




# TivaWare™ Boot Loader

**USER'S GUIDE**

---

# Copyright

Copyright © 2007-2014 Texas Instruments Incorporated. All rights reserved. Tiva and TivaWare are trademarks of Texas Instruments Instruments. ARM and Thumb are registered trademarks and Cortex is a trademark of ARM Limited. Other names and brands may be claimed as the property of others.

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

Texas Instruments  
108 Wild Basin, Suite 350  
Austin, TX 78746  
[www.ti.com/tiva-c](http://www.ti.com/tiva-c)



# Revision Information

This is version 2.1.0.12573 of this document, last updated on February 07, 2014.

---

# Table of Contents

<b>Copyright</b>	<b>2</b>
<b>Revision Information</b>	<b>2</b>
<b>1 Introduction</b>	<b>5</b>
<b>2 Startup Code</b>	<b>9</b>
<b>3 Serial Update</b>	<b>11</b>
3.1 Packet Handling	11
3.2 Transport Layer	12
3.3 Serial Commands	13
<b>4 Ethernet Update</b>	<b>17</b>
<b>5 CAN Update</b>	<b>19</b>
5.1 CAN Bus Clocking	19
5.2 CAN Commands	19
<b>6 USB Device (DFU) Update</b>	<b>23</b>
6.1 USB Device Firmware Upgrade Overview	23
6.2 Tiva-Specific USB Download Commands	28
<b>7 Customization</b>	<b>35</b>
<b>8 Configuration</b>	<b>37</b>
<b>9 Source Details</b>	<b>51</b>
9.1 Autobaud Functions	51
9.2 CAN Functions	52
9.3 Decryption Functions	53
9.4 Ethernet Functions	54
9.5 File System Functions	54
9.6 I2C Functions	54
9.7 Main Functions	56
9.8 Packet Handling Functions	57
9.9 SSI Functions	59
9.10 UART Functions	60
9.11 Update Check Functions	62
9.12 USB Device Functions	63
<b>IMPORTANT NOTICE</b>	<b>70</b>



# 1 Introduction

The Texas Instruments® Tiva® boot loader is a small piece of code that can be programmed at the beginning of flash to act as an application loader as well as an update mechanism for applications running on a Tiva ARM® Cortex™-M3-based microcontroller. The boot loader can be built to use either the UART0, SSI0, I2C0, CAN, Ethernet, or USB ports to update the code on the microcontroller. The boot loader is customizable via source code modifications, or simply deciding at compile time which routines to include. Since full source code is provided, the boot loader can be completely customized.

Three update protocols are utilized. On UART0, SSI0, I2C0, and CAN, a custom protocol is used to communicate with the download utility to transfer the firmware image and program it into flash. When using Ethernet or USB DFU, however, different protocols are employed. On Ethernet the standard bootstrap protocol (BOOTP) is used and for USB DFU, updates are performed via the standard Device Firmware Upgrade (DFU) class.

When configured to use UART0, Ethernet, or USB, the LM Flash Programmer GUI can be used to download an application via the boot loader. The LM Flash Programmer utility is available for download from [www.ti.com/tiva](http://www.ti.com/tiva).

## Source Code Overview

The following is an overview of the organization of the source code provided with the boot loader.

<code>bl_autobaud.c</code>	The code for performing the auto-baud operation on the UART port. This is separate from the remainder of the UART code so that the linker can remove it when it is not used.
<code>bl_can.c</code>	The functions for performing a firmware update via the CAN port.
<code>bl_can.h</code>	Definitions used by the CAN update routine.
<code>bl_check.c</code>	The code to check if a firmware update is required, or if a firmware update is being requested by the user.
<code>bl_check.h</code>	Prototypes for the update check code.
<code>bl_commands.h</code>	The list of commands and return messages supported by the boot loader.
<code>bl_config.c</code>	A dummy source file used to translate the <code>bl_config.h</code> C header file into a header file that can be included in assembly code. This is needed for the Keil tool chain since it is not able to pass assembly source code through the C preprocessor.
<code>bl_config.h.tmp1</code>	A template for the boot loader configuration file. This contains all of the possible configuration values.

<code>bl_decrypt.c</code>	The code to perform an in-place decryption of the downloaded firmware image. No decryption is actually performed in this file; this is simply a stub that can be expanded to perform the require decryption.
<code>bl_decrypt.h</code>	Prototypes for the in-place decryption routines.
<code>bl_enet.c</code>	The functions for performing a firmware update via the Ethernet port.
<code>bl_fs.c</code>	The functions to provide simple FAT file system support.
<code>bl_fs.h</code>	Prototypes for the file system functions.
<code>bl_i2c.c</code>	The functions for transferring data via the I2C0 port.
<code>bl_i2c.h</code>	Prototypes for the I2C0 transfer functions.
<code>bl_link.ld</code>	The linker script used when the <code>codered</code> , <code>gcc</code> , or <code>sourcerygxx</code> compiler is being used to build the boot loader.
<code>bl_link.sct</code>	The linker script used when the <code>rvmdk</code> compiler is being used to build the boot loader.
<code>bl_link.xcl</code>	The linker script used when the <code>ewarm</code> compiler is being used to build the boot loader.
<code>bl_link_ccs.cmd</code>	The linker script used when the <code>ccs</code> compiler is being used to build the boot loader.
<code>bl_main.c</code>	The main control loop of the boot loader.
<code>bl_packet.c</code>	The functions for handling the packet processing of commands and responses.
<code>bl_packet.h</code>	Prototypes for the packet handling functions.
<code>bl_ssi.c</code>	The functions for transferring data via the SSI0 port.
<code>bl_ssi.h</code>	Prototypes for the SSI0 transfer functions.
<code>bl_startup_ccs.s</code>	The start-up code used when the <code>ccs</code> compiler is being used to build the boot loader.
<code>bl_startup_codered.S</code>	The start-up code used when the <code>codered</code> compiler is being used to build the boot loader.
<code>bl_startup_ewarm.S</code>	The start-up code used when the <code>ewarm</code> compiler is being used to build the boot loader.

<code>bl_startup_gcc.S</code>	The start-up code used when the <code>gcc</code> compiler is being used to build the boot loader.
<code>bl_startup_rvmdk.S</code>	The start-up code used when the <code>rvmdk</code> compiler is being used to build the boot loader.
<code>bl_startup_sourcerygxx.S</code>	The start-up code used when the <code>sourcerygxx</code> compiler is being used to build the boot loader.
<code>bl_uart.c</code>	The functions for transferring data via the UART0 port.
<code>bl_uart.h</code>	Prototypes for the UART0 transfer functions.
<code>bl_usb.c</code>	Main functions implementing the USB DFU protocol boot loader.
<code>bl_usbfuncs.c</code>	A cut-down version of the USB library containing support for enumeration and the endpoint 0 transactions required to implement the USB DFU device.
<code>bl_usbfuncs.h</code>	Prototypes for the functions provided in <code>bl_usbfuncs.c</code> .
<code>usbdfu.h</code>	Type definitions, labels related to the USB Device Firmware Upgrade class boot loader.





## 2 Startup Code

The start-up code contains the minimal set of code required to configure a vector table, initialize memory, copy the boot loader from flash to SRAM, and execute from SRAM. Because some tool chain-specific constructs are used to indicate where the code, data, and bss segments reside in memory, each supported tool chain has its own separate file that implements the start-up code. The start-up code is contained in the following files:

- `bl_startup_ewarm.S` (IAR Embedded Workbench)
- `bl_startup_gcc.S` (GNU GCC)
- `bl_startup_rvmdk.S` (Keil RV-MDK)
- `bl_startup_sourcerygxx.S` (Sourcery CodeBench)
- `bl_startup_ccs.s` (Texas Instruments Code Composer Studio)

Accompanying the start-up code for each tool chain are linker scripts that are used to place the vector table, code segment, data segment initializers, and data segments in the appropriate locations in memory. The scripts are located in the following files:

- `bl_link.ld` (GNU GCC and Sourcery CodeBench)
- `bl_link.sct` (Keil RV-MDK)
- `bl_link.xcl` (IAR Embedded Workbench)
- `bl_link_ccs.cmd` (TI Code Composer Studio)

The boot loader's code and its corresponding linker script use a memory layout that exists entirely in SRAM. This means that the load address of the code and read-only data are not the same as the execution address. This memory map allows the boot loader to update itself since it is actually running from SRAM only. The first part of SRAM is used as the copy space for the boot loader while the rest is reserved for stack and read/write data for the boot loader. Once the boot loader calls the application, all SRAM becomes usable by the application.

The vector table of the Cortex-M3 microprocessor contains four required entries: the initial stack pointer, the reset handler address, the NMI handler address, and the hard fault handler address. Upon reset, the processor loads the initial stack pointer and then starts executing the reset handler. The initial stack pointer is required since an NMI or hard fault can occur at any time; the stack is required to take those interrupts since the processor automatically pushes eight items onto the stack.

The `Vectors` array contains the boot loader's vector table which varies in size based on the addition of the auto-baud feature or USB DFU support. These options requires additional interrupt handlers expand the vector table to populate the relevant entries. Since the boot loader executes from SRAM and not from flash, tool chain-specific constructs are used to provide a hint to the linker that this array is located at `0x2000.0000`.

The `IntDefaultHandler` function contains the default fault handler. This is a simple infinite loop, effectively halting the application if any unexpected fault occurs. The application state is, therefore, preserved for examination by a debugger. If desired, a customized boot loader can provide its own handlers by adding the appropriate handlers to the `Vectors` array.

After a reset, the start-up code copies the boot loader from flash to SRAM, branches to the copy of the boot loader in SRAM, and checks to see if an application update should be performed by calling `CheckForceUpdate()`. If an update is not required, the application is called. Otherwise the functions that are called are based on the mode of operation for the boot loader. For UART0, SSI0,

and I2C0, the microcontroller is initialized by calling `ConfigureDevice()` and then the boot loader calls the serial control loop `Updater()`. For Ethernet, the microcontroller is initialized by calling `ConfigureEnet()` and then the boot loader calls the Ethernet control loop `UpdateBOOTP()`. For CAN, the microcontroller is initialized by calling `ConfigureCAN()` and then the boot loader calls the CAN control loop `UpdaterCAN()`. For USB, the microcontroller is initialized by calling `ConfigureUSB()` after which the function `UpdaterUSB()` configures the USB interface for device mode.

The check for an application update (in `CheckForceUpdate()`) consists of checking the beginning of the application area and optionally checking the state of a GPIO pin. The application is assumed to be valid if the first location is a valid stack pointer (that is, it resides in SRAM, and has a value of `0x2xxx.xxxx`), and the second location is a valid reset handler address (that is, it resides in flash, and has a value of `0x000x.xxxx`, where the value is odd). If either of these tests fail, then the application is assumed to be invalid and an update is forced. The GPIO pin check can be enabled with **ENABLE\_UPDATE\_CHECK** in the `bl_config.h` header file, in which case an update can be forced by changing the state of a GPIO pin (for example, with a push button). If the application is valid and the GPIO pin is not requesting an update, the application is called. Otherwise, an update is started by entering the main loop of the boot loader.

Additionally, the application can call the boot loader in order to perform an application-directed update. In this case, the boot loader assumes that the application has already configured the peripheral that it will use for the update. This allows the boot loader to use the peripheral as is to perform the update. The boot loader also assumes that the interrupt to the core has been left enabled as well, which means that that application should not call `IntMasterDisable()` before calling the boot loader. Once the application calls the boot loader, the boot loader copies itself to SRAM, branches to the SRAM copy of the boot loader, and starts the update by calling `Updater()` (for UART0, SSI0, and I2C0), `UpdateBOOTP()` (for Ethernet), `AppUpdaterCAN()` (for CAN) or `AppUpdaterUSB()` (for USB). The `svCall` entry of the vector table contains the location of the application-directed update entry point.

## 3 Serial Update

When performing an update via a serial port (UART0, SSI0, or I2C0), `ConfigureDevice()` is used to configure the selected serial port, making it ready to be used to update the firmware. Then, `Updater()` sits in an endless loop accepting commands and updating the firmware when requested. All transmissions from this main routine use the packet handler functions (`SendPacket()`, `ReceivePacket()`, `AckPacket()`, and `NakPacket()`). Once the update is complete, the boot loader can be reset by issuing a reset command to the boot loader.

When a request to update the application comes through and **FLASH\_CODE\_PROTECTION** is defined, the boot loader first erases the entire application area before accepting the binary for the new application. This prevents a partial erase of flash from exposing any of the code before the new binary is downloaded to the microcontroller. The boot loader itself is left in place so that it will not boot a partially erased program. Once all of the application flash area has been successfully erased, the boot loader proceeds with the download of the new binary. When **FLASH\_CODE\_PROTECTION** is not defined, the boot loader only erases enough space to fit the new application that is being downloaded.

In the event that the boot loader itself needs to be updated, the boot loader must replace itself in flash. An update of the boot loader is recognized by performing a download to address 0x0000.0000. Once again the boot loader operates differently based on the setting of **FLASH\_CODE\_PROTECTION**. When **FLASH\_CODE\_PROTECTION** is defined and the download address indicates an boot loader update, the boot loader protects any application code already on the microcontroller by erasing the entire application area before erasing and replacing itself. If the process is interrupted at any point, either the old boot loader remains present in the flash and does not boot the partial application or the application code will have already been erased. When **FLASH\_CODE\_PROTECTION** is not defined, the boot loader only erases enough space to fit its own code and leaves the application intact.

### 3.1 Packet Handling

The boot loader uses well-defined packets to ensure reliable communications with the update program. The packets are always acknowledged or not acknowledged by the communicating devices. The packets use the same format for receiving and sending packets. This includes the method used to acknowledge successful or unsuccessful reception of a packet. While the actual signaling on the serial ports is different, the packet format remains independent of the method of transporting the data.

The boot loader uses the `SendPacket()` function in order to send a packet of data to another device. This function encapsulates all of the steps necessary to send a valid packet to another device including waiting for the acknowledge or not-acknowledge from the other device. The following steps must be performed to successfully send a packet:

1. Send out the size of the packet that will be sent to the device. The size is always the size of the data + 2.
2. Send out the checksum of the data buffer to help ensure proper transmission of the command. The checksum algorithm is implemented in the `Checksum()` function provided and is simply a sum of the data bytes.
3. Send out the actual data bytes.

4. Wait for a single byte acknowledgment from the device that it either properly received the data or that it detected an error in the transmission.

Received packets use the same format as sent packets. The boot loader uses the `ReceivePacket()` function in order to receive or wait for a packet from another device. This function does not take care of acknowledging or not-acknowledging the packet to the other device. This allows the contents of the packet to be checked before sending back a response. The following steps must be performed to successfully receive a packet:

1. Wait for non-zero data to be returned from the device. This is important as the device may send zero bytes between a sent and received data packet. The first non-zero byte received will be the size of the packet that is being received.
2. Read the next byte which will be the checksum for the packet.
3. Read the data bytes from the device. There will be packet size - 2 bytes of data sent during the data phase. For example, if the packet size was 3, then there is only 1 byte of data to be received.
4. Calculate the checksum of the data bytes and ensure if it matches the checksum received in the packet.
5. Send an acknowledge or not-acknowledge to the device to indicate the successful or unsuccessful reception of the packet.

The steps necessary to acknowledge reception of a packet are implemented in the `AckPacket()` function. Acknowledge bytes are sent out whenever a packet is successfully received and verified by the boot loader.

A not-acknowledge byte is sent out whenever a sent packet is detected to have an error, usually as a result of a checksum error or just malformed data in the packet. This allows the sender to re-transmit the previous packet.

## 3.2 Transport Layer

The boot loader supports updating via the I2C0, SSI0, and UART0 ports which are available on Tiva microcontrollers. The SSI port has the advantage of supporting higher and more flexible data rates but it also requires more connections to the microcontroller. The UART has the disadvantage of having slightly lower and possibly less flexible rates. However, the UART requires fewer pins and can be easily implemented with any standard UART connection. The I2C interface also provides a standard interface, only uses two wires, and can operate at comparable speeds to the UART and SSI interfaces.

### 3.2.1 I2C Transport

The I2C handling functions are `I2CSend()`, `I2CReceive()`, and `I2CFlush()` functions. The connections required to use the I2C port are the following pins: **I2CSCL** and **I2CSDA**. The device communicating with the boot loader must operate as the I2C master and provide the **I2CSCL** signal. The **I2CSDA** pin is open drain and can be driven by either the master or the slave I2C device.

### 3.2.2 SSI Transport

The SSI handling functions are `SSISend()`, `SSIReceive()`, and `SSIFlush()`. The connections required to use the SSI port are the following four pins: **SSITx**, **SSIRx**, **SSIClk**, and **SSIFss**. The device communicating with the boot loader is responsible for driving the **SSIRx**, **SSIClk**, and **SSIFss** pins, while the Tiva microcontroller drives the **SSITx** pin. The format used for SSI communications is the Motorola format with SPH set to 1 and SPO set to 1 (see Tiva Family data sheet for more information on this format). The SSI interface has a hardware requirement that limits the maximum rate of the SSI clock to be at most 1/12 the frequency of the microcontroller running the boot loader.

### 3.2.3 UART Transport

The UART handling functions are `UARTSend()`, `UARTReceive()`, and `UARTFlush()`. The connections required to use the UART port are the following two pins: **U0Tx** and **U0Rx**. The device communicating with the boot loader is responsible for driving the **U0Rx** pin on the Tiva microcontroller, while the Tiva microcontroller drives the **U0Tx** pin.

While the baud rate is flexible, the UART serial format is fixed at 8 data bits, no parity, and one stop bit. The baud rate used for communication can either be auto-detected by the boot loader, if the auto-baud feature is enabled, or it can be fixed at a baud rate supported by the device communicating with the boot loader. The only requirement on baud rate is that the baud rate should be no more than 1/32 the frequency of the microcontroller that is running the boot loader. This is the hardware requirement for the maximum baud rate for a UART on any Tiva microcontroller.

When using a fixed baud rate, the frequency of the crystal connected to the microcontroller must be specified. Otherwise, the boot loader will not be able to configure the UART to operate at the requested baud rate.

The boot loader provides a method to automatically detect the baud rate being used to communicate with it. This automatic baud rate detection is implemented in the `UARTAutoBaud()` function. The auto-baud function attempts to synchronize with the updater application and indicates if it is successful in detecting the baud rate or if it failed to properly detect the baud rate. The boot loader can make multiple calls to `UARTAutoBaud()` to attempt to retry the synchronization if the first call fails. In the example boot loader provided, when the auto-baud feature is enabled, the boot loader will wait forever for a valid synchronization pattern from the host.

## 3.3 Serial Commands

The following commands are used by the custom protocol on the UART0, SSI0, and I2C0 ports:

`COMMAND_PING`

This command is used to receive an acknowledge from the boot loader indicating that communication has been established. This command is a single byte.

The format of the command is as follows:

```
unsigned char ucCommand[1];  
ucCommand[0] = COMMAND_PING;
```

COMMAND\_DOWNLOAD

This command is sent to the boot loader to indicate where to store data and how many bytes will be sent by the `COMMAND_SEND_DATA` commands that follow. The command consists of two 32-bit values that are both transferred MSB first. The first 32-bit value is the address to start programming data into, while the second is the 32-bit size of the data that will be sent. This command also triggers an erasure of the full application area in the flash or possibly the entire flash depending on the address used. This causes the command to take longer to send the ACK/NAK in response to the command. This command should be followed by a `COMMAND_GET_STATUS` to ensure that the program address and program size were valid for the microcontroller running the boot loader.

The format of the command is as follows:

```
unsigned char ucCommand[9];

ucCommand[0] = COMMAND_DOWNLOAD;
ucCommand[1] = Program Address [31:24];
ucCommand[2] = Program Address [23:16];
ucCommand[3] = Program Address [15:8];
ucCommand[4] = Program Address [7:0];
ucCommand[5] = Program Size [31:24];
ucCommand[6] = Program Size [23:16];
ucCommand[7] = Program Size [15:8];
ucCommand[8] = Program Size [7:0];
```

COMMAND\_RUN

This command is sent to the boot loader to transfer execution control to the specified address. The command is followed by a 32-bit value, transferred MSB first, that is the address to which execution control is transferred.

The format of the command is as follows:

```
unsigned char ucCommand[5];

ucCommand[0] = COMMAND_RUN;
ucCommand[1] = Run Address [31:24];
ucCommand[2] = Run Address [23:16];
ucCommand[3] = Run Address [15:8];
ucCommand[4] = Run Address [7:0];
```

**COMMAND\_GET\_STATUS**

This command returns the status of the last command that was issued. Typically, this command should be received after every command is sent to ensure that the previous command was successful or, if unsuccessful, to properly respond to a failure. The command requires one byte in the data of the packet and the boot loader should respond by sending a packet with one byte of data that contains the current status code.

The format of the command is as follows:

```
unsigned char ucCommand[1];

ucCommand[0] = COMMAND_GET_STATUS;
```

The following are the definitions for the possible status values that can be returned from the boot loader when **COMMAND\_GET\_STATUS** is sent to the the microcontroller.

```
COMMAND_RET_SUCCESS
COMMAND_RET_UNKNOWN_CMD
COMMAND_RET_INVALID_CMD
COMMAND_RET_INVALID_ADD
COMMAND_RET_FLASH_FAIL
```

**COMMAND\_SEND\_DATA**

This command should only follow a **COMMAND\_DOWNLOAD** command or another **COMMAND\_SEND\_DATA** command, if more data is needed. Consecutive send data commands automatically increment the address and continue programming from the previous location. The transfer size is limited by the size of the receive buffer in the boot loader (as configured by the **BUFFER\_SIZE** parameter). The command terminates programming once the number of bytes indicated by the **COMMAND\_DOWNLOAD** command has been received. Each time this function is called, it should be followed by a **COMMAND\_GET\_STATUS** command to ensure that the data was successfully programmed into the flash. If the boot loader sends a NAK to this command, the boot loader will not increment the current address which allows for retransmission of the previous data.

The format of the command is as follows:

```
unsigned char ucCommand[9];

ucCommand[0] = COMMAND_SEND_DATA
ucCommand[1] = Data[0];
ucCommand[2] = Data[1];
ucCommand[3] = Data[2];
ucCommand[4] = Data[3];
ucCommand[5] = Data[4];
ucCommand[6] = Data[5];
ucCommand[7] = Data[6];
ucCommand[8] = Data[7];
```

COMMAND\_RESET

This command is used to tell the boot loader to reset. This is used after downloading a new image to the microcontroller to cause the new application or the new boot loader to start from a reset. The normal boot sequence occurs and the image runs as if from a hardware reset. It can also be used to reset the boot loader if a critical error occurs and the host device wants to restart communication with the boot loader.

The boot loader responds with an ACK signal to the host device before actually executing the software reset on the microcontroller running the boot loader. This informs the updater application that the command was received successfully and the part will be reset.

The format of the command is as follows:

```
unsigned char ucCommand[1];  
  
ucCommand[0] = COMMAND_RESET;
```



## 4 Ethernet Update

When performing an Ethernet update, `ConfigureEnet()` is used to configure the Ethernet controller, making it ready to be used to update the firmware. Then, `UpdateBOOTP()` begins the process of the firmware update.

The bootstrap protocol (BOOTP) is a predecessor to the DHCP protocol and is used to discover the IP address of the client, the IP address of the server, and the name of the firmware image to use. BOOTP uses UDP/IP packets to communicate between the client and the server; the boot loader acts as the client. First, it will send a BOOTP request using a broadcast message. When the server receives the request, it will reply, thereby informing the client of its IP address, the IP address of the server, and the name of the firmware image. Once this reply is received, the BOOTP protocol has completed.

Then, the trivial file transfer protocol (TFTP) is used to transfer the firmware image from the server to the client. TFTP also uses UDP/IP packets to communicate between the client and the server, and the boot loader also acts as the client in this protocol. As each data block is received, it is programmed into flash. Once all data blocks are received and programmed, the device is reset, causing it to start running the new firmware image.

The uIP stack (<http://www.sics.se/~adam/uip>) is used to implement the UDP/IP connections. The TCP support is not needed and is therefore disabled, greatly reducing the size of the stack.

The Ethernet controller will be configured to use the MAC address stored in the USER0/UART1 data registers or the MAC address that is provided in the boot loader configuration file (`bl_config.h`). When using the MAC address from USER0/USER1, it will be interpreted as a MAC address of U0B0:U0B1:U0B2:U1B0:U1B1:U1B2 (where U0B0 is USER0 bits 7-0, or byte 0, U0B1 is USER0 bits 15-8, or byte 1, and so on).

**Note:**

When using the Ethernet update, the boot loader can not update itself since there is no mechanism in BOOTP to distinguish between a firmware image and a boot loader image. Therefore, the boot loader does not know if a given image is a new boot loader or a new firmware image. It assumes that all images provided are firmware images.

The following IETF specifications define the protocols used by the Ethernet update mechanism:

- RFC951 (<http://tools.ietf.org/html/rfc951.html>) defines the bootstrap protocol.
- RFC1350 (<http://tools.ietf.org/html/rfc1350.html>) defines the trivial file transfer protocol.



## 5 CAN Update

When performing a CAN update the boot loader calls `ConfigureCAN()` to configure the CAN controller and prepare the boot loader to update the firmware. The CAN update mechanism allows the boot loader to be entered from a functioning CAN application as well from startup when no application has been downloaded to the microcontroller. The boot loader provides the main routine for performing the CAN update in the `UpdaterCAN()` function which is used in both cases.

When the device enters the boot loader from a running CAN network, the boot loader will not re-configure the CAN clocks or bit timing and will assume that they have been configured as expected by the firmware update device. The boot loader assumes that the application has taken the device off of the CAN network by putting it in "Init mode" but left the CAN bit timings untouched. When the boot loader is run without an application, it is necessary to configure the CAN bit rate using the default CAN clocking which uses the #define values `CAN_BIT_RATE` and `CRYSTAL_FREQ`. These settings must be identical to the CAN bit rate settings used by the application. When the last data is received, the CAN update application must issue an explicit `LM_API_UPD_RESET` command to restart the device.

### 5.1 CAN Bus Clocking

There are two global definitions that are required to configure the CAN boot loader to meet the application's timing requirements. They are both used to determine how the CAN bit rate is configured based on the clock provided to the CAN controller as well as the desired bit rate. The `CAN_BIT_RATE` value sets the transfer rate for data on the CAN bus in bits per second. The other value, `CRYSTAL_FREQ`, is used to set the input frequency to the CAN controller.

### 5.2 CAN Commands

The CAN firmware update provides a short list of commands that are used during the firmware update operation. The definitions for these commands are provided in the file `bl_can.h`. The description of each of these commands is covered in the rest of this section.

`LM_API_UPD_PING`

This command is used to receive an acknowledge command from the boot loader indicating that communication has been established. This command has no data. If the device is present it will respond with a `LM_API_UPD_PING` back to the CAN update application.

**LM\_API\_UPD\_DOWNLOAD**

This command sets the base address for the download as well as the size of the data to write to the device. This command should be followed by a series of `LM_API_UPD_SEND_DATA` that send the actual image to be programmed to the device. The command consists of two 32-bit values that are transferred LSB first. The first 32-bit value is the address to start programming data into, while the second is the 32-bit size of the data that will be sent. This command also triggers an erasure of the full application area in the flash. This flash erase operation causes the command to take longer to send the `LM_API_UPD_ACK` in response to the command which should be taken into account by the CAN update application.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = Download Address [7:0];
ucData[1] = Download Address [15:8];
ucData[2] = Download Address [23:16];
ucData[3] = Download Address [31:24];
ucData[4] = Download Size [7:0];
ucData[5] = Download Size [15:8];
ucData[6] = Download Size [23:16];
ucData[7] = Download Size [31:24];
```

**LM\_API\_UPD\_SEND\_DATA**

This command should only follow a `LM_API_UPD_DOWNLOAD` command or another `LM_API_UPD_SEND_DATA` command when more data is needed. Consecutive send data commands automatically increment the address and continue programming from the previous location. The transfer size is limited to 8 bytes at a time based on the maximum size of an individual CAN transmission. The command terminates programming once the number of bytes indicated by the `LM_API_UPD_DOWNLOAD` command have been received. The CAN boot loader will send a `LM_API_UPD_ACK` in response to each send data command to allow the CAN update application to throttle the data going to the device and not overrun the boot loader with data.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = Data[0];
ucData[1] = Data[1];
ucData[2] = Data[2];
ucData[3] = Data[3];
ucData[4] = Data[4];
ucData[5] = Data[5];
ucData[6] = Data[6];
ucData[7] = Data[7];
```

LM\_API\_UPD\_RESET

This command is used to tell the CAN boot loader to reset the microcontroller. This is used after downloading a new image to the microcontroller to cause the new application or the new boot loader to start from a reset. The normal boot sequence occurs and the image runs as if from a hardware reset. It can also be used to reset the boot loader if a critical error occurs and the CAN update application needs to restart communication with the boot loader.



## 6 USB Device (DFU) Update

When performing a USB update, the boot loader calls `ConfigureUSB()` to configure the USB controller and prepare the boot loader to update the firmware. The USB update mechanism allows the boot loader to be entered from a functioning application as well as from startup when no application has been downloaded to the microcontroller. The boot loader provides the main routine for performing the USB update in the `UpdaterUSB()` function which is used in both cases.

When the USB boot loader is invoked from a running application, the boot loader will reconfigure the USB controller to publish the required descriptor set for a Device Firmware Upgrade (DFU) class device. If the main application had previously been offering any USB device class, it must remove the device from the bus by calling `USBDevDisconnect()` prior to entering the boot loader.

The USB boot loader also assumes that the main application is using the PLL as the source of the system clock.

The USB boot loader allows a USB host to upgrade the firmware on a USB device. To make use of it, therefore, the board running the boot loader must be capable of acting as a USB device. Firmware upgrade of boards which operate solely as USB hosts is not supported by the USB DFU class or the USB boot loader.

### 6.1 USB Device Firmware Upgrade Overview

The USB boot loader enumerates as a Device Firmware Upgrade (DFU) class device. This standard device class specifies a set of class-specific requests and a state machine that can be used to download and flash firmware images to a device and, optionally, upload the existing firmware image to the USB host. The full specification for the device class can be downloaded from the USB Implementer's Forum web site at [http://www.usb.org/developers/devclass\\_docs#approved](http://www.usb.org/developers/devclass_docs#approved).

All communication with the DFU device takes place using the USB control endpoint, endpoint 0. The device publishes a standard device descriptor with vendor, product and device revisions as specified in the `bl_config.h` header file used to build the boot loader binary. It also publishes a single configuration descriptor and a single interface descriptor where the interface class of `0xFE` indicates an application-specific class and the subclass of `0x01` indicates "Device Firmware Upgrade". Attached to the interface descriptor is a DFU Functional Descriptor which provides information to the host on DFU-specific device capabilities such as whether the device can perform upload operations and what the maximum transfer size for upload and download operations is.

DFU functions are initiated by means of a set of class-specific requests. Each request, which follows the standard USB request format, performs some operation and moves the DFU device between a series of well-defined states. Additional requests allow the host to query the current state of the device to determine whether, for example, it is ready to receive the next block of download data.

A DFU device may operation in one of two modes - "Run Time" mode or "DFU" mode. In "Run Time" mode, the device publishes the DFU interface and functional descriptors alongside any other descriptors that the device requires for normal operation. It does not, however, need to respond to any DFU class-specific requests other than `DFU_DETACH` which indicates that it should switch to "DFU" mode.

In "DFU" mode, the device supports all DFU functionality and can perform upload and download operations as specified in its DFU functional descriptor.

The USB boot loader supports only “DFU” mode operation. If an main application wishes to publish DFU descriptors and respond to the DFU\_DETACH request, it can cause a switch to “DFU” mode on receiving a DFU\_DETACH request by removing itself from the USB bus using a call to USBDevDisconnect() before transferring control to the USB boot loader by making a call through the SVC vector in the usual manner.

## 6.1.1 DFU Requests

Requests supported by the USB boot loader are as follow:

DFU_DNLOAD	<p>This OUT request is used to send a block of binary data to the device. The DFU class specification does not define the content and format of the binary data but typically this will be either binary data to be written to some position in the device’s flash memory or a device-specific command. The request payload size is constrained by the maximum packet size specified in the DFU functional descriptor. In this implementation, that maximum is set to 1024 bytes.</p> <p>After sending a DFU_DNLOAD request, the host must poll the device status and wait until the state reverts to DNLOAD_IDLE before sending another request. If the host wishes to indicate that it has finished sending download data, it sends a DFU_DNLOAD request with a payload length of 0.</p>
DFU_UPLOAD	<p>This IN request is used to request a block of binary data from the device. The data returned is device-specific but will typically be the contents of a region of the device’s flash memory or a device-specific response to a command previously sent via a DFU_DNLOAD request. As with DFU_DNLOAD, the maximum amount of data that can be requested is governed by the maximum packet size specified in the DFU functional descriptor, here 1024 bytes.</p>
DFU_GETSTATUS	<p>This IN request allows the host to query the current status of the DFU device. It is typically used during download operations to determine when it is safe to send the next block of data. Depending upon the state of the DFU device, this request may also trigger a state change. During download, for example, the device enters DNLOAD_SYNC state after receiving a block of data and remains there until the data has been processed and a DFU_GETSTATUS request is received at which point the state changes to DNLOAD_IDLE.</p>
DFU_CLRSTATUS	<p>This request is used to reset any error condition reported by the DFU device. If an error is reported via the response to a DFU_GETSTATUS request, that error condition is cleared when this request is received and the device returns to IDLE state.</p>
DFU_GETSTATE	<p>This IN request is used to query the current state of the device without triggering any state change. The single byte of data returned indicates the current state of the DFU device.</p>



DFU\_ABORT This request is used cancel any partially complete upload or download operation and return the device to IDLE state in preparation for some other request.

## 6.1.2 DFU States

During operation, the DFU device transitions between a set of class-defined states. The host must query the current state to determine when a new operation can be performed or to determine the cause of any errors reported. These states are:

IDLE The IDLE state indicates to the host that the DFU device is ready to start an upload or download operation.

DNLOAD\_SYNC After each DFU\_DNLOAD request is received, DNLOAD\_SYNC state is entered. This state remains in effect until the host issues a DFU\_GETSTATUS request at which point the state will change to DNLOAD\_IDLE if the last download operation has completed or DNBUSY otherwise.

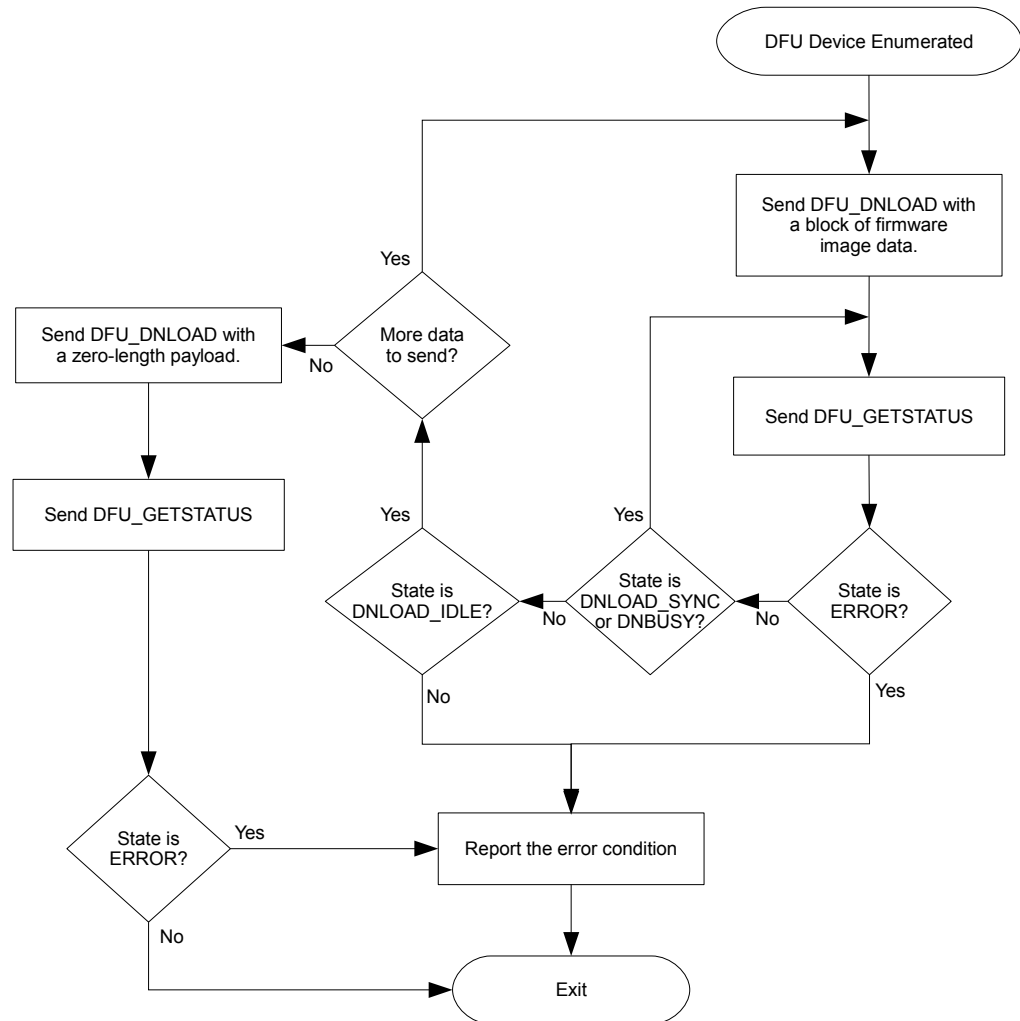
DNLOAD\_IDLE This state indicates that a download operation is in progress and that the device is ready to receive another DFU\_DNLOAD request with the next block of data.

DNBUSY This state is reported if a DFU\_GETSTATUS request is received while a block of downloaded data is still being processed. The host must refrain from issuing another DFU\_GETSTATUS request for a time specified in the structure returned following the request. After this time, the device state reverts to DNLOAD\_SYNC.  
To reduce the USB boot loader image size, this state is not supported. Instead of reporting DNBUSY, the USB boot loader remains in state DNLOAD\_SYNC until the previous data has been processed then transitions to DNLOAD\_IDLE on receipt of the first DFU\_GETSTATUS request following completion of block programming.

MANIFEST_SYNC	<p>The end of a download operation is signaled by the host sending a DFU_DNLOAD request with a 0 length payload. When this request is received, the DFU device transitions from state DNLOAD_IDLE to MANIFEST_SYNC. This state indicates that the complete firmware image has been received and the device is waiting for a DFU_GETSTATUS request before finalizing programming of the image.</p> <p>The USB boot loader programs downloaded blocks as they are received so does not need to perform any additional processing after all blocks have been received. It also reports that it is “manifest tolerant”, indicating to the host that it will still respond to requests after a download has completed. As a result, the device will transition from this state to IDLE once the DFU_GETSTATUS request is received.</p>
MANIFEST	<p>This state indicates to the host that the device is programming a previously- received firmware image and is entered on receipt of a DFU_GETSTATUS request while a device that is not manifest tolerant is in MANIFEST_SYNC state.</p> <p>This state is not used by the USB boot loader since it is manifest tolerant and reverts to IDLE state after completion of a download.</p>
MANIFEST_WAIT_RESET	<p>This state indicates that a device which is not manifest tolerant has finished writing a downloaded image and is waiting for a USB reset to signal it to boot the new firmware.</p> <p>This state is not used by the USB boot loader since it is manifest tolerant and reverts to IDLE state after completion of a download.</p>
UPLOAD_IDLE	<p>Following receipt of a DFU_UPLOAD request, the device remains in this state until it receives another DFU_UPLOAD request asking for less than the maximum transfer size of data. This indicates that the upload is complete and the device will transition back to IDLE state.</p>
ERROR	<p>The ERROR state is entered when some error occurs. The device remains in this state until the host sends a DFU_CLRSTATUS request at which point the state reverts to IDLE and that error code, which is reported in the data returned in response to DFU_GETSTATUS, is cleared.</p>

### 6.1.3 Typical Firmware Download Sequence

The following flow chart illustrates a typical firmware image download sequence from the perspective of the host application.



## 6.2 Tiva-Specific USB Download Commands

The DFU class specification provides the framework necessary to download and upload firmware files to the USB device but does not specify the actual format of the binary data that is transferred. As a result, different device implementations have used different methods to perform operations which are not defined in the standard such as:

- Setting the address that a downloaded binary should be flashed to.
- Setting the address and size of the area of flash whose contents are to be uploaded.
- Erasing sections of the flash.
- Querying the size of flash and writeable area addresses.

The USB boot loader implementation employs a small set of commands which can be sent to the DFU device via a DFU\_DNLOAD request when the device is in IDLE state. Each command takes the form of an 8 byte structure which defines the operation to carry out and provides any required additional parameters.

To ensure that a host application which does not have explicit support for Tiva-specific commands can still be used to download binary firmware images to the device, the protocol is defined such that only a single 8 byte header structure need be placed at the start of the binary image being downloaded. This header and the DFU-defined suffix structure can both be added using the supplied “dfuwrap” command-line application, hence providing a single binary that can be sent to a device running the Tiva USB boot loader using a standard sequence of DFU\_DNLOAD requests with no other embedded commands or device-specific operations required. An application which does understand the Tiva-specific commands may make use of them to offer additional functionality that would not otherwise be available.

### 6.2.1 Querying Command Support

Since the device-specific commands defined here are sent to the DFU device in DFU\_DNLOAD requests, the possibility exists that sending them to a device which does not understand the protocol could result in corruption of that device’s firmware. To guard against this possibility, the Tiva USB boot loader supports an additional USB request which is used to query the device capabilities and allow a host to determine whether or not the device supports the Tiva commands. A device which does not support the commands will either stall the request or return unexpected data.

To determine whether a target DFU device supports the Tiva-specific DFU commands, send the following IN request to the DFU interface:

bmRequest-Type	bRequest	wValue	wIndex	wLength	Data
10100001b	0x42	0x23	Interface	4	Protocol Info

where the protocol information returned is a 4 byte structure, the first two bytes of which are 0x4D, 0x4C and where the second group of two bytes indicates the protocol version supported, currently 0x01 and 0x00 respectively.

### 6.2.2 Download Command Definitions

The following commands may be sent to the USB boot loader as the first 8 bytes of the payload to a DFU\_DNLOAD request. The boot loader will expect any DFU\_DNLOAD request received while

in IDLE state to contain a command header but will not look for command unless the state is IDLE. This allows an application which is unaware of the command header to download a DFU-wrapped binary image using a standard sequence of multiple DFU\_DNLOAD and DFU\_GETSTATUS requests without the need to insert additional command headers during the download.

The commands defined here and their parameter block structures can be found in header file `usbdfu.h`. In all cases where multi-byte numbers are specified, the numbers are stored in little-endian format with the least significant byte in the lowest addressed location. The following definitions specify the command byte ordering unambiguously but care must be taken to ensure correct byte swapping if using the command structure types defined in `usbdfu.h` on big-endian systems.

`DFU_CMD_PROG` This command is used to provide the USB boot loader with the address at which the next download should be written and the total length of the firmware image which is to follow. This structure forms the header that is written to the DFU-wrapped file generated by the `dfuwrap` tool. The start address is provided in terms of 1024 byte flash blocks. To convert a byte address to a block address, merely divide by 1024. The start address must always be on a 1024 byte boundary. This command may be followed by up to 1016 bytes of firmware image data, this number being the maximum transfer size minus the 8 bytes of the command structure.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = DFU_CMD_PROG (0x01)
ucData[1] = Reserved - set to 0x00
ucData[2] = Start Block Number [7:0];
ucData[3] = Start Block Number [15:8];
ucData[4] = Image Size [7:0];
ucData[5] = Image Size [15:8];
ucData[6] = Image Size [23:16];
ucData[7] = Image Size [31:24];
```

DFU\_CMD\_READ

This command is used to set the address range whose content will be returned on subsequent DFU\_UPLOAD requests from the host.

The start address is provided in terms of 1024 byte flash blocks. To convert a byte address to a block address, merely divide by 1024. The start address must always be on a 1024 byte boundary.

To read back a the contents of a region of flash, the host should send a DFU\_DNLOAD request with command DFU\_CMD\_READ, start address set to the 1KB block start address and length set to the number of bytes to read. The host should then send one or more DFU\_UPLOAD requests to receive the current flash contents from the configured addresses. Data returned will include an 8 byte DFU\_CMD\_PROG prefix structure unless the prefix has been disabled by sending a DFU\_CMD\_BIN command with the bBinary parameter set to 1. The host should, therefore, be prepared to read 8 bytes more than the length specified in the READ command if the prefix is enabled.

By default, the 8 byte prefix is enabled for all upload operations. This is required by the DFU class specification which states that uploaded images must be formatted to allow them to be directly downloaded back to the device at a later time.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = DFU_CMD_READ (0x02)
ucData[1] = Reserved - set to 0x00
ucData[2] = Start Block Number [7:0];
ucData[3] = Start Block Number [15:8];
ucData[4] = Image Size [7:0];
ucData[5] = Image Size [15:8];
ucData[6] = Image Size [23:16];
ucData[7] = Image Size [31:24];
```

DFU\_CMD\_CHECK

This command is used to check a region of flash to ensure that it is completely erased.

The start address is provided in terms of 1024 byte flash blocks. To convert a byte address to a block address, merely divide by 1024. The start address must always be on a 1024 byte boundary. The length must also be a multiple of 4.

To check that a region of flash is erased, the DFU\_CMD\_CHECK command should be sent with the required start address and region length set then the host should issue a DFU\_GETSTATUS request. If the erase check was successful, the returned bStatus value will be OK (0x00), otherwise it will be erCheckErased (0x05).

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = DFU_CMD_CHECK (0x03)
ucData[1] = Reserved - set to 0x00
ucData[2] = Start Block Number [7:0];
ucData[3] = Start Block Number [15:8];
ucData[4] = Region Size [7:0];
ucData[5] = Region Size [15:8];
ucData[6] = Region Size [23:16];
ucData[7] = Region Size [31:24];
```

DFU\_CMD\_ERASE

This command is used to erase a region of flash.

The start address is provided in terms of 1024 byte flash blocks. To convert a byte address to a block address, merely divide by 1024. The start address must always be on a 1024 byte boundary. The length must also be a multiple of 4. The size of the region to erase is expressed in terms of flash blocks. The block size can be determined using the DFU\_CMD\_INFO command.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = DFU_CMD_ERASE (0x04)
ucData[1] = Reserved - set to 0x00
ucData[2] = Start Block Number [7:0];
ucData[3] = Start Block Number [15:8];
ucData[4] = Number of Blocks [7:0];
ucData[5] = Number of Blocks [15:8];
ucData[6] = Reserved - set to 0x00
ucData[7] = Reserved - set to 0x00
```

DFU\_CMD\_INFO

This command is used to query information relating to the target device and programmable region of flash. The device information structure, `tDFUDeviceInfo`, is returned on the next `DFU_UPLOAD` request following this command.

The format of the command is as follows:

```

unsigned char ucData[8];

ucData[0] = DFU_CMD_INFO (0x05)
ucData[1] = Reserved - set to 0x00
ucData[2] = Reserved - set to 0x00
ucData[3] = Reserved - set to 0x00
ucData[4] = Reserved - set to 0x00
ucData[5] = Reserved - set to 0x00
ucData[6] = Reserved - set to 0x00
ucData[7] = Reserved - set to 0x00

//*****
//
// Payload returned in response to the DFU_CMD_INFO command.
//
// This structure is returned in response to the first DFU_UPLOAD
// request following a DFU_CMD_INFO command. Note that byte ordering
// of multi-byte fields is little-endian.
//
//*****
typedef struct
{
    //
    // The size of a flash block in bytes.
    //
    unsigned short usFlashBlockSize;

    //
    // The number of blocks of flash in the device. Total
    // flash size is usNumFlashBlocks * usFlashBlockSize.
    //
    unsigned short usNumFlashBlocks;

    //
    // Information on the part number, family, version and
    // package as read from SYSTL register DID1.
    //
    unsigned long ulPartInfo;

    //
    // Information on the part class and revision as read
    // from SYSTL DID0.
    //
    unsigned long ulClassInfo;

    //
    // Address 1 byte above the highest location the boot
    // loader can access.
    //
    unsigned long ulFlashTop;

    //
    // Lowest address the boot loader can write or erase.
    //
    unsigned long ulAppStartAddr;
}
PACKED tDFUDeviceInfo;

```



## DFU\_CMD\_BIN

By default, data returned in response to a DFU\_UPLOAD request includes an 8 byte DFU\_CMD\_PROG prefix structure. This ensures that an uploaded image can be directly downloaded again without the need to further wrap it but, in cases where pure binary data is required, can be awkward. The DFU\_CMD\_BIN command allows the upload prefix to be disabled or enabled under host control.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = DFU_CMD_BIN (0x06)
ucData[1] = 0x01 to disable upload prefix, 0x00 to enable
ucData[2] = Reserved - set to 0x00
ucData[3] = Reserved - set to 0x00
ucData[4] = Reserved - set to 0x00
ucData[5] = Reserved - set to 0x00
ucData[6] = Reserved - set to 0x00
ucData[7] = Reserved - set to 0x00
```

## DFU\_CMD\_RESET

This command may be sent to the USB boot loader to cause it to perform a soft reset of the board. This will reboot the system and, assuming that the main application image is present, run the main application. Note that a reboot will also take place if a firmware download operation completes and the host issues a USB reset to the DFU device.

The format of the command is as follows:

```
unsigned char ucData[8];

ucData[0] = DFU_CMD_RESET (0x07)
ucData[1] = Reserved - set to 0x00
ucData[2] = Reserved - set to 0x00
ucData[3] = Reserved - set to 0x00
ucData[4] = Reserved - set to 0x00
ucData[5] = Reserved - set to 0x00
ucData[6] = Reserved - set to 0x00
ucData[7] = Reserved - set to 0x00
```



## 7 Customization

The boot loader allows for customization of its features as well as the interfaces used to update the microcontroller. This allows the boot loader to include only the features that are needed by the application. There are two types of features that can be customized. The first type are the features that are conditionally included or excluded at compile time. The second type of customizations are more involved and include customizing the actual code that is used by the boot loader.

The boot loader can be modified to have any functionality. As an example, the main loop can be completely replaced to use a different set of commands and still use the packet and transport functions from the boot loader. The method of detecting a forced update can be modified to suit the needs of the application when toggling a GPIO to detect an update request may not be the best solution. If the boot loader's packet format does not meet the needs of the application, it can be completely replaced by replacing `ReceivePacket()`, `SendPacket()`, `AckPacket()`, and `NakPacket()`.

The boot loader also provides a method to add a new serial transmission interface beyond the UART, SSI, and I2C that are provided by the boot loader. In order for the packet functions to use the new transport functions, the `SendData()`, `ReceiveData()`, and `FlushData()` defines need to be modified to use the new functions. For example:

```
#ifdef FOO_ENABLE_UPDATE
#define SendData          FooSend
#define FlushData         FooFlush
#define ReceiveData       FooReceive
#endif
```

would use the functions for the hypothetical Foo peripheral.

The combination of these customizable features provides a framework that allows the boot loader to define whatever protocol it needs, or use any port that it needs to perform updates of the microcontroller.



## 8 Configuration

There are a number of defines that are used to configure the operation of the boot loader. These defines are located in the `bl_config.h` header file, for which there is a template (`bl_config.h.tmpl`) provided with the boot loader.

The configuration options are:

`CRYSTAL_FREQ`

This defines the crystal frequency used by the microcontroller running the boot loader. If this is unknown at the time of production, then use the `UART_AUTOBAUD` feature to properly configure the UART.

- This value must be defined if using the UART for the update and not using the auto-baud feature, and when using CAN, USB, or Ethernet for the update.
- If using CAN, only a 1 MHz, 2 MHz, 4 MHz, 5 MHz, 6 MHz, 8 MHz, 10 MHz, 12 MHz, or 16 MHz crystal can be used.

`APP_START_ADDRESS`

The starting address of the application. This must be a multiple of 1024 bytes (making it aligned to a page boundary). A vector table is expected at this location, and the perceived validity of the vector table (stack located in SRAM, reset vector located in flash) is used as an indication of the validity of the application image.

- This value must be defined.
- The flash image of the boot loader must not be larger than this value.

`VTABLE_START_ADDRESS`

The address at which the application locates its exception vector table. This must be a multiple of 1024 bytes (making it aligned to a page boundary). Typically, an application will start with its vector table and this value should be set to `APP_START_ADDRESS`. This option is provided to cater for applications which run from external memory which may not be accessible by the NVIC (the vector table offset register is only 30 bits long).

- This value must be defined.

`FLASH_PAGE_SIZE`

The size of a single, erasable page in the flash. This must be a power of 2. The default value of 1024 bytes represents the page size for the internal flash on all Tiva MCUs and this value should only be overridden if configuring a boot loader to access external flash devices with a page size different from this.

- This value must be defined.

FLASH_RSVD_SPACE	The amount of space at the end of flash to reserve. This must be a multiple of 1024 bytes (making it aligned to a page boundary). This reserved space is not erased when the application is updated, providing non-volatile storage that can be used for parameters.
STACK_SIZE	The number of words of stack space to reserve for the boot loader. <ul style="list-style-type: none"><li>■ This value must be defined.</li></ul>
BUFFER_SIZE	The number of words in the data buffer used for receiving packets. This value must be at least 3. If using auto-baud on the UART, this must be at least 20. The maximum usable value is 65 (larger values will result in unused space in the buffer). <ul style="list-style-type: none"><li>■ This value must be defined if updating via UART, SSI, or I2C .</li></ul>
ENABLE_BL_UPDATE	Enables updates to the boot loader. Updating the boot loader is an unsafe operation since it is not fully fault tolerant (losing power to the device partway through could result in the boot loader no longer being present in flash). The boot loader can not be updated via the Ethernet port.

---

**CHECK\_CRC**

Enables runtime CRC checking in the boot loader. If this label is not defined, the boot loader will transfer control to a main application image if the initial stack pointer and reset vector of the image appear to be valid in flash. No additional checking is performed. When this label is defined, however, the firmware image's CRC32 value is checked against a value stored in a header at the top of the image's vector table and the firmware is only booted if the calculated CRC matches the value in the header. If the header is absent or the calculated CRC does not match the expected value, the boot loader retains control and waits for a new firmware image to be downloaded. As a special case to aid debugging, the image will be booted if the header is found and the length field is set to 0xFFFFFFFF, regardless of the value of the CRC32 field. This debug behavior can be disabled by also defining ENFORCE\_CRC.

To use the CHECK\_CRC option, firmware images must be built with an 8 word header appended at the top of the interrupt vector table. This header must have the first 4 words populated as follow:

- Word 0: 0xFF01FF02
- Word 1: 0xFF02FF03
- Word 2: Length of the firmware binary image in bytes.
- Word 3: CRC32 calculated over entire image except for the 4 bytes occupied by this word. The CRC calculation includes the header marker words and the length word.

The remaining 4 words in the header are reserved for future extensions and should be set to 0xFFFFFFFF.

This header should be added by reserving 8 additional words above all the required entries in the project's vector table (typically in the startup C or assembler file depending upon the toolchain in use) and initializing the first two to be the required marker words and the remainder to value 0xFFFFFFFF. The length and CRC32 value can be inserted by passing the firmware binary as the input to the binpack.exe tool found in the tools directory of your TivaWare release.

**ENFORCE\_CRC**

This definition may be used in conjunction with CHECK\_CRC and will remove the debug behaviour described above. When both CHECK\_CRC and ENFORCE\_CRC are defined, the boot loader will only boot a main firmware image if it contains a valid image information header at the top of the vector table and if the CRC32 calculated for the image matches the CRC32 in the image information header.

FLASH_CODE_PROTECTION	This definition will cause the the boot loader to erase the entire flash on updates to the boot loader or to erase the entire application area when the application is updated. This erases any unused sections in the flash before the firmware is updated.
ENABLE_DECRYPTION	Enables the call to decrypt the downloaded data before writing it into flash. The decryption routine is empty in the reference boot loader source, which simply provides a placeholder for adding an actual decryption algorithm. Although this option is retained for backwards compatibility, it is recommended that a decryption function be specified using the newer hook function mechanism and <code>BL_DECRYPT_FN_HOOK</code> instead.
ENABLE_MOSCFAIL_HANDLER	Enables support for the MOSCFAIL handler in the NMI interrupt. <ul style="list-style-type: none"><li>■ Sandstorm or Fury devices do not provide the MOSCFAIL reset, so this feature should not be enabled for these devices.</li></ul>
FLASH_PATCH_COMPATIBLE	Enables support for the code to cooperate with the flash patch that is preloaded into the flash of certain Tiva devices. This support should only be enabled for devices that require it. <ul style="list-style-type: none"><li>■ Enabling this feature will cause the boot loader to expect to be loaded at 0x1000, despite the fact that debuggers will still think that it should be loaded at 0x0. Therefore, LM Flash Programmer must be used to program the boot loader into flash when using this feature.</li></ul>
ENABLE_UPDATE_CHECK	Enables the pin-based forced update check. When enabled, the boot loader will go into update mode instead of calling the application if a pin is read at a particular polarity, forcing an update operation. In either case, the application is still able to return control to the boot loader in order to start an update. For applications which need to perform more complex checking than is possible using a single GPIO, a hook function may be provided using <code>BL_CHECK_UPDATE_FN_HOOK</code> instead.
FORCED_UPDATE_PERIPH	The GPIO module to enable in order to check for a forced update. This will be one of the <code>SYSCCTL_RCGC2_GPIOx</code> values, where “x” is replaced with the port name (such as B). The value of “x” should match the value of “x” for <code>FORCED_UPDATE_PORT</code> . <ul style="list-style-type: none"><li>■ This value must be defined if <code>ENABLE_UPDATE_CHECK</code> is defined.</li></ul>



---

FORCED_UPDATE_PORT	<p>The GPIO port to check for a forced update. This will be one of the <code>GPIO_PORTx_BASE</code> values, where “x” is replaced with the port name (such as B). The value of “x” should match the value of “x” for <code>FORCED_UPDATE_PERIPH</code>.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>ENABLE_UPDATE_CHECK</code> is defined.</li></ul>
FORCED_UPDATE_PIN	<p>The pin to check for a forced update. This is a value between 0 and 7.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>ENABLE_UPDATE_CHECK</code> is defined.</li></ul>
FORCED_UPDATE_POLARITY	<p>The polarity of the GPIO pin that results in a forced update. This value should be 0 if the pin should be low and 1 if the pin should be high.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>ENABLE_UPDATE_CHECK</code> is defined.</li></ul>
FORCED_UPDATE_WPU FORCED_UPDATE_WPD	<p>This enables a weak pull-up or pull-down for the GPIO pin used in a forced update. Only one of <code>FORCED_UPDATE_WPU</code> or <code>FORCED_UPDATE_WPD</code> should be defined, or neither if a weak pull-up or pull-down is not required.</p>
FORCED_UPDATE_KEY	<p>This enables the use of the <code>GPIO_LOCK</code> mechanism for configuration of protected GPIO pins (for example JTAG pins). If this value is not defined, the locking mechanism will not be used. The only legal values for this feature are <code>GPIO_LOCK_KEY</code> for Fury devices and <code>GPIO_LOCK_KEY_DD</code> for all other devices except Sandstorm devices, which do not support this feature.</p>
UART_ENABLE_UPDATE	<p>Selects the UART as the port for communicating with the boot loader.</p>
UART_AUTOBAUD	<p>Enables automatic baud rate detection. This can be used if the crystal frequency is unknown, or if operation at different baud rates is desired.</p> <ul style="list-style-type: none"><li>■ This value or <code>UART_FIXED_BAUDRATE</code> must be defined if <code>UART_ENABLE_UPDATE</code> is defined.</li></ul>
UART_FIXED_BAUDRATE	<p>Selects the baud rate to be used for the UART.</p> <ul style="list-style-type: none"><li>■ This value or <code>UART_AUTOBAUD</code> must be defined if <code>UART_ENABLE_UPDATE</code> is defined.</li></ul>

SSI_ENABLE_UPDATE	Selects the SSI port as the port for communicating with the boot loader.
I2C_ENABLE_UPDATE	Selects the I2C port as the port for communicating with the boot loader.
I2C_SLAVE_ADDR	Specifies the I2C address of the boot loader. <ul style="list-style-type: none"><li>■ This value must be defined if I2C_ENABLE_UPDATE is defined.</li></ul>
ENET_ENABLE_UPDATE	Selects Ethernet update via the BOOTP/TFTP protocol.
ENET_ENABLE_LEDS	Enables the use of the Ethernet status LED outputs to indicate traffic and connection status.
ENET_MAC_ADDR?	Specifies the hard coded MAC address for the Ethernet interface. There are six individual values (ENET_MAC_ADDR0 through ENET_MAC_ADDR5) that provide the six bytes of the MAC address, where ENET_MAC_ADDR0 through ENET_MAC_ADDR2 provide the organizationally unique identifier (OUI) and ENET_MAC_ADDR3 through ENET_MAC_ADDR5 provide the extension identifier. If these values are not provided, the MAC address will be extracted from the user registers.
ENET_BOOTP_SERVER	Specifies the name of the BOOTP server from which to request information. The use of this specifier allows a board-specific BOOTP server to co-exist on a network with the DHCP server that may be part of the network infrastructure. The BOOTP server provided by Texas Instruments requires that this be set to "tiva".
USB_ENABLE_UPDATE	Selects USB update via Device Firmware Update class.
USB_VENDOR_ID	The USB vendor ID published by the DFU device. This value is the TI Tiva vendor ID. Change this to the vendor ID you have been assigned by the USB-IF. <ul style="list-style-type: none"><li>■ This value must be defined if USB_ENABLE_UPDATE is defined.</li></ul>
USB_PRODUCT_ID	The USB device ID published by the DFU device. If you are using your own vendor ID, chose a device ID that is different from the ID you use in non-update operation. If you have sublicensed TI's vendor ID, you must use an assigned product ID here. <ul style="list-style-type: none"><li>■ This value must be defined if USB_ENABLE_UPDATE is defined.</li></ul>

---

USB_DEVICE_ID	<p>Selects the BCD USB device release number published in the device descriptor.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>USB_ENABLE_UPDATE</code> is defined.</li></ul>
USB_MAX_POWER	<p>Sets the maximum power consumption that the DFU device will report to the USB host in the configuration descriptor. Units are milliamps.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>USB_ENABLE_UPDATE</code> is defined.</li></ul>
USB_BUS_POWERED	<p>Specifies whether the DFU device reports to the host that it is self-powered (defined as 0) or bus-powered (defined as 1).</p>
USB_HAS_MUX	<p>Specifies whether the target board uses a multiplexer to select between USB host and device modes.</p>
USB_MUX_PERIPH	<p>Specifies the GPIO peripheral containing the pin which is used to select between USB host and device modes. The value is of the form <code>SYSCTL_RCGC2_GPIOx</code>, where <code>GPIOx</code> represents the required GPIO port.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>USB_HAS_MUX</code> is defined.</li></ul>
USB_MUX_PORT	<p>Specifies the GPIO port containing the pin which is used to select between USB host and device modes. The value is of the form <code>GPIO_PORTx_BASE</code>, where <code>PORTx</code> represents the required GPIO port.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>USB_HAS_MUX</code> is defined.</li></ul>
USB_MUX_PIN	<p>Specifies the GPIO pin number used to select between USB host and device modes. Valid values are 0 through 7.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>USB_HAS_MUX</code> is defined.</li></ul>
USB_MUX_DEVICE	<p>Specifies the state of the GPIO pin required to select USB device-mode operation. Valid values are 0 (low) or 1 (high).</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>USB_HAS_MUX</code> is defined.</li></ul>
USB_VBUS_CONFIG	<p>Specifies whether the target board requires configuration of the pin used for VBUS. This applies to Blizzard class and later devices.</p>

USB_VBUS_PERIPH	<p>Specifies the GPIO peripheral containing the pin which is used for VBUS. The value is of the form SYSCTL_RCGCGPIO_Rx, where the Rx represents the required GPIO port. This applies to Blizzard class and later devices.</p> <ul style="list-style-type: none"><li>■ This value must be defined if USB_VBUS_CONFIG is defined.</li></ul>
USB_VBUS_PORT	<p>Specifies the GPIO port containing the pin which is used for VBUS. The value is of the form GPIO_PORTx_BASE, where PORTx represents the required GPIO port.</p> <ul style="list-style-type: none"><li>■ This value must be defined if USB_VBUS_CONFIG is defined.</li></ul>
USB_VBUS_PIN	<p>Specifies the GPIO pin number used for VBUS. Valid values are 0 through 7.</p> <ul style="list-style-type: none"><li>■ This value must be defined if USB_VBUS_CONFIG is defined.</li></ul>
USB_ID_CONFIG	<p>Specifies whether the target board requires configuration of the pin used for ID. This applies to Blizzard class and later devices.</p>
USB_ID_PERIPH	<p>Specifies the GPIO peripheral containing the pin which is used for ID. The value is of the form SYSCTL_RCGCGPIO_Rx, where the Rx represents the required GPIO port. This applies to Blizzard class and later devices.</p> <ul style="list-style-type: none"><li>■ This value must be defined if USB_ID_CONFIG is defined.</li></ul>
USB_ID_PORT	<p>Specifies the GPIO port containing the pin which is used for ID. The value is of the form GPIO_PORTx_BASE, where PORTx represents the required GPIO port.</p> <ul style="list-style-type: none"><li>■ This value must be defined if USB_ID_CONFIG is defined.</li></ul>
USB_ID_PIN	<p>Specifies the GPIO pin number used for ID. Valid values are 0 through 7.</p> <ul style="list-style-type: none"><li>■ This value must be defined if USB_ID_CONFIG is defined.</li></ul>

---

USB_DP_CONFIG	Specifies whether the target board requires configuration of the pin used for DP. This applies to Blizzard class and later devices.
USB_DP_PERIPH	Specifies the GPIO peripheral containing the pin which is used for DP. The value is of the form SYSCTL_RCGCGPIO_Rx, where the Rx represents the required GPIO port. This applies to Blizzard class and later devices. <ul style="list-style-type: none"><li>■ This value must be defined if USB_DP_CONFIG is defined.</li></ul>
USB_DP_PORT	Specifies the GPIO port containing the pin which is used for DP. The value is of the form GPIO_PORTx_BASE, where PORTx represents the required GPIO port. <ul style="list-style-type: none"><li>■ This value must be defined if USB_DP_CONFIG is defined.</li></ul>
USB_DP_PIN	Specifies the GPIO pin number used for DP. Valid values are 0 through 7. <ul style="list-style-type: none"><li>■ This value must be defined if USB_DP_CONFIG is defined.</li></ul>
USB_DM_CONFIG	Specifies whether the target board requires configuration of the pin used for DM. This applies to Blizzard class and later devices.
USB_DM_PERIPH	Specifies the GPIO peripheral containing the pin which is used for DM. The value is of the form SYSCTL_RCGCGPIO_Rx, where the Rx represents the required GPIO port. This applies to Blizzard class and later devices. <ul style="list-style-type: none"><li>■ This value must be defined if USB_DM_CONFIG is defined.</li></ul>
USB_DM_PORT	Specifies the GPIO port containing the pin which is used for DM. The value is of the form GPIO_PORTx_BASE, where PORTx represents the required GPIO port. <ul style="list-style-type: none"><li>■ This value must be defined if USB_DM_CONFIG is defined.</li></ul>

USB_DM_PIN	<p>Specifies the GPIO pin number used for DM. Valid values are 0 through 7.</p> <ul style="list-style-type: none"> <li>■ This value must be defined if USB_DM_CONFIG is defined.</li> </ul>
CAN_ENABLE_UPDATE	<p>Selects an update via the CAN port.</p>
CAN_REQUIRES_PLL	<p>Indicates that the CAN peripheral operates from a fixed divide of the PLL output, meaning that the PLL must be enabled. This is required by some older Tiva devices, but must not be used on newer Tiva devices. Consult the device data sheet to determine if the CAN peripheral operates from a fixed 8 MHz clock derived from the PLL (meaning this option must be used) or if it operates from the system clock (meaning this option must not be used).</p>
CAN_UART_BRIDGE	<p>Enables the UART to CAN bridging for use when the CAN port is selected for communicating with the boot loader.</p>
CAN_RX_PERIPH	<p>The GPIO module to enable in order to configure the CAN0 Rx pin. This will be one of the SYSCTL_RCGC2_GPIOx values, where “x” is replaced with the port name (such as B). The value of “x” should match the value of “x” for CAN_RX_PORT.</p> <ul style="list-style-type: none"> <li>■ This value must be defined if CAN_ENABLE_UPDATE is defined.</li> </ul>
CAN_RX_PORT	<p>The GPIO port used to configure the CAN0 Rx pin. This will be one of the GPIO_PORTx_BASE values, where “x” is replaced with the port name (such as B). The value of “x” should match the value of “x” for CAN_RX_PERIPH.</p> <ul style="list-style-type: none"> <li>■ This value must be defined if CAN_ENABLE_UPDATE is defined.</li> </ul>
CAN_RX_PIN	<p>The GPIO pin that is shared with the CAN0 Rx pin. This is a value between 0 and 7.</p> <ul style="list-style-type: none"> <li>■ This value must be defined if CAN_ENABLE_UPDATE is defined.</li> </ul>
CAN_TX_PERIPH	<p>The GPIO module to enable in order to configure the CAN0 Tx pin. This will be one of the SYSCTL_RCGC2_GPIOx values, where “x” is replaced with the port name (such as B). The value of “x” should match the value of “x” for CAN_TX_PORT.</p> <ul style="list-style-type: none"> <li>■ This value must be defined if CAN_ENABLE_UPDATE is defined.</li> </ul>

---

CAN_TX_PORT	<p>The GPIO port used to configure the CAN0 Tx pin. This will be one of the <code>GPIO_PORTx_BASE</code> values, where “x” is replaced with the port name (such as B). The value of “x” should match the value of “x” for <code>CAN_TX_PERIPH</code>.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>CAN_ENABLE_UPDATE</code> is defined.</li></ul>
CAN_TX_PIN	<p>The GPIO pin that is shared with the CAN0 Tx pin. This is a value between 0 and 7.</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>CAN_ENABLE_UPDATE</code> is defined.</li></ul>
CAN_BIT_RATE	<p>The bit rate used on the CAN bus. This must be one of 20000, 50000, 125000, 250000, 500000, or 1000000. The CAN bit rate must be less than or equal to the crystal frequency divided by 8 (<code>CRYSTAL_FREQ / 8</code>).</p> <ul style="list-style-type: none"><li>■ This value must be defined if <code>CAN_ENABLE_UPDATE</code> is defined.</li></ul>
BL_HW_INIT_FN_HOOK	<p>Performs application-specific low level hardware initialization on system reset. If hooked, this function will be called immediately after the boot loader code relocation completes. An application may perform any required low-level hardware initialization during this function. Note that the system clock has not been set when this function is called. Initialization that assumes the system clock is set may be performed in the <code>BL_INIT_FN_HOOK</code> function instead.</p>
BL_INIT_FN_HOOK	<p>Performs application-specific initialization on system reset. If hooked, this function will be called during boot loader initialization to perform any board- or application-specific initialization which is required. The function is called following a reset immediately after the selected boot loader peripheral has been configured and the system clock has been set.</p>
BL_REINIT_FN_HOOK	<p>Performs application-specific reinitialization on boot loader entry via SVC. If hooked, this function will be called during boot loader reinitialization to perform any board- or application-specific initialization which is required. The function is called following boot loader entry from an application, after any system clock rate adjustments have been made.</p>
BL_START_FN_HOOK	<p>Informs an application that a download is starting. If hooked, this function will be called when a firmware download is about to begin. The function is called after the first data packet of the download is received but before it has been written to flash.</p>

BL_PROGRESS_FN_HOOK	<p>Informs an application of download progress. If hooked, this function will be called periodically during a firmware download to provide progress information. The function is called after each data packet is received from the host. Parameters provide the number of bytes of data received and, in cases other than Ethernet update, the expected total number of bytes in the download (the TFTP protocol used by the Ethernet boot loader does not send the final image size before the download starts so in this case the <code>ulTotal</code> parameter is set to 0 to indicate that the size is unknown).</p>
BL_END_FN_HOOK	<p>Informs an application that a download has completed. If hooked, this function will be called when a firmware download has just completed. The function is called after the final data packet of the download has been written to flash.</p>
BL_DECRYPT_FN_HOOK	<p>Allows an application to perform in-place data decryption during download. If hooked, this function will be called to perform in-place decryption of each data packet received during a firmware download.</p> <ul style="list-style-type: none"><li>■ This value takes precedence over <code>ENABLE_DECRYPTION</code>. If both are defined, the hook function defined using <code>BL_DECRYPT_FN_HOOK</code> is called rather than the previously-defined <code>DecryptData()</code> stub function.</li></ul>
BL_CHECK_UPDATE_FN_HOOK	<p>Allows an application to force a new firmware download. If hooked, this function will be called during boot loader initialization to determine whether a firmware update should be performed regardless of whether a valid main code image is already present. If the function returns 0, the existing main code image is booted (if present), otherwise the boot loader will wait for a new firmware image to be downloaded.</p> <ul style="list-style-type: none"><li>■ This value takes precedence over <code>ENABLE_UPDATE_CHECK</code> if both are defined. If you wish to perform a GPIO check in addition to any other update check processing required, the GPIO code must be included within the hook function itself.</li></ul>
BL_FLASH_ERASE_FN_HOOK	<p>Allows an application to replace the flash block erase function. If hooked, this function will be called whenever a block of flash is to be erased. The function must erase the block and wait until the operation has completed. The size of the block which will be erased is defined by <code>FLASH_BLOCK_SIZE</code>.</p>



---

<code>BL_FLASH_PROGRAM_FN_HOOK</code>	Allows an application to replace the flash programming function. If hooked, this function will be called to program the flash with firmware image data received during download operations. The function must program the supplied data and wait until the operation has completed.
<code>BL_FLASH_CL_ERR_FN_HOOK</code>	Allows an application to replace the flash error clear function. If hooked, this function must clear any flash error indicators and prepare to detect access violations that may occur in a future erase or program operations.
<code>BL_FLASH_ERROR_FN_HOOK</code>	Reports whether or not a flash access violation error has occurred. If hooked, this function will be called after flash erase or program operations. The return code indicates whether or not an access violation error occurred since the last call to the function defined by <code>BL_FLASH_CL_ERR_FN_HOOK</code> , with 0 indicating no errors and non-zero indicating an error.
<code>BL_FLASH_SIZE_FN_HOOK</code>	Reports the total size of the device flash. If hooked, this function will be called to determine the size of the supported flash device. The return code is the number of bytes of flash in the device. Note that this does not take into account any reserved space defined via the <code>FLASH_RSVD_SPACE</code> value.
<code>BL_FLASH_END_FN_HOOK</code>	Reports the address of the first byte after the end of the device flash. If hooked, this function will be called to determine the address of the end of valid flash. Note that this does not take into account any reserved space defined via the <code>FLASH_RSVD_SPACE</code> value.
<code>BL_FLASH_AD_CHECK_FN_HOOK</code>	Checks whether the start address and size of an image are valid. If hooked, this function will be called when a new firmware download is about to start. Parameters provided are the requested start address for the new download and, when using protocols which transmit the image length in advance, the size of the image that is to be downloaded. The return code will be non-zero to indicate that the start address is valid and the image will fit in the available space, or 0 if either the address is invalid or the image is too large for the device.



## 9 Source Details

Autobaud Functions .....	51
CAN Functions .....	52
Decryption Functions .....	53
Ethernet Functions .....	54
File System Functions .....	54
I2C Functions .....	54
Main Functions .....	56
Packet Handling Functions .....	57
SSI Functions .....	59
UART Functions .....	60
Update Check Functions .....	62
USB Device Functions .....	63

### 9.1 Autobaud Functions

#### Functions

- void [GPIOIntHandler](#) (void)
- int [UARTAutoBaud](#) (uint32\_t \*pui32Ratio)

#### 9.1.1 Detailed Description

The following functions are provided in `bl_autobaud.c` and are used to perform autobauding on the UART interface.

#### 9.1.2 Function Documentation

##### 9.1.2.1 GPIOIntHandler

Handles the UART Rx GPIO interrupt.

**Prototype:**

```
void  
GPIOIntHandler(void)
```

**Description:**

When an edge is detected on the UART Rx pin, this function is called to save the time of the edge. These times are later used to determine the ratio of the UART baud rate to the processor clock rate.

**Returns:**

None.

### 9.1.2.2 UARTAutoBaud

Performs auto-baud on the UART port.

**Prototype:**

```
int
UARTAutoBaud(uint32_t *pui32Ratio)
```

**Parameters:**

***pui32Ratio*** is the ratio of the processor's crystal frequency to the baud rate being used by the UART port for communications.

**Description:**

This function attempts to synchronize to the updater program that is trying to communicate with the boot loader. The UART port is monitored for edges using interrupts. Once enough edges are detected, the boot loader determines the ratio of baud rate and crystal frequency needed to program the UART.

**Returns:**

Returns a value of 0 to indicate that this call successfully synchronized with the other device communicating over the UART, and a negative value to indicate that this function did not successfully synchronize with the other UART device.

## 9.2 CAN Functions

### Functions

- void [AppUpdaterCAN](#) (void)
- void [ConfigureCAN](#) (void)
- void [UpdaterCAN](#) (void)

### 9.2.1 Detailed Description

The following functions are provided in `bl_can.c` and are used to perform an update over the CAN interface.

### 9.2.2 Function Documentation

#### 9.2.2.1 AppUpdaterCAN

This is the application entry point to the CAN updater.

**Prototype:**

```
void
AppUpdaterCAN(void)
```

**Description:**

This function should only be entered from a running application and not when running the boot loader with no application present.

**Returns:**

None.

### 9.2.2.2 ConfigureCAN

Generic configuration is handled in this function.

**Prototype:**

```
void  
ConfigureCAN(void)
```

**Description:**

This function is called by the start up code to perform any configuration necessary before calling the update routine.

**Returns:**

None.

### 9.2.2.3 UpdaterCAN

This is the main routine for handling updating over CAN.

**Prototype:**

```
void  
UpdaterCAN(void)
```

**Description:**

This function accepts boot loader commands over CAN to perform a firmware update over the CAN bus. This function assumes that the CAN bus timing and message objects have been configured elsewhere.

**Returns:**

None.

## 9.3 Decryption Functions

### Functions

- void [DecryptData](#) (uint8\_t \*pui8Buffer, uint32\_t ui32Size)

### 9.3.1 Detailed Description

The following functions are provided in `bl_decrypt.c` and are used to optionally decrypt the firmware data as it is received.

## 9.3.2 Function Documentation

### 9.3.2.1 DecryptData

Performs an in-place decryption of downloaded data.

**Prototype:**

```
void  
DecryptData(uint8_t *pui8Buffer,  
            uint32_t ui32Size)
```

**Parameters:**

***pui8Buffer*** is the buffer that holds the data to decrypt.

***ui32Size*** is the size, in bytes, of the buffer that was passed in via the *pui8Buffer* parameter.

**Description:**

This function is a stub that could provide in-place decryption of the data that is being downloaded to the device.

**Returns:**

None.

## 9.4 Ethernet Functions

The following functions are provided in `bl_enet.c` and are used to perform an update over the Ethernet interface.

## 9.5 File System Functions

The following functions are provided in `bl_fs.c` and are used to provide very basic support for reading from a FAT file system.

## 9.6 I2C Functions

### Functions

- void [I2CFlush](#) (void)
- void [I2CReceive](#) (uint8\_t \*pui8Data, uint32\_t ui32Size)
- void [I2CSend](#) (const uint8\_t \*pui8Data, uint32\_t ui32Size)

### 9.6.1 Detailed Description

The following functions are provided in `bl_i2c.c` and are used to communicate over the I2C interface.

---

## 9.6.2 Function Documentation

### 9.6.2.1 I2CFlush

Waits until all data has been transmitted by the I2C port.

**Prototype:**

```
void  
I2CFlush(void)
```

**Description:**

This function waits until all data written to the I2C port has been read by the master.

**Returns:**

None.

### 9.6.2.2 I2CReceive

Receives data over the I2C port.

**Prototype:**

```
void  
I2CReceive(uint8_t *pui8Data,  
           uint32_t ui32Size)
```

**Parameters:**

***pui8Data*** is the buffer to read data into from the I2C port.

***ui32Size*** is the number of bytes provided in the *pui8Data* buffer that should be written with data from the I2C port.

**Description:**

This function reads back *ui32Size* bytes of data from the I2C port, into the buffer that is pointed to by *pui8Data*. This function will not return until *ui32Size* number of bytes have been received. This function will wait till the I2C Slave port has been properly addressed by the I2C Master before reading the first byte of data from the I2C port.

**Returns:**

None.

### 9.6.2.3 I2CSend

Sends data over the I2C port.

**Prototype:**

```
void  
I2CSend(const uint8_t *pui8Data,  
        uint32_t ui32Size)
```

**Parameters:**

***pui8Data*** is the buffer containing the data to write out to the I2C port.

*ui32Size* is the number of bytes provided in *pui8Data* buffer that will be written out to the I2C port.

**Description:**

This function sends *ui32Size* bytes of data from the buffer pointed to by *pui8Data* via the I2C port. The function will wait till the I2C Slave port has been properly addressed by the I2C Master device before sending the first byte.

**Returns:**

None.

## 9.7 Main Functions

### Functions

- void [ConfigureDevice](#) (void)
- void [Updater](#) (void)

### 9.7.1 Detailed Description

The following functions are provided in `bl_main.c` and comprise the main boot loader application.

### 9.7.2 Function Documentation

#### 9.7.2.1 ConfigureDevice

Configures the microcontroller.

**Prototype:**

```
void  
ConfigureDevice(void)
```

**Description:**

This function configures the peripherals and GPIOs of the microcontroller, preparing it for use by the boot loader. The interface that has been selected as the update port will be configured, and auto-baud will be performed if required.

**Returns:**

None.

#### 9.7.2.2 Updater

This function performs the update on the selected port.



**Prototype:**

```
void  
Updater(void)
```

**Description:**

This function is called directly by the boot loader or it is called as a result of an update request from the application.

**Returns:**

Never returns.

## 9.8 Packet Handling Functions

### Functions

- void [AckPacket](#) (void)
- uint32\_t [Checksum](#) (const uint8\_t \*pui8Data, uint32\_t ui32Size)
- void [NakPacket](#) (void)
- int [ReceivePacket](#) (uint8\_t \*pui8Data, uint32\_t \*pui32Size)
- int [SendPacket](#) (uint8\_t \*pui8Data, uint32\_t ui32Size)

### 9.8.1 Detailed Description

The following functions are provided in `bl_packet.c` and are used to process the data packets in the custom serial protocol.

### 9.8.2 Function Documentation

#### 9.8.2.1 AckPacket

Sends an Acknowledge packet.

**Prototype:**

```
void  
AckPacket(void)
```

**Description:**

This function is called to acknowledge that a packet has been received by the microcontroller.

**Returns:**

None.

#### 9.8.2.2 CheckSum

Calculates an 8-bit checksum

**Prototype:**

```
uint32_t  
Checksum(const uint8_t *pui8Data,  
          uint32_t ui32Size)
```

**Parameters:**

***pui8Data*** is a pointer to an array of 8-bit data of size *ui32Size*.

***ui32Size*** is the size of the array that will run through the checksum algorithm.

**Description:**

This function simply calculates an 8-bit checksum on the data passed in.

**Returns:**

Returns the calculated checksum.

### 9.8.2.3 NakPacket

Sends a no-acknowledge packet.

**Prototype:**

```
void  
NakPacket(void)
```

**Description:**

This function is called when an invalid packet has been received by the microcontroller, indicating that it should be retransmitted.

**Returns:**

None.

### 9.8.2.4 ReceivePacket

Receives a data packet.

**Prototype:**

```
int  
ReceivePacket(uint8_t *pui8Data,  
              uint32_t *pui32Size)
```

**Parameters:**

***pui8Data*** is the location to store the data that is sent to the boot loader.

***pui32Size*** is the number of bytes returned in the *pui8Data* buffer that was provided.

**Description:**

This function receives a packet of data from specified transfer function.

**Returns:**

Returns zero to indicate success while any non-zero value indicates a failure.

### 9.8.2.5 SendPacket

Sends a data packet.

**Prototype:**

```
int
SendPacket (uint8_t *pui8Data,
            uint32_t ui32Size)
```

**Parameters:**

***pui8Data*** is the location of the data to be sent.

***ui32Size*** is the number of bytes to send.

**Description:**

This function sends the data provided in the *pui8Data* parameter in the packet format used by the boot loader. The caller only needs to specify the buffer with the data that needs to be transferred. This function addresses all other packet formatting issues.

**Returns:**

Returns zero to indicate success while any non-zero value indicates a failure.

## 9.9 SSI Functions

### Functions

- void [SSIFlush](#) (void)
- void [SSIReceive](#) (uint8\_t \*pui8Data, uint32\_t ui32Size)
- void [SSISend](#) (const uint8\_t \*pui8Data, uint32\_t ui32Size)

### 9.9.1 Detailed Description

The following functions are provided in `bl_ssi.c` and are used to communicate over the SSI interface.

### 9.9.2 Function Documentation

#### 9.9.2.1 SSIFlush

Waits until all data has been transmitted by the SSI port.

**Prototype:**

```
void
SSIFlush (void)
```

**Description:**

This function waits until all data written to the SSI port has been read by the master.

**Returns:**  
None.

### 9.9.2.2 SSIReceive

Receives data from the SSI port in slave mode.

**Prototype:**  
void  
SSIReceive(uint8\_t \*pui8Data,  
          uint32\_t ui32Size)

**Parameters:**  
***pui8Data*** is the location to store the data received from the SSI port.  
***ui32Size*** is the number of bytes of data to receive.

**Description:**  
This function receives data from the SSI port in slave mode. The function will not return until *ui32Size* number of bytes have been received.

**Returns:**  
None.

### 9.9.2.3 SSISend

Sends data via the SSI port in slave mode.

**Prototype:**  
void  
SSISend(const uint8\_t \*pui8Data,  
          uint32\_t ui32Size)

**Parameters:**  
***pui8Data*** is the location of the data to send through the SSI port.  
***ui32Size*** is the number of bytes of data to send.

**Description:**  
This function sends data through the SSI port in slave mode. This function will not return until all bytes are sent.

**Returns:**  
None.

## 9.10 UART Functions

### Functions

- void [UARTFlush](#) (void)

- void [UARTReceive](#) (uint8\_t \*pui8Data, uint32\_t ui32Size)
- void [UARTSend](#) (const uint8\_t \*pui8Data, uint32\_t ui32Size)

## 9.10.1 Detailed Description

The following functions are provided in `bl_uart.c` and are used to communicate over the UART interface.

## 9.10.2 Function Documentation

### 9.10.2.1 UARTFlush

Waits until all data has been transmitted by the UART port.

**Prototype:**

```
void
UARTFlush(void)
```

**Description:**

This function waits until all data written to the UART port has been transmitted.

**Returns:**

None.

### 9.10.2.2 UARTReceive

Receives data over the UART port.

**Prototype:**

```
void
UARTReceive(uint8_t *pui8Data,
            uint32_t ui32Size)
```

**Parameters:**

***pui8Data*** is the buffer to read data into from the UART port.

***ui32Size*** is the number of bytes provided in the *pui8Data* buffer that should be written with data from the UART port.

**Description:**

This function reads back *ui32Size* bytes of data from the UART port, into the buffer that is pointed to by *pui8Data*. This function will not return until *ui32Size* number of bytes have been received.

**Returns:**

None.

### 9.10.2.3 UARTSend

Sends data over the UART port.

**Prototype:**

```
void
UARTSend(const uint8_t *pui8Data,
          uint32_t ui32Size)
```

**Parameters:**

***pui8Data*** is the buffer containing the data to write out to the UART port.

***ui32Size*** is the number of bytes provided in *pui8Data* buffer that will be written out to the UART port.

**Description:**

This function sends *ui32Size* bytes of data from the buffer pointed to by *pui8Data* via the UART port.

**Returns:**

None.

## 9.11 Update Check Functions

### Functions

- `uint32_t CheckForceUpdate (void)`

#### 9.11.1 Detailed Description

The following functions are provided in `bl_check.c` and are used to check if a firmware update is required.

#### 9.11.2 Function Documentation

##### 9.11.2.1 CheckForceUpdate

Checks if an update is needed or is being requested.

**Prototype:**

```
uint32_t
CheckForceUpdate(void)
```

**Description:**

This function detects if an update is being requested or if there is no valid code presently located on the microcontroller. This is used to tell whether or not to enter update mode.

**Returns:**

Returns a non-zero value if an update is needed or is being requested and zero otherwise.

## 9.12 USB Device Functions

### Data Structures

- [tConfigDescriptor](#)
- [tString0Descriptor](#)
- [tStringDescriptor](#)
- [tUSBRequest](#)

### Functions

- void [AppUpdaterUSB](#) (void)
- void [ConfigureUSB](#) (void)
- void [ConfigureUSBInterface](#) (void)
- void [HandleRequests](#) (tUSBRequest \*psUSBRequest)
- bool [ProcessDFUDnloadCommand](#) (tDFUDownloadHeader \*psCmd, uint32\_t ui32Size)
- void [UpdaterUSB](#) (void)
- void [USBBLInit](#) (void)
- void [USBBLSendDataEPO](#) (uint8\_t \*pui8Data, uint32\_t ui32Size)
- void [USBBLStallEPO](#) (void)
- void [USBConfigurePins](#) (void)

### 9.12.1 Detailed Description

The following functions are provided in `bl_usb.c` and `bl_usbfuncs.c` and are used to communicate over the USB interface.

### 9.12.2 Data Structure Documentation

#### 9.12.2.1 tConfigDescriptor

**Definition:**

```
typedef struct
{
    uint8_t bLength;
    uint8_t bDescriptorType;
    uint16_t wTotalLength;
    uint8_t bNumInterfaces;
    uint8_t bConfigurationValue;
    uint8_t iConfiguration;
    uint8_t bmAttributes;
    uint8_t bMaxPower;
}
tConfigDescriptor
```

**Members:**

- bLength*** The length of this descriptor in bytes. All configuration descriptors are 9 bytes long.
- bDescriptorType*** The type of the descriptor. For a configuration descriptor, this will be USB\_DTYPE\_CONFIGURATION (2).
- wTotalLength*** The total length of data returned for this configuration. This includes the combined length of all descriptors (configuration, interface, endpoint and class- or vendor-specific) returned for this configuration.
- bNumInterfaces*** The number of interface supported by this configuration.
- bConfigurationValue*** The value used as an argument to the SetConfiguration standard request to select this configuration.
- iConfiguration*** The index of a string descriptor describing this configuration.
- bmAttributes*** Attributes of this configuration.
- bMaxPower*** The maximum power consumption of the USB device from the bus in this configuration when the device is fully operational. This is expressed in units of 2mA so, for example, 100 represents 200mA.

**Description:**

This structure describes the USB configuration descriptor as defined in USB 2.0 specification section 9.6.3. This structure also applies to the USB other speed configuration descriptor defined in section 9.6.4.

### 9.12.2.2 tString0Descriptor

**Definition:**

```
typedef struct
{
    uint8_t bLength;
    uint8_t bDescriptorType;
    uint16_t wLANGID[1];
}
tString0Descriptor
```

**Members:**

- bLength*** The length of this descriptor in bytes. This value will vary depending upon the number of language codes provided in the descriptor.
- bDescriptorType*** The type of the descriptor. For a string descriptor, this will be USB\_DTYPE\_STRING (3).
- wLANGID*** The language code (LANGID) for the first supported language. Note that this descriptor may support multiple languages, in which case, the number of elements in the wLANGID array will increase and bLength will be updated accordingly.

**Description:**

This structure describes the USB string descriptor for index 0 as defined in USB 2.0 specification section 9.6.7. Note that the number of language IDs is variable and can be determined by examining bLength. The number of language IDs present in the descriptor is given by  $((bLength - 2) / 2)$ .



### 9.12.2.3 tStringDescriptor

**Definition:**

```
typedef struct
{
    uint8_t bLength;
    uint8_t bDescriptorType;
    uint8_t bString;
}
tStringDescriptor
```

**Members:**

**bLength** The length of this descriptor in bytes. This value will be 2 greater than the number of bytes comprising the UNICODE string that the descriptor contains.

**bDescriptorType** The type of the descriptor. For a string descriptor, this will be USB\_DTYPE\_STRING (3).

**bString** The first byte of the UNICODE string. This string is not NULL terminated. Its length (in bytes) can be computed by subtracting 2 from the value in the bLength field.

**Description:**

This structure describes the USB string descriptor for all string indexes other than 0 as defined in USB 2.0 specification section 9.6.7.

### 9.12.2.4 tUSBRequest

**Definition:**

```
typedef struct
{
    uint8_t bmRequestType;
    uint8_t bRequest;
    uint16_t wValue;
    uint16_t wIndex;
    uint16_t wLength;
}
tUSBRequest
```

**Members:**

**bmRequestType** Determines the type and direction of the request.

**bRequest** Identifies the specific request being made.

**wValue** Word-sized field that varies according to the request.

**wIndex** Word-sized field that varies according to the request; typically used to pass an index or offset.

**wLength** The number of bytes to transfer if there is a data stage to the request.

**Description:**

The standard USB request header as defined in section 9.3 of the USB 2.0 specification.

## 9.12.3 Function Documentation

### 9.12.3.1 AppUpdaterUSB

This is the application entry point to the USB updater.

**Prototype:**

```
void  
AppUpdaterUSB(void)
```

**Description:**

This function should only be entered from a running application and not when running the boot loader with no application present. If the calling application supports any USB device function, it must remove itself from the USB bus prior to calling this function. This function assumes that the calling application has already configured the system clock to run from the PLL.

**Returns:**

None.

### 9.12.3.2 ConfigureUSB

Generic configuration is handled in this function.

**Prototype:**

```
void  
ConfigureUSB(void)
```

**Description:**

This function is called by the start up code to perform any configuration necessary before calling the update routine. It is responsible for setting the system clock to the expected rate and setting flash programming parameters prior to calling [ConfigureUSBInterface\(\)](#) to set up the USB hardware and place the DFU device on the bus.

**Returns:**

None.

### 9.12.3.3 ConfigureUSBInterface

Configure the USB controller and place the DFU device on the bus.

**Prototype:**

```
void  
ConfigureUSBInterface(void)
```

**Description:**

This function configures the USB controller for DFU device operation, initializes the state machines required to control the firmware update and places the device on the bus in preparation for requests from the host. It is assumed that the main system clock has been configured at this point.

**Returns:**  
None.

#### 9.12.3.4 HandleRequests

Handle USB requests sent to the DFU device.

**Prototype:**  
void  
HandleRequests([tUSBRequest](#) \*psUSBRequest)

**Parameters:**  
*psUSBRequest* is a pointer to the USB request that the device has been sent.

**Description:**  
This function is called to handle all non-standard requests received by the device. This will include all the DFU endpoint 0 commands along with the TIVA-specific request we use to query whether the device supports our flavor of the DFU binary format. Incoming DFU requests are processed by request handlers specific to the particular state of the DFU connection. This state machine implementation is chosen to keep the software as close as possible to the USB DFU class documentation.

**Returns:**  
None.

#### 9.12.3.5 ProcessDFUDnloadCommand

Process TIVA-specific commands passed via DFU download requests.

**Prototype:**  
bool  
ProcessDFUDnloadCommand([tDFUDownloadHeader](#) \*psCmd,  
uint32\_t ui32Size)

**Parameters:**  
*psCmd* is a pointer to the first byte of the **DFU\_DNLOAD** payload that is expected to hold a command.

*ui32Size* is the number of bytes of data pointed to by *psCmd*. This function is called when a DFU download command is received while in **STATE\_IDLE**. New downloads are assumed to contain a prefix structure containing one of several TIVA-specific commands and this function is responsible for parsing the download data and processing whichever command is contained within it.

**Returns:**  
Returns **true** on success or **false** on failure.

#### 9.12.3.6 void UpdaterUSB (void)

This is the main routine for handling updating over USB.

This function forms the main loop of the USB DFU updater. It polls for commands sent from the USB request handlers and is responsible for erasing flash blocks, programming data into erased blocks and resetting the device.

**Returns:**  
None.

#### 9.12.3.7 void USBBLInit (void)

Initialize the boot loader USB functions.

This function initializes the boot loader USB functions and places the DFU device onto the USB bus.

**Returns:**  
None.

#### 9.12.3.8 void USBBLSendDataEP0 (uint8\_t \* *pui8Data*, uint32\_t *ui32Size*)

This function requests transfer of data to the host on endpoint zero.

**Parameters:**  
*pui8Data* is a pointer to the buffer to send via endpoint zero.  
*ui32Size* is the amount of data to send in bytes.

**Description:**  
This function handles sending data to the host when a custom command is issued or non-standard descriptor has been requested on endpoint zero.

**Returns:**  
None.

#### 9.12.3.9 USBBLStallEP0

This function generates a stall condition on endpoint zero.

**Prototype:**  
void  
USBBLStallEP0 (void)

**Description:**  
This function is typically called to signal an error condition to the host when an unsupported request is received by the device. It should be called from within the callback itself (in interrupt context) and not deferred until later since it affects the operation of the endpoint zero state machine.

**Returns:**  
None.

### 9.12.3.10 USBConfigurePins

Initialize the pins used by USB functions.

**Prototype:**

```
void  
USBConfigurePins(void)
```

**Description:**

This function configures the pins for USB functions depending on defines from the `bl_config.h` file.

**Returns:**

None.

---

# IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

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

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

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

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

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have **not** been so designated is solely at the Buyer’s risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

## Products

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

## Applications

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

**TI E2E Community** [e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2007-2014, Texas Instruments Incorporated