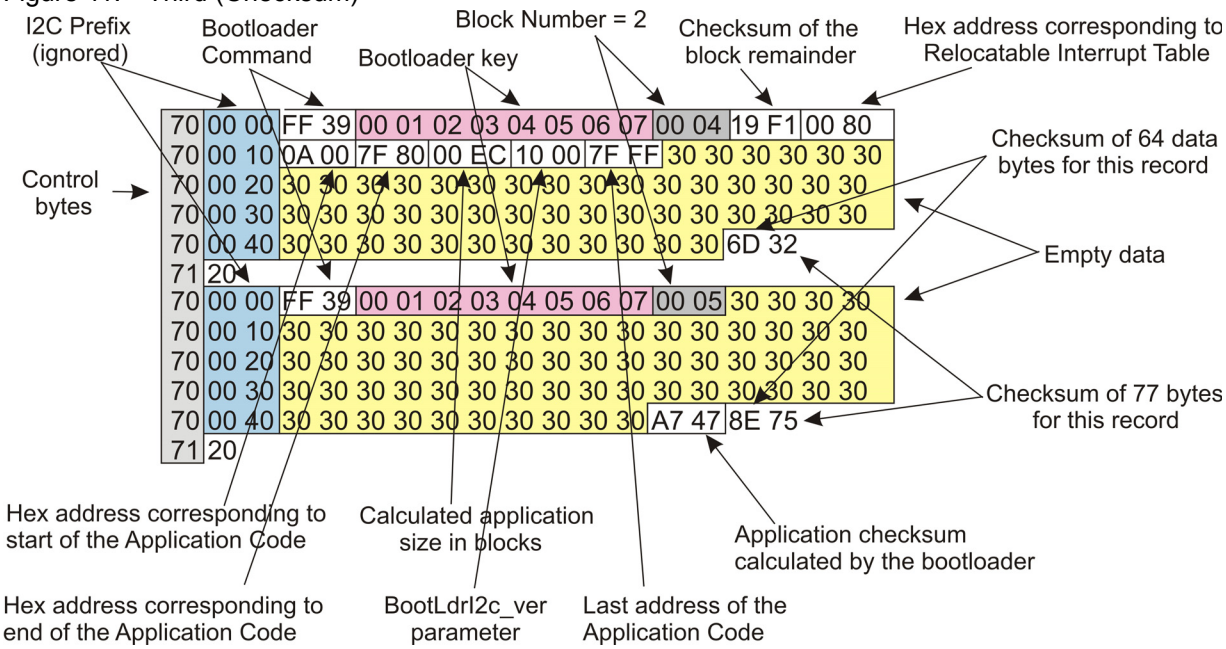
The first line of the write block command contains a control byte, an ignored 2-byte I^2C prefix, the write block command, the bootloader key, the block number being transmitted, and the first four bytes of data. The block number in this example is 0x0002, which corresponds to ROM address 0x0080.

The next three lines contain only the control byte, the I^2C prefix, and 16 bytes of data. The last line of the write block command contains the control byte, the I^2C prefix, the final 12 bytes of data, and two 1-byte checksums. The first checksum, 0x9A in this example, is the checksum of the data bytes for this record. The second checksum, 0x8A in this example, is the checksum of the entire 77 byte record, excluding address bytes and prefixes. Address bytes and prefixes are verified internally by the bootloader as they are received.

At the conclusion of the write block command, another status request is sent and it results in the response shown.

All the blocks transmitted have the same format. The third block contains the checksum information. Figure 9 shows the format of this record:

Figure 11. Third (Checksum)



The third record contains the checksum block (note that the block number is always 0x0004). The data in the record is described in this section.

The first line contains a control byte, an I^2C prefix, the bootloader write block command, the bootloader key, and the block number just as the other records did. The next two bytes contain an optional checksum for the remainder of the block, 0x0E8C in this case. The last two bytes of the line contain the hex address of the Relocatable Interrupt Vectors Table (see Figure 2 for more information).

The second line of the record contains a control byte and an I^2C prefix, followed by a two byte value that represents the hex address of the ApplicationCode_Start_Block user module parameter calculated from block 0x29. The next two bytes are the hex address of the end of Application Code calculated from block 0xFF. This is followed by two bytes that are the application size in blocks. The final two byte real data value on this line is the bootloader version number from the BootLdrI2C_ver parameter. The remainder of the line is empty data space.

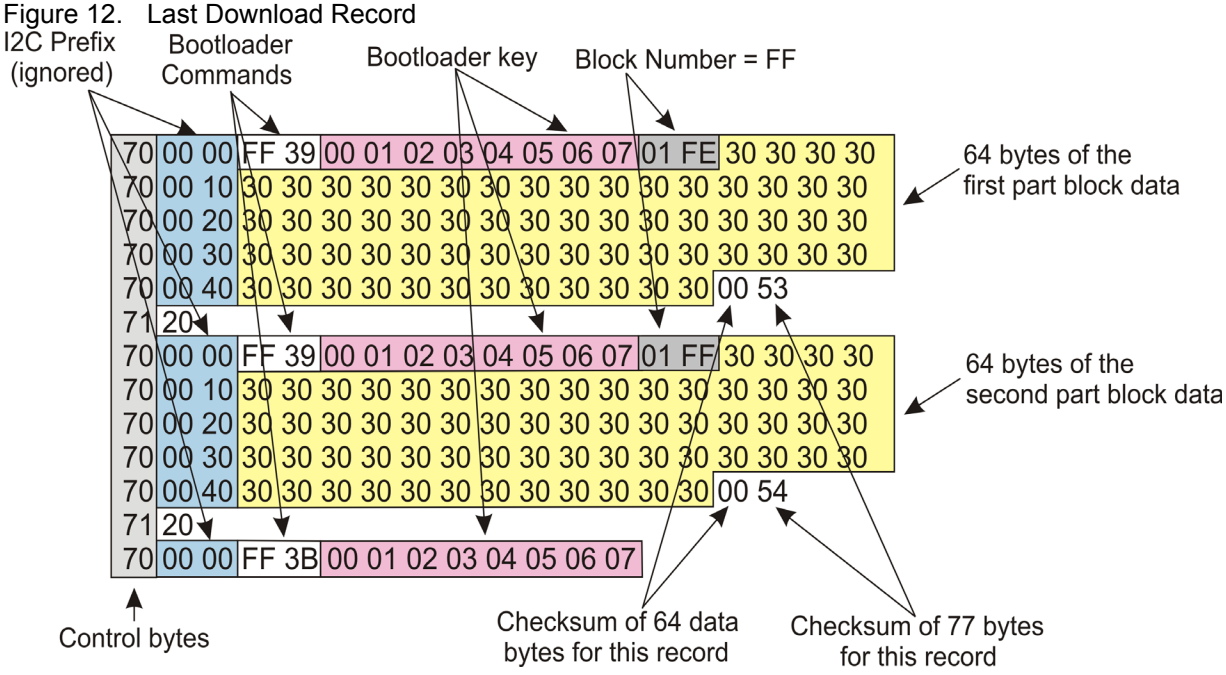
The next two lines contain additional empty data space. The last line of the checksum block contains empty data space until the last four bytes of the line. The last four bytes contain a two byte application checksum calculated by the bootloader, a one byte block checksum from the Intel hex record, and finally the checksum of the entire 77 byte record, excluding address bytes and prefixes. Address bytes and prefixes are verified internally by the bootloader as they are received.

The next line contains another status request and response.

The bootloader exit command consists of control byte 70, a two byte prefix, the bootloader exit command 0xFF3B, and the bootloader key.

Figure 10 shows the last download record:

Figure 12. Last Download Record

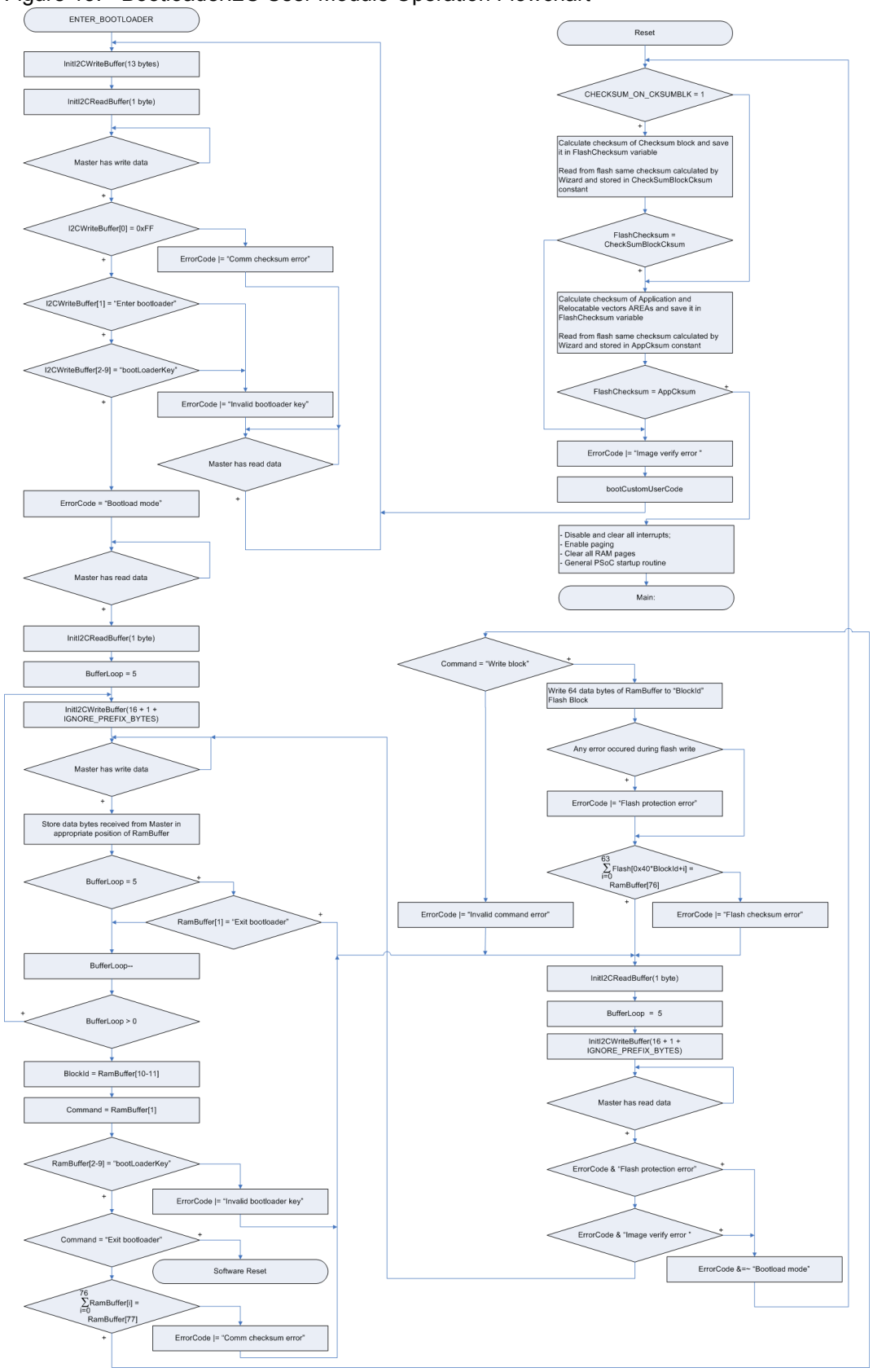


The last line is a final status request and possibly a response. When the exit bootloader command is received, the target system immediately executes an internal reset and begins verifying the checksum for the downloaded application. This is done using the parameters given in the checksum block. Depending on the speed of the host system, the bootloader may already have begun its reset process before the master is able to receive a valid status byte. For this reason, the status (0x20) may not always be present. Instead, the address 0x71 may simply be NAK'ed.

BootLdrI2C and E2PROM User Module Coexistence

When you place an E2PROM User Module in a Bootloader project, allocate the E2PROM blocks in the Customer Reserved Blocks area. This area is between the Bootloader Code Area and the Application Code Area (see Bootloader Memory Organization for information). This ensures that the E2PROM blocks are not part of the Application Code Area, and are not calculated as part of the Application checksum.

Figure 13. BootloaderI2C User Module Operation Flowchart



Version History

Version	Originator	Description
1.2	DHA	Added Version History
2.00	DHA	1. Reorganized the memory map. 2. Placed Reloc Interrupt Vectors Table at address 0x0080. 3. Placed Checksum Block at address 0x0100. 4. Placed Bootloader Start at address 0x0140. 5. Added SetTemperature() function. 6. Added Bootloader API Jump Table. 7. Updated user module Parameters table.
2.10	DHA	1. Replaced .Literal and .EndLiteral statement with .nocc around the SSC call. 2. Removed export `@INSTANCE_NAME`_EnterBootloader statement. 3. Added user code section for I2C address compare customization.

Version	Originator	Description
2.20	DHA	1. Updated the initialization of Application_Checksum_Block and TWO_Block_Relocatable_Interrupt_Table. 2. Added support to display bootloader output files in Workspace Explorer. 3. Updated the description in the "Improper Settings in Flashsecurity.txt" section. 4. Added "I2C and Sleep" section. 5. Corrected paths to the flashsecurity.example, custom.lkp and boot.tpl templates for the CY8C27x43 devices.
2.30	DHA	1. Updated area declarations to support Imagecraft optimization. 2. Added more information in this user module datasheet about the checksum calculation in the *.iic file. 3. Added javascript updates to enhance the wizard performance. 4. Added program temperature initialization. 5. Fixed issues related to the coexistence with the watchdog timer.
2.40	DHA	1. Added output in csv format. 2. Added CY20X34 device support. 3. Limited BootLoaderKey parameter to 16 symbols.
3.00	MYKZ	1. Corrected the method of clearing posted interrupts. 2. Added support for CY8CLED0xx0x families. 3. Added a warning message to notify the user when the user module is removed from a project. 4. Corrected GenericApplicationStart and ENTER_BOOTLOADER labels to support CY8C28xxx family. 5. Fixed memory overlap problem: variables used by both Bootloader and Application were locked at the end of RAM page 0.

Note PSoC Designer 5.1 introduces a Version History in all user module datasheets. This section documents high level descriptions of the differences between the current and previous user module versions.

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