

Booting and Flashing via the DaVinci TMS320DM644x Serial Interface

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ABSTRACT

This application report describes two related pieces of software that are used together to boot the ARM core of the DM644x via the universal asynchronous receiver/transmitter (UART0) serial interface. Additionally, this software allows you to write the needed files to a NAND or NOR flash device, connected to the DM644x AEMIF, such that the ARM core can boot from these external memories. The software consists of a host application, which runs on your PC, and a user boot loader (UBL), which runs on the DM644x ARM core. This UBL also can be placed in the NAND flash memory to enable booting from this device. The software presented in this application report is an extension of that discussed in *Basic Application Loading over the Serial Interface for the DaVinci TMS320DM644x* ([SPRAAI0](#)).

This application report contains project code that can be downloaded from <http://www.ti.com/lit/zip/SPRAAI4>.

NOTE: The associated software described by this document is no longer supported and is meant for informational and archival purposes. The information contained in this document regarding the boot processes of the DM644x device itself is still correct and accurate. Details about updated software tools can be found at the following URL:
[http://wiki.davincidsp.com/index.php?title=Serial Boot and Flash Loading Utility](http://wiki.davincidsp.com/index.php?title=Serial_Boot_and_Flash_Loading_UTILITY).

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1 TMS320DM644x Boot Overview

This section gives an overview of the boot process of the DM644x device. This section mirrors the presentation given in the Chapter 12 of the *TMS320DM644x DMSoC ARM Subsystem Reference Guide (SPRUE14)*. The reader should be familiar with all the information in that chapter before proceeding. Additional details can be found in the boot mode section of the *TMS320DM6446 Digital Media System-on-Chip* data manual ([SPRS283](#)).

Upon reset or power up, the DM644x begins executing code from its ROM boot loader (RBL). The RBL determines how to boot based on the logic levels at pins BTSEL[1..0]. These values are latched into the BOOTCFG register bits 7..6 at reset, and the RBL reads this register to determine the intended boot mode. On the Spectrum Digital DVEVM board, these pins are attached to switches S3-2 and S3-1, respectively, allowing you to change the intended boot mode while the board is powered off. [Table 1](#) shows the available boot modes for the DM644x.

In this application report, particular attention is paid to the UART-boot mode. This mode is unique in that it generally requires a connection to an external host system in order to function. The traditional intention is that a secondary boot loader, referred to as a User Boot Loader (UBL) in the *TMS320DM644x DMSoC ARM Subsystem Reference Guide (SPRUE14)*, would be downloaded by the RBL. This UBL would then be used to initialize certain subsystems of the chip, such as the DDR2 memory controller, and download a tertiary boot loader or application. An example would be the u-boot boot loader, which has been written with the objective of loading the Linux®kernel onto embedded systems. In the NAND-boot mode, the RBL requires a similar UBL to exist in the NAND memory to load the tertiary boot loader or application from NAND to RAM. The NOR-boot mode can use a UBL, though it is not required. Details of how the UBL is structured and used are given in [Section 2](#).

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Table 1. Boot Modes for DM644x Device

BTSEL0 (DVEVM SW3-1)	BTSEL1 (DVEVM SW3-2)	Boot Mode
0	0	NAND Flash Boot
1	0	NOR Flash Boot
0	1	Reserved
1	1	UART Boot

The presence of the attached host in the UART-boot mode allows you to do more than simply load additional executable code. With a properly written host and target application (i.e., the UBL), a number of low-level system functions can be executed. This application report describes the development of a target application that can act as a UBL for all three boot modes, and provides additional means, while in the UART-boot mode, to prepare the NAND or NOR flash devices for booting. This document also provides details of the host application that interfaces with the UBL over the serial link. Emphasis is placed on how these two pieces of software must be developed jointly. Details of the UBL's use as a flashing application are given in [Section 3](#). Details of the host application can be found in [Section 4](#). The reader should note that the UBL and host application presented here are more complex extensions of the target and host applications described in the *Basic Application Loading Over the Serial Interface for the DaVinci TMS320DM644x* ([SPRAAI0](#)).

2 Target Application Used as a UBL

The target application is the binary executable that is downloaded via the UART during the UART boot process, i.e., the UART UBL. This UBL is downloaded to the ARM internal memory. Once located there, the UBL is verified and begins execution. The UBL is then responsible for initializing the system to a desired state. Usually this will involve turning on the DDR memory interface and setting the system clock. See the *dm644x.c* file and [SPRAAI0](#) for more details.

The target application presented in this document has been written so that it also can be used as a boot loader for the NAND- and NOR-boot modes, as well as the UART-boot mode. Consequently, the terms 'target application' and 'UBL' are used interchangeably for the remainder of the document. In this section, the discussion focuses on how the UBL code is written to act as a boot loader (i.e., downloading and executing an application or tertiary boot loader) for the three possible boot modes. [Section 2.1](#) presents the overall structure of the code files that make up the UBL and their role in the various boot modes. [Section 2.2](#) to [Section 2.4](#) give details of each of the boot modes and the use of the UBL in these modes.

2.1 General Description of UBL Code

The source code for the UBL, found in the *ubl/src* directory, is divided logically into files by boot mode and function, with the exception of three general files. The filenames and their descriptions are shown in [Table 2](#). The file *dm644x.c* contains the necessary system initialization procedures, such as those described in [SPRAAI0](#) (the code is nearly identical). The file *util.c* contains some miscellaneous code used to allocate memory from the initialized RAM space, provide wait loops throughout the UBL, and decode Motorola S-record images downloaded over the UART or loaded out of flash memory. The file *ubl.c* contains the entry point and exit point functions, self-copy code that is used in NOR boots, and the main function used to determine the selected boot mode, call the initialization routines, and branch to the correct boot code. The *ubl.c* is equivalent to the *uartapp.c* file discussed in [SPRAAI0](#). The source files are supported by number of header file found in the *ubl/include* directory. Further information about compiling the UBL sources can be found in the *readme.txt* file in the source zip archive.

Table 2. Overview of UBL Source Code Files and Structure

Source File	Description of contents
dm644x.c	Contains the necessary system initialization code
ubl.c	Contains the entry point, exit point, and main boot mode detection and code branching
util.c	Contains a collection of miscellaneous utilities, including code for rudimentary RAM memory allocation and S-Record decoding
uart.c	Driver file for UART transmissions
uartboot.c	UBL code for UART-boot mode
nand.c	Driver file for reading and writing to supported NAND flash devices
nandboot.c	UBL code for NAND-boot mode - loads boot image into RAM
nor.c	Driver file for identifying and writing CFI-compliant NOR flash devices
norboot.c	UBL code for NOR boot mode - loads boot image into RAM

The heart of the UBL functionality is found in the driver files - *nand.c*, *nor.c*, and *uart.c* - and boot files - *nandboot.c*, *norboot.c*, and *uartboot.c*. These files are discussed to some degree in the following sections, along with details of how the RBL hands control to the UBL in each boot mode.

2.2 UBL Usage in the NAND-Boot Mode

The DM644x has support for a limited number of NAND devices fixed in the RBL. When the NAND-boot mode is selected, the RBL attempts to identify the NAND device attached to the CS2 memory region. The data width is determined by the value of the EM_WIDTH pin, which is latched into the BOOTCFG register at power-up. If the device is identified as supported, the RBL begins the attempt to boot from the NAND flash. It does this by looking for a UBL header and the UBL binary data starting in block 1 of the NAND flash. The RBL contains its own driver code to access the NAND device because such devices have multiplexed I/O pins for both address and data. This allows the RBL to read the NAND flash memory pages and inspect their contents. [Figure 1](#) shows how the RBL's program flow for loading the UBL out of the NAND flash.

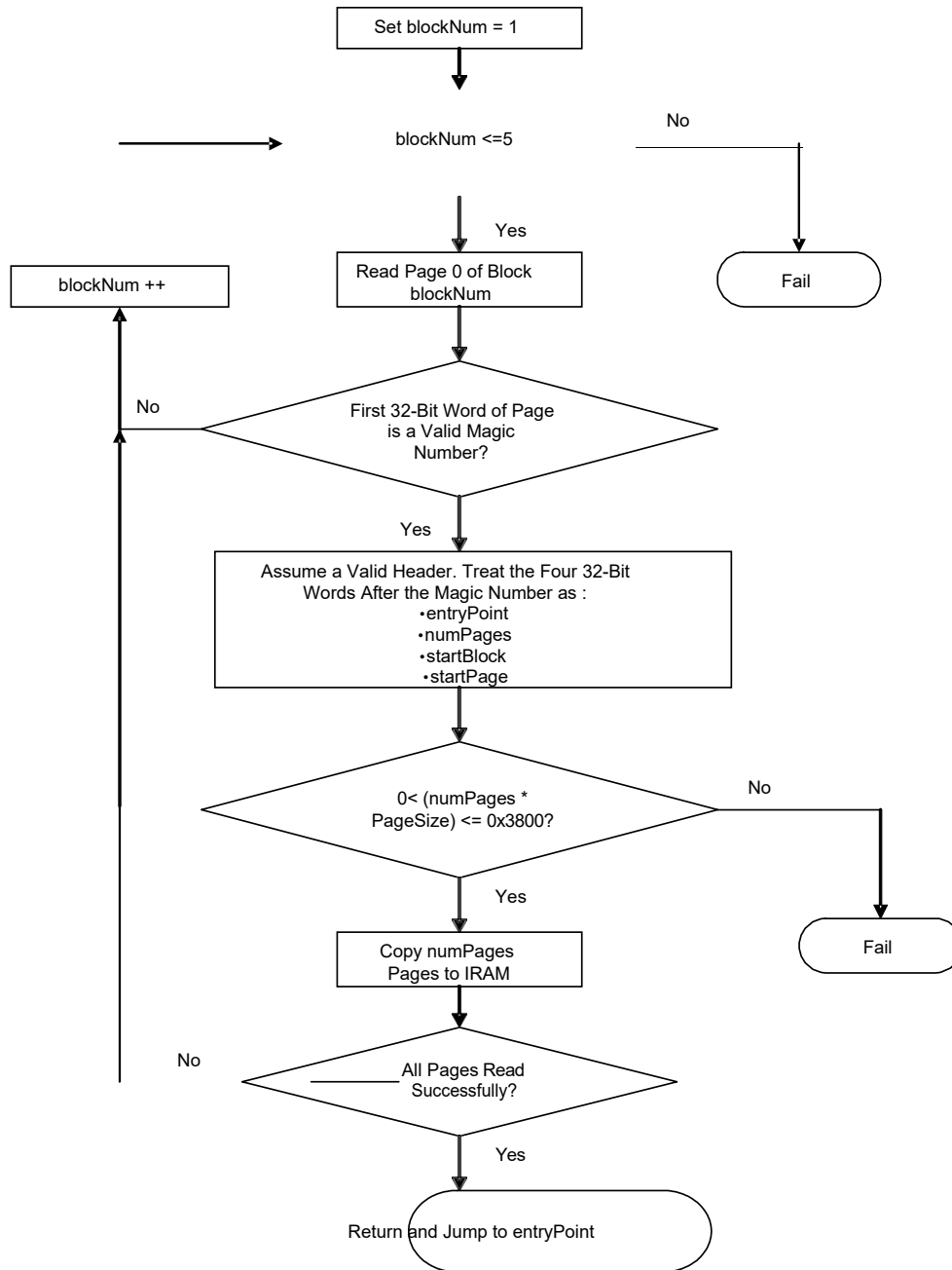


Figure 1. ROM Boot Loader NAND Mode Program Flow

As [Figure 1](#) shows, the RBL attempts to find an acceptable magic number in the first four bytes of page 0 of the blocks 1 through 5 of the NAND memory. A list of valid magic numbers can be found in the *TMS320DM644x DMSoC ARM Subsystem Reference Guide (SPRUE14)*. Different magic numbers enable certain features of the DM644x, such as cache and EDMA. Because the UBL code is small, in general it is safest to use UBL_MAGIC_SAFE without any noticeable performance penalty. If the other features are needed by the application or tertiary boot loader, they can be enabled as part of that code.

NOTE: If the NAND boot process fails, the RBL automatically tries to boot using the UART. The BOOTCFG bits still reflect that the DM644x boot pins are set for NAND-boot mode. It may be important to consider what chip peripherals are enabled by default in the different boot modes.

NOTE: When the RBL reads the NAND memory pages, it always verifies the data by checking ECC values. [Appendix E](#) provides details of how the RBL does this. Users who write UBLs to the NAND device need to acutely aware of how the ECC checks are handled or the NAND boot process will fail.

Once a valid magic number is found, the RBL assumes that a valid UBL header has been found in the first 20 bytes of the page (with the magic number occupying the first four of those 20 bytes). The structure of this header is shown in [Table 3](#). The data in the header allows the RBL to locate the UBL image, copy it to the IRAM, and then begin executing it.

The UBL begins by initializing all necessary subsystems of the DM644x and then checks what boot mode is in effect. A switch statement provides individual code paths for each boot mode. In the case of the NAND-boot mode, control passes to the `NAND_copy()` function in the file `nandboot.c`. The `NAND_copy()` function returns to the NAND device in the CS2 memory space and begins searching at page 0 of block 6 (because blocks 1 through 5 might contain the UBL) for the NAND application header. If the header is not found in block 6, the UBL tries each successive block up to block 50. The UBL, like the RBL, needs to have a NAND driver to access and read the NAND flash contents. The file `nand.c` contains all needed code to initialize, identify, read, write, and erase supported NAND memory devices.

This application header, like the UBL header, contains the needed information to find and copy the application image from the NAND flash to the DDR RAM space. Its contents are detailed in [Table 4](#). The magic number of this header indicates whether the image is in S-record form or binary form. The other entries are identical to those found in the UBL header. A new entry, the load address, tells the UBL where to load a binary image. An S-record image has this load address included as part of its format and ignores this field. Once the image is copied and, if needed, decoded, the UBL passes control to the code at the entry point address, concluding the boot loading process.

NOTE: If the `NAND_Copy()` function fails, the UBL defaults to trying to load an application image over the UART, as if a UART boot had been initiated. This behavior echoes that of the RBL when the NAND boot fails. The DVFlasher host application, described in more detail in [Section 4](#), can be used to complete the operation using the `noRBL` command-line option.

Table 3. NAND UBL Header

Address in Page		Description
0x00	0xA1ACEDxx	A valid magic number of the NAND-boot mode
0x04	UBL entry point address	32-bit absolute entry-point address for UBL
0x08	numPages	The number of pages the UBL occupies
0x0C	startBlock	The starting block in NAND where the UBL can be found
0x10	startPage	The starting page within the starting block where the UBL can be found

Table 4. NAND Application Header

Address in Page		Description
0x00	0xA1ACEDxx	A valid magic number used to indicate image type
0x04	Application entry point address	32-bit absolute entry-point address for application
0x08	numPages	The number of pages the application occupies
0x0C	startBlock	The starting block in NAND where the application can be found
0x10	startPage	The starting page within the starting block where the application can be found
0x14	loadAddr	Starting load address (in RAM) where the image should be copied (binary image only)

2.3 UBL Usage in the NOR-Boot Mode

The main difference between using NAND flash and NOR flash memories via the AEMIF interface is that the NOR flash can be directly addressed as a memory device by the CPU, while a NAND device cannot. This means that the ARM core of the DM644x can execute code directly from a NOR flash in any of the CSx memory spaces. In NOR-boot mode, the RBL essentially detects the boot mode and then jumps to the CS2 memory region (address 0x02000000) to start executing the code found there. If the memory is empty, an exception will most likely occur, execution will return to the RBL, and the process will repeat in an infinite loop. There is no failsafe mechanism to execute a UART boot as there is with the NAND mode.

Table 5. NAND vs NOR Flash Comparison

Feature	NAND	NOR
Read Speed	Slower	Faster
Single-Byte Write Speed	Slow	Fast
Multi-Byte Write Speed	Faster	Slower
Erase Speed	Fast	Slow
Ease of Use/Integration	Low	High
Cost Per Bit	Low	High
Active Power Consumption	Low	High

There are tradeoffs between the two types of flashes, many of which are shown in [Table 5](#). In addition, on the TMS320DM644x, the NOR flash device is limited to 32 MB in size because that is the limit of each CSx memory region. While direct bus addressing provides for easy integration of NOR devices, it also limits their maximum size. The NAND device, because its interface uses multiplexed I/O, can be much larger.

Because the code can be executed in-place with the NOR flash, a UBL is technically not needed. NOR devices, however, still require special commands to write data, so data storage must be placed in RAM. For this reason, any code in NOR usually begins by initializing the system and copying itself to RAM (either on-chip or external). The U-boot Linux bootloader works this way for example, initializing RAM and copying itself there. A UBL would need to do the same. But why use a UBL if it is not needed? One reason might be to simplify application code, placing all system initialization and loading code into the UBL. Another scenario might be if you are using a compressed application image. The UBL could be used to initialize the DDR RAM and decompress the application code there. It would make more sense in this case to have two separate code images instead of single, partly-compressed, partly-uncompressed image.

In this application report, the UBL has been written to function in the case of a NOR boot. The UBL is placed at the start of the CS2 memory space so that it begins execution first. The UBL is compiled and linked so that the code at the beginning of the UBL copies the entire UBL image to the IRAM of the ARM core. The self-copy code then passes control to the normal UBL entry point (i.e., the same one used in the UART and NAND-boot modes). The UBL then detects that the DM644x is in NOR-boot mode and passes control to the `NOR_Copy()` function in the `norboot.c` file. The driver file `nor.c` is used to initialize the AEMIF interface for NOR interfacing, but it is not needed to perform reads.

The `NOR_Copy()` function looks for a NOR application image header (defined as part of the UBL and in [Table 6](#)), at the beginning of the first block following the block containing the end of the UBL image. The header provides information about the image, such as whether the image is in S-record or binary format, the image size in bytes, and the load address. If a valid header is found, the UBL either copies or decodes the image to the DDR RAM, depending on its format (binary or S-record). The image is found in the `appSize` bytes immediately following the NOR image header (starting at address 0x10 of the block). Once the image has been relocated to RAM, the UBL passes control to the specified entry point of the application image. The boot loading process is now complete.

Table 6. NOR Application Header

Address in Block		Description
0x00	0xA1ACEDxx	A valid magic number used to indicate image type
0x08	entry point	32-bit absolute entry-point address for application
0x04	appSize	Size of application in bytes
0x0C	ldAddress	Starting load address (in RAM) where the image should be copied (binary image only)

2.4 UBL Usage in the UART-Boot Mode

The use of the UART-boot mode to download and execute code is thoroughly discussed in *Basic Application Loading Over Serial Interface for the DaVinci TMS320DM644x* ([SPRAAI0](#)). The only difference between that case and the one under consideration in this application report is that the simple serial application is a user boot loader. The UBL expects continued interaction with the host system to download and execute a larger application or tertiary boot loader like U-boot. The discussion of how the RBL interfaces to the host PC is presented in Section 2 of [SPRAAI0](#) and is not repeated here. [SPRAAI0](#) also provides details of the UART driver file, *uart.c*, and therefore is not mentioned in this section. Instead, this section focuses on how the UBL code is written to perform its duty when in the UART-boot mode after the UBL has been loaded via the RBL.

As in the previous two cases, the UBL begins by checking the boot mode and initializing the system peripherals. In addition, the UBL waits until the UART0 Line Status register indicates that there are no transmissions still in progress via the following command

```
while((UART0->LSR & 0x40) == 0 );
```

This is important to ensure that the last bytes being sent by the UBL are allowed to clear out of the UART FIFO before it is reinitialized.

Once all initializations are complete, the boot mode switch statement passes control to the `UART_Boot()` function in the *uartboot.c* file. This function displays the prompt `BOOTPSP\0` (the '\0' symbol represents the ASCII NULL character, 0x00) to the host over the serial connection and then waits for a command from the host. The command takes the form of a 32-bit magic number, similar to the magic numbers used by the RBL in the NAND-boot mode, but defined for use in this UBL only. The commands could have taken any form, but much of the conceptual design of the UBL came from the RBL, so the choice was made to extend the magic number table to make command values.

There are a number of possible commands that can be handled within the `UART_Boot()` function. A switch block determines what course of action is followed with the default being to download and run an application; that is, to act as a UART UBL. The other commands involve operations on the NAND or NOR flash devices. They allow the UBL to act as a flashing application instead of a boot loader. This is discussed in [Section 3](#).

To download an application or tertiary boot loader over the serial interface, the host application, which interfaced with the RBL to transfer the UBL, must continue running, now interfacing with the UBL. The host application detects the `BOOTPSP\0` string and replies with the `^^^CMD\0` sequence (the '^' symbol represents the ASCII space character) and the 32-bit magic command number. The command is determined by you when the host application is called. For booting over the UART, the host sends the `UBL_MAGIC_SAFE` command and the UBL replies with the sequence, `SENDAPP\0`. The host then sends a header describing the application. Finally, the host packages and sends the binary application image in the S-record format. The UBL decodes the S-record back to binary form in RAM. The UBL then passes control to the image's specified entry point, which was provided in the header. At this point the boot loading process is complete.

3 Target Application to Write to NAND or NOR Flash in UART-Boot Mode

[Section 2.4](#) discusses how the UBL can be used to load an application image to the DDR RAM of the DM644x in the UART-boot mode. It is mentioned that there are other commands available in the `UART_Boot()` function to operate on the NAND or NOR Flash devices. This section describes in more detail these commands and how they work. [Section 3.1](#) presents some preliminary details of how the UBL is compiled for use in flashing the NAND and NOR devices. [Section 3.2](#) details how the NAND flashing code works, and [Section 3.3](#) gives details of how the NOR flashing code works.

3.1 Notes Regarding Compilation of the UBL Binaries

The extra functionality that is available in the UART-boot mode increases code size. To support erasing and writing of all possible NOR flash configurations and all supported NAND devices adds significantly to the `nand.c` and `nor.c` driver files. The `uartboot.c` file also increases in size due to the added command paths. All the additional code results in the size of the UBL growing larger than the 14 kB limit that the RBL accepts.

To overcome this issue, the code base must be divided into two separate UBLs. Because the desired operation is determined when the host application is called, the UBL can be split into a NAND version and a NOR version. The UBL downloaded at the start of the UART process will be correct based on the desired operation. If a UBL needs to be written to the flash memory, the correct version is again selected based on the operation selected on the command-line. If the selected operation is a simple boot loading operation, either version can be used.

To accomplish this UBL partitioning, the C code uses preprocessor directives to enable conditional compilation. The Makefile is written such that the UBL code is compiled twice with two different `#defines` passed via the gcc command-line. The result is two binary files, `ubl_davinci_nor.bin` and `ubl_davinci_nand.bin`. The code affected by the conditional `#defines` includes the following:

- NAND and NOR cases of boot mode switch statement in the `main()` function of `ubl.c`
- `nand.c` and `nandboot.c` (only compiled for NAND UBL)
- `nor.c` and `norboot.c` (only compiled for NOR UBL)
- NAND and NOR command cases of the command switch statement in the `uartboot()` function in `uartboot.c`

These two distinct binary files are then embedded in the host executable as resources. When the host is called with a command that targets the NOR memory, the NOR UBL is accessed and transmitted to the target. When the host is called with a command that targets the NAND memory, the NAND UBL is accessed and transmitted to the target instead.

3.2 NAND Flash Support

In the NAND UBL there are three commands available to operate on the NAND flash. These are defined in [Table 7](#). The first two commands are used to write a NAND UBL and application image to the NAND flash attached to the CS2 AEMIF, in either S-record or binary form. (The S-record image is approximately three times larger than the binary image.) The last command is used to perform a global erase of the NAND device. There is no command to perform a local erase over a smaller range, though the write command does erase individual blocks that it puts data into. These commands are discussed in the following sections. The discussion of code is not extend to the low-level details of how to interface with (i.e., read, write, erase) supported NAND flash devices. Only the highest, most abstract functions of the `nand.c` driver file are discussed. For reference, a list of supported NAND flash devices is supplied in [Appendix D](#).

Table 7. Table of Acceptable NAND Commands for Use in NAND UBL UART-Boot Mode

Command Name	Command Value
UBL_MAGIC_NAND_SREC_BURN	0xA1ACEDBB
UBL_MAGIC_NAND_BIN_BURN	0xA1ACEDCC
UBL_MAGIC_NAND_GLOBAL_ERASE	0xA1ACEDDD

3.2.1 NAND Flashing Commands

The two NAND flashing commands are used to write four items to the NAND flash. These items are the NAND UBL header, the NAND UBL binary, an application image header, and the application image. The only difference between these two commands is the type of the application image. It can be either an S-record or a binary image. As seen in [Table 4](#), the application image header contains a magic number, which indicates the format of the image. The possible values of this number and their meanings are shown in [Table 8](#). Since the two commands are so similar, they jointly use a single case of the *uartboot.c*'s command switch statement. The code for this is given in [Section A.1.0](#).

Table 8. NAND Application Image Header Magic Number

Number Name	Number Value	Description
UBL_MAGIC_SAFE	0xA1ACED00	Indicates that the application image is in S-record format.
UBL_MAGIC_BIN_IMG	0xA1ACED66	Indicates that the application image is in binary format.

When the NAND flash command code begins executing, it issues the *SENDUBL\0* prompt to indicate that the DM644x is waiting for the flash-bound UBL to be transmitted. The UBL code calls the `UARTGetHeaderAndData(&ackHeader)` function, found in the *uart.c* driver file, to receive the acknowledgement header and the image data from the host. All images transferred over the serial link are in S-record format. When they are received, they are decoded to a binary format to verify the data integrity. When the `UARTGetHeaderAndData(&ackHeader)` call returns, there are two versions of the image in DDR memory - one binary and one S-record. The `ackHeader` struct holds the address to both versions, as well as information about the size of both versions, the binary entry point, and the magic number. When the received image is a UBL UBL, only the binary data is used.

After the UBL is received, the NAND is initialized by a call to `NAND_Init()`, found in the *nand.c* driver file. The NAND UBL header is assigned appropriate values, some of which were received by `UARTGetHeaderAndData()`. The header and the data are written to the NAND memory through a call to `NAND_WriteHeaderAndData()`, also defined in the NAND driver file, with block 1 as the destination. Based on a given block destination, this function determines if this data is a UBL or application and attempts the appropriate number of rewrites if there are blocks with errors. (See [Section 2.2](#) for details on how bad blocks are handled in the boot process.)

The process outlined above begins again when the UBL requests the application image by sending the sequence *SENDAPP\0*. The host again transmits a header and data, and the target receives them via the `UARTGetHeaderAndData()` function. The NAND application header is set up and the header and data are written to the NAND flash by calling `NAND_WriteHeaderAndData()`. The difference in this case, is that the address of the image and the number of bytes in the image are selected between the S-record and binary versions depending on the value of the magic number. If, at any time during these operations, a failure occurs, the program flow terminates and the UART boot starts again by sending the *BOOTPSP\0* sequence and waiting for the *^^^CMD\0* sequence and a command value from the host.

3.2.2 NAND Erase Command

The NAND erase command does not require any further input from the host via the serial port. NAND devices are erased on a block basis. This code erases blocks 1 through the last block of the device. Block 0 is never touched, whether the operation is writing or erasing. First the NAND device is initialized by calling `NAND_Init()`. This function call populates the `gNandInfo` structure with the values defining the NAND interface and the identified device. Then the blocks that are to be erased are first unprotected by calling `NAND_UnProtectBlocks()` with the range of block numbers. `NAND_EraseBlocks()` is then called on that same range of blocks (which should be all blocks but block 0). If the erasure completes without error, the `NAND_ProtectBlocks()` function is called to protect all blocks in the device. Details of the code can be found in [Section A.2.0](#). The NAND erase function does require a measurable amount of time, but it is significantly quicker than the erasure of a similarly-sized NOR device.

3.3 NOR Flash Support

In the NOR UBL there are four commands available to operate on the NOR flash. These are defined in [Table 9](#). The first command does not have an analog in the set NAND flash commands. The remaining three commands mirror the three NAND commands. All of these commands are discussed in the following sections. As in the NAND case, the discussion does not consider many details of the NOR driver file, *nor.c*. A few details of the hardware cases that the NOR driver file supports can be found in [Appendix C](#).

Table 9. Table of Acceptable NOR Commands for Use in NOR UBL UART-Boot Mode

Command Name	Command Value
UBL_MAGIC_NOR_RESTORE	0xA1ACED77
UBL_MAGIC_NOR_SREC_BURN	0xA1ACED88
UBL_MAGIC_NOR_BIN_BURN	0xA1ACED99
UBL_MAGIC_NOR_GLOBAL_ERASE	0xA1ACEDAA

3.3.1 NOR Restore Command

The UBL_MAGIC_NOR_RESTORE command is used to place a downloaded image at the start of the NOR flash without a UBL. The image should be executable starting at its base and perform any needed system initialization routines because the UBL is not in place to do this. This command is called the RESTORE command since its primary purpose is to return the Spectrum Digital DVEVM to a bootable state by writing a NOR U-boot image to the NOR flash (without having to use CCS), though technically any data can be written to the start of the NOR flash with this command. The NOR U-boot image contains all needed initialization and start-up code and can be further used to boot and use Linux® software to restore the hard drive contents, etc. The code to execute this command, found in *uartboot.c*, is included in [Section A.3.0](#).

The code shows that the UBL responds to the restore commands with the *SENDAPP0* sequence. The host application then sends the header and application image, which the UBL reads with the same *UARTGetHeaderAndData()* function. *NOR_Init()* is called to identify and initialize the flash memory. This step fills the *gNorInfo* structure with important information about the flash device(s), including its total size, the number and size of its blocks, and the command set used to access the device(s). The blocks that will contain the binary bytes of the UBL, starting at the base of the flash memory (0x02000000), are then erased by calling *NOR_Erase()*. Finally, the data is written to the NOR flash using the *NOR_WriteBytes()* command.

3.3.2 NOR Flash Commands

The UBL_MAGIC_NOR_SREC_BURN and UBL_MAGIC_NOR_BIN_BURN commands mirror the NAND versions in function. The main difference is the manner in which the UBL is handled. In the NAND version, the UBL must be written with a header to certain location in the NAND device. In this way the RBL can find the header and know how to find and read the UBL. In the case of the NOR flash, the RBL does not do anything except pass execution to the start of NOR flash. The NOR UBL is written to the base of the flash so it begins execution in the NOR-boot mode. Moreover, the UBL image is laid out such that a block of self-copy code is found at the beginning of the UBL image. This code can be seen in [Appendix B](#). After the UBL copies itself to the ARM internal RAM, the UBL entry point, the *boot()* function, is called and the UBL begins its normal execution.

The code in [Section A.4.0](#) shows how the NOR flash setup uses the UBL in this way. Upon receipt of the NOR flash command, the UBL responds with the *SENDUBL/0* sequence and then receives the UBL data via the `UARTGetHeaderAndData()` function. The flash blocks that will hold this binary data (block 0 and any needed sequential blocks) are erased. The binary bytes are written to the memory (writing can take place on individual bytes, not just entire blocks). The UBL then requests the application image via the *SENDAPP/0* sequence. The data is again received via the `UARTGetHeaderAndData()` command. The magic number of the header is examined to determine if the S-record image or decoded binary image should be written to the NOR flash (see [Table 8](#)). The number of blocks needed for the image header and data is then calculated and the blocks are erased, starting at the first block after the last block occupied by the UBL. This avoids erasure of any UBL code and provides a common starting location for the `NOR_Copy()` function (found in *norboot.c*) to look for the application image. The header and the application image are written to consecutive memory locations with no gaps between them.

3.3.3 NOR Erase Command

The NOR global erase command is simple. Once the command is received, `NOR_Init()` is called to setup the NOR and learn its parameters. Then the UBL executes the erase command by calling `NOR_GlobalErase()`, which in turn calls the more general `NOR_Erase()` function using the flash base address and the flash size as parameters. These parameters were set up in the `NOR_Init()` function. The erase of the NOR flash is slow, taking several minutes for the largest supported devices.

4 Host Application

The host application is a critical part of the functioning that is exposed in the example UBL's UART-boot mode. It is important to realize that the UBL and the host application must be jointly developed to take advantage of the extra capability provided by an independent host. Each program must be written with the other in mind so that they can interface properly to achieve desired results. To emphasize this point, it should be noted that the binary NAND and NOR UBLs generated by the ARM cross-compiler tools are embedded into the host application binary (that is they become part of the host executable) so that they can always be used as the basis for interfacing during the UART-boot mode. Another UBL would not suffice to allow the execution of the commands described in [Section 3](#). This section provides some details of the DVFlasher host application. The source code is available with this application note. The *readme.txt* file in the source archive has more details about the application, including how to compile it.

4.1 General Information

The host application was written in the C# language. C# is a standardized object-oriented programming language (ECMA and ISO standards) that, like Java, aims to be cross platform by targeting a common language infrastructure (CLI). An implementation of the CLI has been developed for multiple platforms and programs compiled on one platform for one implementation should work equally well on another. This is accomplished partially because the compiled code exists as an intermediate language.

Surrounding the CLI, there can be a precompiled framework of classes that are used to perform common functions and provide basic utilities (much like the standard libraries of C or C++). Microsoft® Corporation has provided a framework of this type known as the Microsoft® .Net Framework, currently at version 3.0. An open source project sponsored by Novell®, called the Mono Project, has developed an open-source cross-platform CLI and framework that is mostly compatible (and aims to be fully compatible) with Microsoft's closed .Net Framework. The provided host application has been tested and verified to work on both frameworks. As a result, the application can be used on a host running Microsoft Windows® or any recent Linux distribution. Under Windows, the application can use either the .Net Framework (provided for free at <http://www.microsoft.com/>) or the Mono Framework (available at <http://www.mono-project.com/>). Under Linux, the Mono Framework is the only option.

The code is found in the *DVFlasher.cs* and *CRC32.cs* files. The compiled executable is *DVFlasher_X_YY.exe*, where X is the major revision number and YY is the minor revision number. Each source file provides a single class - a main program class and a CRC32 class. The CRC32 is used in the RBL negotiations. The main class holds all the remaining functionality of the application. Its most important job is to spawn the worker thread, which handles all serial port communications with the DM644x, and monitor key presses that indicate a user abort.

4.2 Host Program Details

Figure 2 shows the general flow of the host application from start to finish. It also shows the use of threads in the application, with the worker thread handling all interfacing to the DM644x, both to the RBL for transmitting the UBL, and to the executing UBL to process commands. More details about how the RBL interfacing works can be found in [SPRAA10](#).

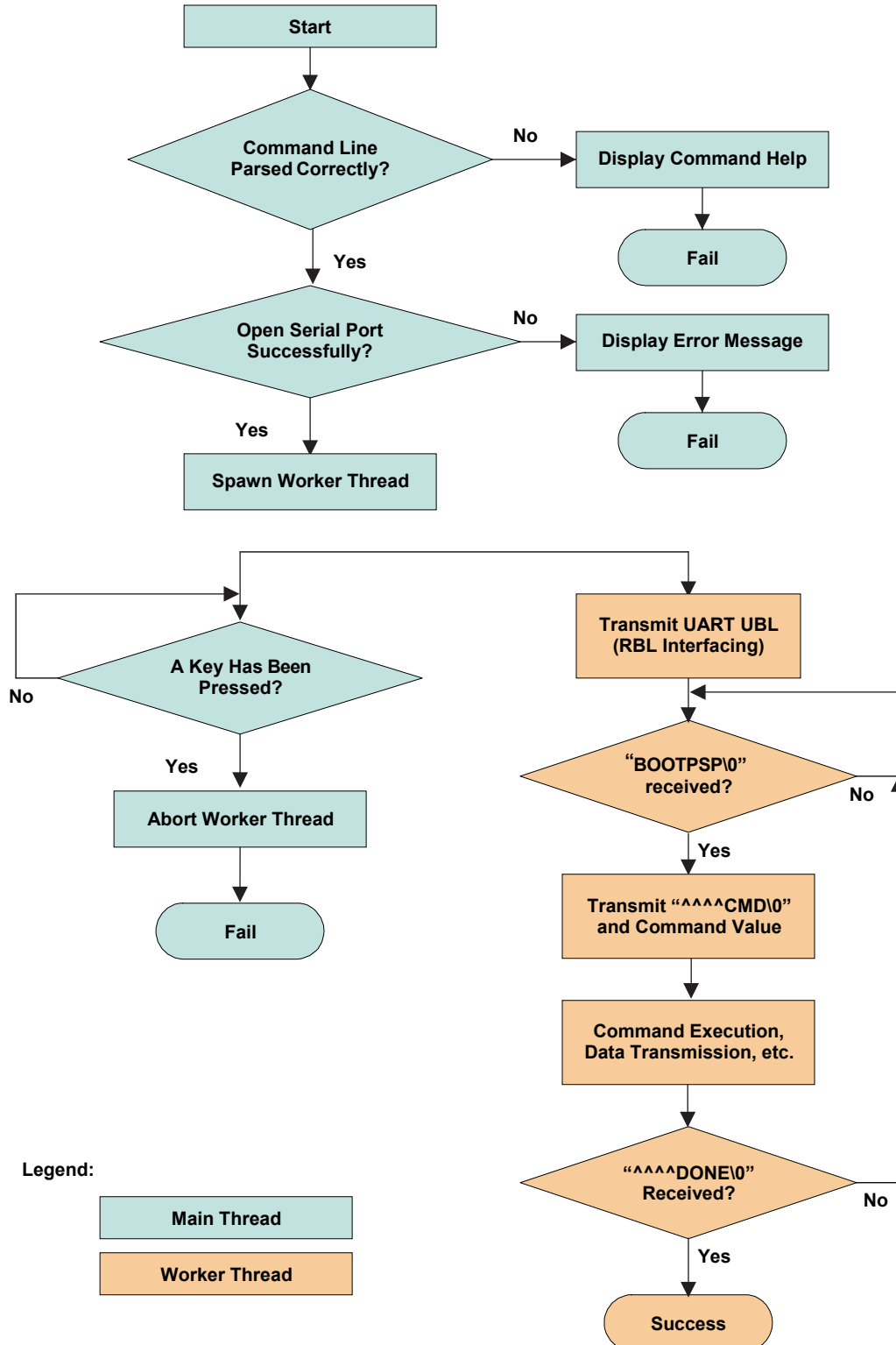


Figure 2. General Host Program Flow

The UBL interfacing depends on a series of sequences that are agreed upon by the UBL and host. Like other design features (such as the magic numbers), these sequences resemble the sequences used in the RBL for negotiation with the host (eight bytes, including null terminator). Table 10 shows these sequences and describes how they are used. Note that the '^' symbol is used to indicate the ASCII space character

Table 10. UBL/Host Interfacing Sequences

Sequence	Produced By	Description
BOOTPSP\0	UBL	Initiating sequence indicating UBL has been loaded correctly and is awaiting a command
^^^CMD\0	Host	Prefix sent before the command intended for execution by the UBL
SENDUBL\0	UBL	Sequence to instruct the host to send the UBL that will be written into the flash memory (NOR or NAND)
SENDAPP\0	UBL	Sequence to instruct the host to send the application image that will be written into the flash memory or run from RAM
^^^ACK\0	Host	Sequence sent as prefix to the header attached to all S-record images, which is parsed by the UARTGetHeaderAndData() function on the UBL
^^BEGIN\0	UBL	Sequence sent by the UARTGetHeaderAndData() function to indicate that ACK header was received and the UBL is now ready to receive the S-record data
^^DONE\0	UBL	Sequence to indicate successful reception of all S-record bytes, successful completion of S-record decode, and successful completion of the entire UBL command

The DVFlasher class consists of a number of functions (or methods) that are used in one of the two threads seen in Figure 2. The following sections outline what these functions are and what they do. No details of the code itself will be given, though the reader is encouraged to refer to the source files to understand how the functions work. This is especially true if the reader intends to use this source as a starting point for their own application.

4.2.1 Main Thread Functions

- `private static void DispHelp()`
This function displays a screen of help on how to use the program.
- `public static ProgramCmdParams ParseCmdLine(String[] args)`
This function parses the input command line arguments and populates a struct of the pertinent information. It also sets up and
- `static Int32 Main(String[] args)`
This function is the entry point for the entire application. It calls `ParseCmdLine()` and then sets up and opens the serial port. Finally it spawns the worker thread to handle the RBL and UBL serial negotiations. While the worker thread executes, the main function monitors key presses that would signify a user abort.

4.2.2 Worker Thread Functions

- `public static void WorkerThreadStart()`
This function is the entry point and main function for the worker thread.
- `private static Stream GetEmbeddedUBLStream()`
This function is used to access the NAND or NOR UBLs embedded in the host executable. The NOR UBL is accessed by default unless a NAND command is being called.
- `private static Byte[] GetFileData(String filename, UInt32 decAddr)`
This function is used to access data from the binary application files that are to be sent via the UART.
- `private static void TransmitUARTUBL()`
This function is called first by the `WorkerThreadStart()` function to transmit the UART UBL via negotiations with the ARM ROM bootloader.
- `private static Boolean TransmitCMDSuccessful()`
This function is called to send the user-selected command to the UART UBL executing on the DM644x. It waits for the `BOOTPSP\0` sequence and responds with the `^^^CMD\0` sequence and the command number. It then waits for a `^^DONE\0` sequence.

- `private static void TransmitErase()`
This function sends the erase command (NAND or NOR) and then awaits a `^^^DONE!0` sequence indicating successful completion.
- `private static void TransmitAPP()`
This function is used to transmit an application image only. It is called when the `-r` or `-b` command-line options are selected.
- `private static void TransmitFLASHUBLandAPP()`
This function is used with the NAND and NOR flashing commands where a UBL and an application image will be written to the flash device.
- `private static Boolean waitForSequence(String str,String altStr,SerialPort sp,Boolean verbose)`
This function is used to wait for a particular sequence on the serial port (the string `str`). It also will detect an alternate sequence that would indicate failure (the string `altStr`). The boolean `verbose` allows the output from the DM644x to be shown or suppressed.
- `private static Boolean waitForSequence(String str,String altStr,SerialPort sp)`
This function is the same as the previous except now the verbosity is chosen by the command-line option `-v`.

5 References

- *Basic Application Loading over the Serial Interface for the DaVinci TMS320DM644x* ([SPRAAI0](#))
- *TMS320DM644x DMSoC ARM Subsystem Reference Guide* ([SPRUE14](#))
- *TMS320DM644x DMSoC DDR2 Memory Controller User's Guide* ([SPRUE22](#))
- *TMS320DM644x DMSoC Universal Asynchronous Receiver/Transmitter (UART) User's Guide* ([SPRUE33](#))
- *NAND vs. NOR Flash Memory*, Toshiba America Electronics Components, Inc., 2006, http://www.toshiba.com/taec/components/Generic/Memory_Resources/NANDvsNOR.pdf.
- *Common Flash Interface (CFI) and Command Sets, AN 646*, Intel, Inc., April 2000, <http://download.intel.com/design/flcomp/applnots/29220404.pdf>

Appendix A UART-Boot Mode Flash Command Code

This appendix shows the UBL code from the *uartboot.c* file that implements the NAND and NOR flashing functionality that is available in the device's UART-boot mode.

A.1 NAND Flashing Code

```

If ( UARTSendData((Uint8*)"SENDUBL", TRUE) != E_PASS) goto UART_tryAgain; // Get the UBL into
binary form if (UARTGetHeaderAndData(&ackHeader) != E_PASS) { goto UART_tryAgain; } // Initialize
the NAND Flash NAND_Init(); // Get magicNum nandBoot.magicNum = ackHeader.magicNum; // Get
entrypoint for UBL nandBoot.entryPoint = (Uint32) (0x0000FFFF & ackHeader.appStartAddr); // The
UBL image is 14kBytes plus do some rounding nandBoot.numPage = 0; while ( (nandBoot.numPage *
gNandInfo.bytesPerPage) < (0x3800)) { nandBoot.numPage++; } // The page is always page 0 for the
UBL header, so we use page 1 for data nandBoot.page = 1; // The block is always block is always 1
(to start with) for the UBL header nandBoot.block = START_UBL_BLOCK_NUM; // This field doesn't
matter for the UBL header nandBoot.ldAddress = 0; // Write header to page 0 of block 1(or up to
block 5) // Write the UBL to the same block, starting at page 1 (since blocks are 16k)
UARTSendData((Uint8 *) "Writing UBL to NAND flash\r\n", FALSE); if
(NAND_WriteHeaderAndData(&nandBoot, (Uint8 *) ackHeader.binAddr) != E_PASS) goto UART_tryAgain;
// Send SENDAPP command if (UARTSendData((Uint8*)"SENDAPP", TRUE) != E_PASS) goto UART_tryAgain;
// Get the application header and data if (UARTGetHeaderAndData(&ackHeader) != E_PASS) { goto
UART_tryAgain; } // Set parameters depending on whether binary or srecord if (bootCmd ==
UBL_MAGIC_NAND_SREC_BURN) { dataByteCnt = ackHeader.srecByteCnt; dataAddr = ackHeader.srecAddr; }
else if (bootCmd == UBL_MAGIC_NAND_BIN_BURN) { dataByteCnt = ackHeader.binByteCnt; dataAddr =
ackHeader.binAddr; } // Rely on the host applciation to send over the right magic number (safe or
bin) nandBoot.magicNum = ackHeader.magicNum; // Use the entrypoint received in ACK header
nandBoot.entryPoint = ackHeader.appStartAddr; // The APP s-record image is dataByteCnt bytes plus
do some rounding nandBoot.numPage = 0; while ( (nandBoot.numPage * gNandInfo.bytesPerPage) <
dataByteCnt ) { nandBoot.numPage++; } // The page is always page 0 for the header, so we use page
1 for data nandBoot.page = 1; // The block is always 6 (to start with) for the APP header
nandBoot.block = START_APP_BLOCK_NUM; // The load address is only important if this is a binary
image nandBoot.ldAddress = ackHeader.binAddr; // Nand Burn of application data
UARTSendData((Uint8 *) "Writing APP to NAND flash\r\n", FALSE); if
(NAND_WriteHeaderAndData(&nandBoot, (Uint8 *) dataAddr) != E_PASS) goto UART_tryAgain; // Set the
entry point to nowhere, since there isn't an appropriate binary image to run */ gEntryPoint =
0x0; break;

```

A.2 NAND Erasing Code

```

if (NAND_Init() != E_PASS) goto UART_tryAgain; // Unprotect the NAND Flash
NAND_UnProtectBlocks(1,gNandInfo.numBlocks - 1); // Erase all the pages of the device if
(NAND_EraseBlocks(1,(gNandInfo.numBlocks - 1)) != E_PASS) { UARTSendData((Uint8 *)"Erase
failed.\r\n", FALSE); goto UART_tryAgain; } else { UARTSendData((Uint8 *)"Erase completed
successfully.\r\n", FALSE); } // Protect the device NAND_ProtectBlocks(); // Set the entry point
for code execution // Go to reset in this case since no code was downloaded gEntryPoint = 0x0;
break;

```

A.3 NOR Restore Code

```
// Get the APP (should be u-boot) into binary form if ( UARTSendData((UInt8*)"SENDAPP", TRUE) !=
E_PASS) goto UART_tryAgain; if ( UARTGetHeaderAndData(&ackHeader) != E_PASS ) goto UART_tryAgain;
// Initialize the NOR Flash if ( NOR_Init() != E_PASS ) goto UART_tryAgain; // Erasing the Flash
if ( NOR_Erase(gNorInfo.flashBase, ackHeader.binByteCnt) != E_PASS ) goto UART_tryAgain; // Write
the actual application to the flash if ( NOR_WriteBytes(gNorInfo.flashBase, ackHeader.binByteCnt,
ackHeader.binAddr) != E_PASS ) goto UART_tryAgain; // Set the entry point for code execution
gEntryPoint = gNorInfo.flashBase; break;
```

A.4 NOR Flashing Code

```
if ( UARTSendData((UInt8*)"SENDUBL", TRUE) != E_PASS) goto UART_tryAgain; // Get the UBL into
binary form if (UARTGetHeaderAndData(&ackHeader) != E_PASS) { goto UART_tryAgain; } // Initialize
the NOR Flash NOR_Init(); // Erasing the Flash NOR_Erase(gNorInfo.flashBase,
ackHeader.binByteCnt); // Write binary UBL to NOR flash NOR_WriteBytes(gNorInfo.flashBase,
ackHeader.binByteCnt, ackHeader.binAddr); // Send SENDAPP command if (
UARTSendData((UInt8*)"SENDAPP", TRUE) != E_PASS) goto UART_tryAgain; // Get the application
header and data if (UARTGetHeaderAndData(&ackHeader) != E_PASS) { goto UART_tryAgain; } //
Determine whether to use binary or srec if (bootCmd == UBL_MAGIC_NOR_BIN_BURN) { dataByteCnt =
ackHeader.binByteCnt; dataAddr = ackHeader.binAddr; } else if (bootCmd ==
UBL_MAGIC_NOR_SREC_BURN) { dataByteCnt = ackHeader.srecByteCnt; dataAddr = ackHeader.srecAddr; }
// Erase the NOR flash where header and data will go DiscoverBlockInfo( (gNorInfo.flashBase +
UBL_IMAGE_SIZE), &blkSize, &blkAddress ); baseAddress = (blkAddress + blkSize); NOR_Erase(
baseAddress, (dataByteCnt + sizeof(norBoot)) ); norBoot.magicNum = ackHeader.magicNum;
//MagicFlag for Application (binary or safe) norBoot.appSize = dataByteCnt; //Bytes of
application (either srec or binary) norBoot.entryPoint = ackHeader.appStartAddr; //Value from ACK
header norBoot.ldAddress = ackHeader.binAddr; //Should be same as AppStartAddr // Write the
NOR_BOOT header to the flash NOR_WriteBytes( baseAddress, sizeof(norBoot), (UInt32) &norBoot); //
Write the application data to the flash NOR_WriteBytes((baseAddress + sizeof(norBoot)),
dataByteCnt, dataAddr); // Set the entry point for code execution to the newly copied binary UBL
gEntryPoint = gNorInfo.flashBase; break;
```

A.5 NOR Erasing Code

```
NOR_Init(); // Erasing the Flash if (NOR_GlobalErase() != E_PASS) { UARTSendData((UInt8
*)"r\nErase failed.\r\n", FALSE); } else { UARTSendData((UInt8 *)"r\nErase completed
successfully.\r\n", FALSE); } // Set the entry point for code execution // Go to reset in this
case since no code was downloaded gEntryPoint = 0x0; break;
```

Appendix B Self-Copy Code for NOR UBL

The self-copy function is prototyped in the *ubl.h* file as

```
void selfcopy( void )__attribute__((naked,section (".selfcopy")));
```

The linker script sets the *selfcopy* run-time address at the beginning of the CS2 memory space, where the NOR flash should be. Its load address, which determines its place in the binary file, is set for 0x0. Therefore, when the binary imaged is placed in the NOR flash, the self-copy code is located at 0x02000000, which is its correct run-time address.

The self-copy function is defined in the *ubl.c* file as

```
void selfcopy() { // Self copy setup extern Uint32_selfcopysrc,__selfcopydest,
__selfcopydestend; //Enable ITCM asm(" MRC p15, 0, r0, c9, c1, 1"); asm(" MOV r0, #0x1"); asm("
MCR p15, 0, r0, c9, c1, 1"); //Enable DTCM asm(" MRC p15, 0, r0, c9, c1, 0"); asm(" MOV r0,
#0x8000"); asm(" ORR r0, r0, #0x1"); asm(" MCR p15, 0, r0, c9, c1, 0"); VUint32* src =
&(_selfcopysrc); VUint32* dest = &(_selfcopydest); VUint32* destend = &(_selfcopydestend); //
Copy the words while (dest < destend) { *dest = *src; dest++; src++; } //Jump to the normal entry
point boot(); }
```

The *selfcopy()* function uses symbols from the linker command script, *ubl_davinci.lds* (*_selfcopysrc*, *__selfcopydest*, *selfcopydestend*) to copy the data from the NOR flash in the CS2 memory space to the IRAM. The assembly instructions ensure that the IRAM blocks are enabled. Finally the function calls the *boot()* function, which is the normal UBL entry located in IRAM.

Appendix C Supported NOR Devices and Configurations

C.1 NOR AEMIF Information

The AEMIF interface of the TMS320DM644x can operate in 16-bit or 8-bit widths. The maximum addressable size in 16-bit mode is 32MB, while in 8-bit mode it is only 16 MB. Code can be placed in a NOR flash device and executed directly in the NOR-boot mode. The EM_WIDTH pin must be set to match the width of the device or access to the NOR device will fail.

C.2 Supported NOR Configurations

The `nor.c` driver code should detect and support the configuration listed in [Table 11](#). For the driver to properly detect the number of devices and their configuration, all devices must be compliant with the Common Flash Interface (CFI) specification. Any recent NOR flash device should be CFI-compliant, but you should verify this with the devices' datasheet. By querying the CFI information on the device, the driver can appropriately decide to use the AMD command set or the Intel command set.

Table 11. NOR Configurations Supported by the `nor.c` Driver

Bus Width	Number of Devices	Device Type	Device Operating Mode
x8	1	x8	x8
x8	1	x8/x16	x8
x16	1	x8/x16	x16
x16	2 (in parallel)	x8	x8
x16	2 (in parallel)	x8/x16	x8
x16	1	x16/x32	x16

Appendix D Supported NAND Devices

Table 12 shows the device IDs and the parameters of the supported NAND devices. These devices are the bootable devices that the TMS320DM644x supports. Additional non-bootable (i.e not supported by the ROM) devices could easily be handled by the `nand.c` driver by expanding the device table, which is found at the top of the NAND driver file, `nand.c`.

Table 12. NAND Devices Supported by the `nand.c` Driver

Device ID	Number of Blocks	Pages Per Block	Bytes Per Page	Total Size
0x6E	256	16	256+8	1 MB
0x68	256	16	256+8	1 MB
0xEC	256	16	256+8	1 MB
0xE8	256	16	256+8	1 MB
0xEA	512	16	256+8	2 MB
0xE3	512	16	512+16	4 MB
0xE5	512	16	512+16	4 MB
0xE6	1024	16	512+16	8 MB
0x39	1024	16	512+16	8 MB
0x6B	1024	16	512+16	8 MB
0x73	1024	32	512+16	16 MB
0x33	1024	32	512+16	16 MB
0x75	2048	32	512+16	32 MB
0x35	2048	32	512+16	32 MB
0x43	1024	32	512+16	16 MB
0x45	2048	32	512+16	32 MB
0x53	1024	32	512+16	16 MB
0x55	2048	32	512+16	32 MB
0x36	4096	32	512+16	64 MB
0x46	4096	32	512+16	64 MB
0x56	4096	32	512+16	64 MB
0x76	4096	32	512+16	64 MB
0x74	8192	32	512+16	128 MB
0x79	8192	32	512+16	128 MB
0x71	16384	32	512+16	256 MB
0xF1	1024	64	2048+64	128 MB
0xA1	1024	64	2048+64	128 MB
0xAA	2048	64	2048+64	256 MB
0xDA	2048	64	2048+64	256 MB
0xDC	4096	64	2048+64	512 MB
0xAC	4096	64	2048+64	512 MB
0xB1	1024	64	2048+64	128 MB
0xC1	1024	64	2048+64	128 MB

Appendix E NAND ECC Considerations

When the RBL reads NAND memory pages, it attempts to verify a correct read by checking ECC values. For every 512 bytes read from the NAND the EMIF interface generates an ECC value in the NANDFxECC register of the AEMIF peripheral. The RBL will compare this value against the value stored in the spare bytes of the NAND page it is reading. These stored values should be placed in the spare bytes region when the page is written. Therefore, any program which writes a UBL header and UBL binary to the NAND flash must know where the RBL will look for the stored ECC values when it tries to load the UBL.

The exact location of where the RBL expects to find the stored ECC depends on the page size of the device. For 256-byte and 512-byte page devices, the ECC value is stored in the first four bytes of the spare byte region. For 2048-byte page devices, there are four ECC values, one for each set of 512 bytes read, which should be stored at addresses 0x08, 0x18, 0x28, and 0x38 of the spare bytes region. The 32-bit ECC values should be in **BIG ENDIAN** order. The charts below show the locations graphically. The provided example UBL respects these ECC requirements, as can be seen by inspecting the source file, *nand.c*.

Table 13. ECC Value Location in Spare Page Bytes of 256-Byte/Page NAND Devices

ECC[3]	ECC[2]	ECC[1]	ECC[0]	XX	XX	XX	XX
0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07

Table 14. ECC Value Location in Spare Page Bytes of 512-Byte/Page NAND Devices

ECC[3]	ECC[2]	ECC[1]	ECC[0]	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09	0x0A	0x0B	0x0C	0x0D	0x0E	0x0F

Table 15. ECC Value Location in Spare Page Bytes of 2048-Byte/Page NAND Devices

XX	XX	XX	XX	XX	XX	XX	XX	ECC1[3]	ECC1[2]	ECC1[1]	ECC1[0]	XX	XX	XX	XX
0x00	0x01	0x02	0x03	0x04	0x05	0x06	0x07	0x08	0x09	0x0A	0x0B	0x0C	0x0D	0x0E	0x0F
XX	XX	XX	XX	XX	XX	XX	XX	ECC2[3]	ECC2[2]	ECC2[1]	ECC2[0]	XX	XX	XX	XX
0x10	0x11	0x12	0x13	0x14	0x15	0x16	0x17	0x18	0x19	0x1A	0x1B	0x1C	0x1D	0x1E	0x1F
XX	XX	XX	XX	XX	XX	XX	XX	ECC3[3]	ECC3[2]	ECC3[1]	ECC3[0]	XX	XX	XX	XX
0x20	0x21	0x22	0x23	0x24	0x25	0x26	0x27	0x28	0x29	0x2A	0x2B	0x2C	0x2D	0x2E	0x2F
XX	XX	XX	XX	XX	XX	XX	XX	ECC4[3]	ECC4[2]	ECC4[1]	ECC4[0]	XX	XX	XX	XX
0x30	0x31	0x32	0x33	0x34	0x35	0x36	0x37	0x38	0x39	0x3A	0x3B	0x3C	0x3D	0x3E	0x3F

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