



Bootloader Generator User's Guide

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NOTES:

Preface

NOTICE TO CUSTOMERS

All documentation becomes dated, and this manual is no exception. Microchip tools and documentation are constantly evolving to meet customer needs, so some actual dialogs and/or tool descriptions may differ from those in this document. Please refer to our website (www.microchip.com) to obtain the latest documentation available.

Documents are identified with a “DS” number. This number is located on the bottom of each page, in front of the page number. The numbering convention for the DS number is “DSXXXXA”, where “XXXX” is the document number and “A” is the revision level of the document.

For the most up-to-date information on development tools, see the MPLAB® IDE online help. Select the Help menu, and then Topics to open a list of available online help files.

INTRODUCTION

This chapter contains general information that will be useful to know before using the Bootloader Generator. Items discussed in this chapter include:

- Document Layout
- Conventions Used in this Guide
- Warranty Registration
- Recommended Reading
- The Microchip Website
- Development Systems Customer Change Notification Service
- Customer Support
- Revision History

DOCUMENT LAYOUT

This document describes how to use the Bootloader Generator software library through MCC to produce code for application integration, along with use of MPLAB® X and the Unified Bootloader Application. The document is organized as follows:

- **Chapter 1. “Overview”**
- **Chapter 2. “Options, Parts and Pieces”**
- **Chapter 3. “Hex File”**
- **Chapter 4. “MCC Bootloader Generator”**
- **Chapter 5. “Merge Bootloader with the Application”**
- **Chapter 6. “Bootloader Host Application”**
- **Chapter 7. “Bootloader Protocol”**

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CONVENTIONS USED IN THIS GUIDE

This manual uses the following documentation conventions:

DOCUMENTATION CONVENTIONS

Description	Represents	Examples
Arial font:		
Italic characters	Referenced books	<i>MPLAB[®] IDE User's Guide</i>
	Emphasized text	...is the <i>only</i> compiler...
Initial caps	A window	the Output window
	A dialog	the Settings dialog
	A menu selection	select Enable Programmer
Quotes	A field name in a window or dialog	"Save project before build"
Underlined, italic text with right angle bracket	A menu path	<u><i>File>Save</i></u>
Bold characters	A dialog button	Click OK
	A tab	Click the Power tab
N'Rnnnn	A number in verilog format, where N is the total number of digits, R is the radix and n is a digit.	4'b0010, 2'hF1
Text in angle brackets < >	A key on the keyboard	Press <Enter>, <F1>
Courier New font:		
Plain Courier New	Sample source code	#define START
	Filenames	autoexec.bat
	File paths	c:\mcc18\h
	Keywords	_asm, _endasm, static
	Command-line options	-Opa+, -Opa-
	Bit values	0, 1
	Constants	0xFF, 'A'
Italic Courier New	A variable argument	<i>file.o</i> , where <i>file</i> can be any valid filename
Square brackets []	Optional arguments	mcc18 [options] <i>file</i> [options]
Curly brackets and pipe character: { }	Choice of mutually exclusive arguments; an OR selection	errorlevel {0 1}
Ellipses...	Replaces repeated text	var_name [, var_name...]
	Represents code supplied by user	void main (void) { ... }

WARRANTY REGISTRATION

Please complete the enclosed Warranty Registration Card and mail it promptly. Sending in the Warranty Registration Card entitles users to receive new product updates. Interim software releases are available at the Microchip website.

RECOMMENDED READING

This user's guide describes how to use Bootloader Generator MCC software library, and Unified Bootloader host application. Other useful documents are listed below. The following Microchip documents are available and recommended as supplemental reference resources.

Release Notes for MPLAB ICD 3 In-Circuit Debugger

For the latest information on using Bootloader Generator, read the "Readme for Bootloader Generator.htm" file (an HTML file) in the Readmes subdirectory of the MPLAB IDE installation directory. The release notes (Readme) contains update information and known issues that may not be included in this user's guide.

THE MICROCHIP WEBSITE

Microchip provides online support via our website at www.microchip.com. This website is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the website contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

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The Development Systems product group categories are:

- **Compilers** – The latest information on Microchip C compilers, assemblers, linkers and other language tools. These include all MPLAB C compilers; all MPLAB assemblers (including MPASM™ assembler); all MPLAB linkers (including MPLINK™ object linker); and all MPLAB librarians (including MPLIB™ object librarian).
- **Emulators** – The latest information on Microchip in-circuit emulators. This includes the MPLAB REAL ICE™ and MPLAB ICE 2000 in-circuit emulators.
- **In-Circuit Debuggers** – The latest information on the Microchip in-circuit debuggers. This includes MPLAB ICD 3 in-circuit debuggers and PICKIT™ 3 debug express.

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- **MPLAB® IDE** – The latest information on Microchip MPLAB IDE, the Windows® Integrated Development Environment for development systems tools. This list is focused on the MPLAB IDE, MPLAB IDE Project Manager, MPLAB Editor and MPLAB SIM simulator, as well as general editing and debugging features.
- **Programmers** – The latest information on Microchip programmers. These include production programmers such as MPLAB REAL ICE in-circuit emulator, MPLAB ICD 3 in-circuit debugger and MPLAB PM3 device programmers. Also included are nonproduction development programmers such as PICSTART® Plus and PICkit 2 and 3.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the website at:

<http://www.microchip.com/support>.

REVISION HISTORY

Revision A (October, 2016)

This is the initial release of this document.

Revision B (December, 2016)

Updated chapters 1 and 2; Added chapters 4-7, replacing former ones.

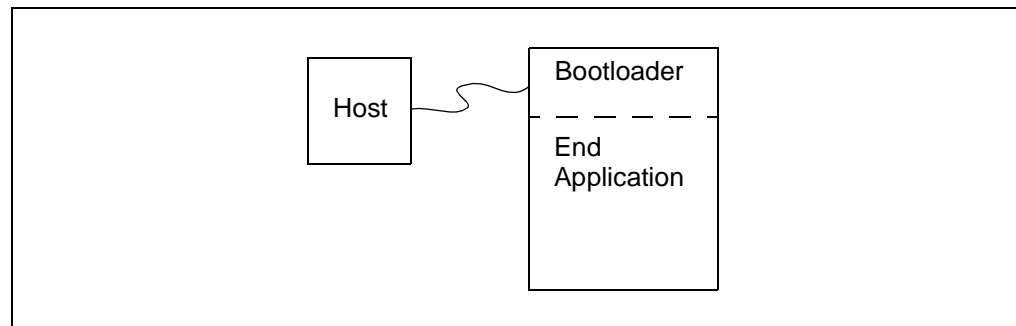
Chapter 1. Overview

1.1 BOOTLOADER OVERVIEW

Integration of bootloader support in a product consists of three parts (see Figure 1-1):

- Host Application – Utility used to process End Application memory space and firmware version
- Device Bootloader – Dedicated firmware responsible for managing End Application on device
- Device End Application – Products operational application firmware.

FIGURE 1-1: BOOTLOADER UNIVERSE



The host application is responsible for loading the new hex file, and send it to the bootloader through supported command syntax. The end application is required to be aware of the bootloader, and must understand how to return control to the bootloader upon request, or configured events. The bootloader by default is generated to run upon start-up, and confirms if a valid application is loaded. If a valid application is present, control is relinquished, otherwise operation will remain within the bootloader. This is further explained in [Chapter 5. “Bootloader Host Application”](#).

The host application used to manage the bootload process can be Microchip’s Unified Bootloader Application, a custom made stand-alone application, or a separate external Microcontroller device. Either way, the end purpose remains the same; updating the end application firmware version through use of the Bootloader and supported commands. This user’s guide describes one form of implementation, using the Bootloader Generator MCC software library to produce code which supports proper command syntax for interaction with Unified Bootloader host Application.

It will describe how to configure an end-application to be aware of boot-loading possibility which transfers control back to the Bootloader under a triggering condition.

1.2 BOOTLOADER REQUIREMENTS

The main requirements for the generated bootloader code are:

- Determine if a valid end-application is loaded
- Communicate/Execute supported Commands
- Erase/Rewrite end-application memory space
- Transfer control to end application

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A few additional features may be optionally required:

- Ensure Erase/Write address are outside bootloader program memory range
- Allow the host to read the program memory*
- Detect corrupted end-application code and recover gracefully

Note: Some developers see the Read Program command as a possible security hole and typically wish to omit functionality.

Chapter 2. Options, Parts and Pieces

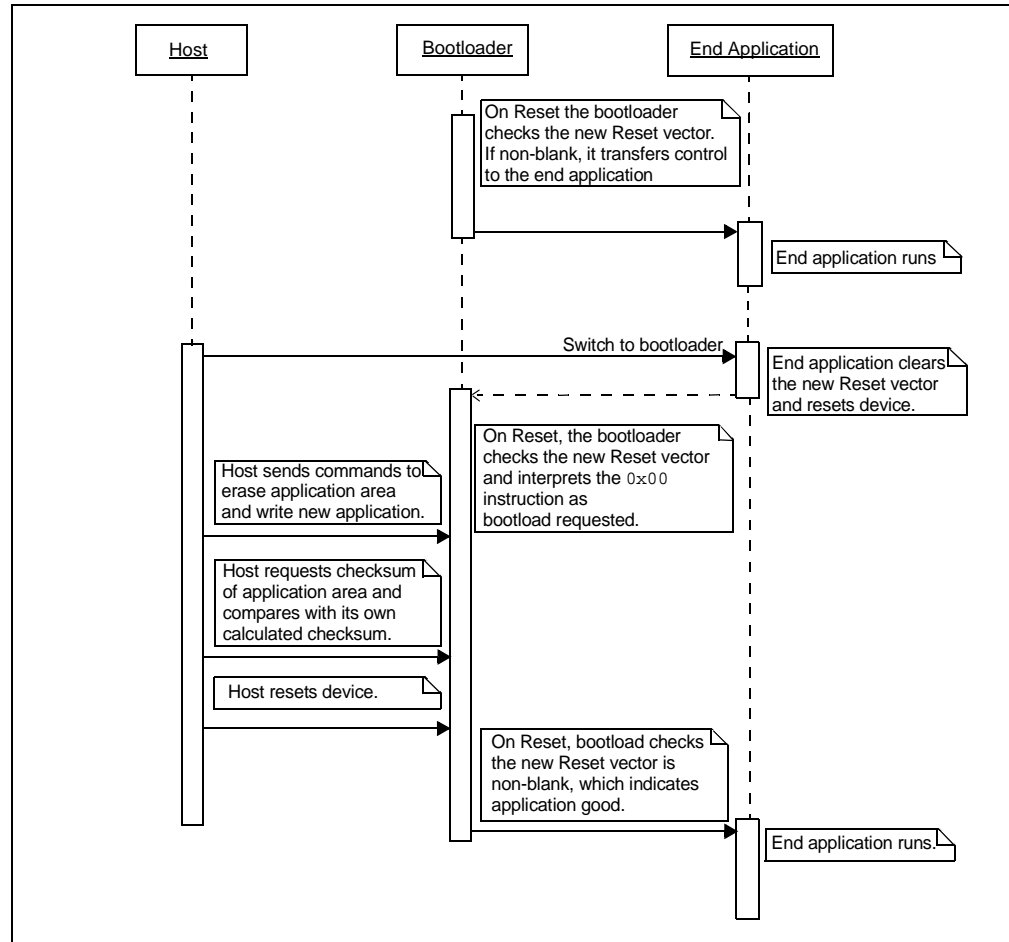
There are many choices to consider when implementing a bootloader. Some key questions to consider are:

- How does the bootloader decide if a valid application is loaded?
- How are commands communicated between bootloader and host application?
- Is the ability to Read/Write EE Data memory supported by the bootloader?
- When does the bootloader relinquish control to the end-application?
- How will the end-application restore control to the bootloader when required?

There are several ways to decide if a valid application is loaded. For example, “AN851 – *A Flash Bootloader for PIC16 and PIC18 Devices*” (DS00851) inspects the instruction written to the end-application’s new Reset vector. If the contents of the Reset vector is the erased value (0x3FFF; MOVWI [-1] FSR1), the bootloader assumes the rest of memory is erased, that no valid end-application is loaded, and remains in bootloader operation. For this type of implementation it is recommended that instructions written to the end-application’s new Reset Vector location be written last to ensure full bootloader of firmware was successful. (see [Figure 2-1](#)).

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FIGURE 2-1: CHECK RESET VECTOR ADDRESS



Another method involves use of a state variable stored in nonvolatile memory; this location is known by both bootloader and end-application. The bootloader on start-up will inspect the value for a specific value representing a “valid application” code. Values used do not matter, but should be consistent and known by both bootloader and end-application firmware.

The state variable at a minimal must support three states:

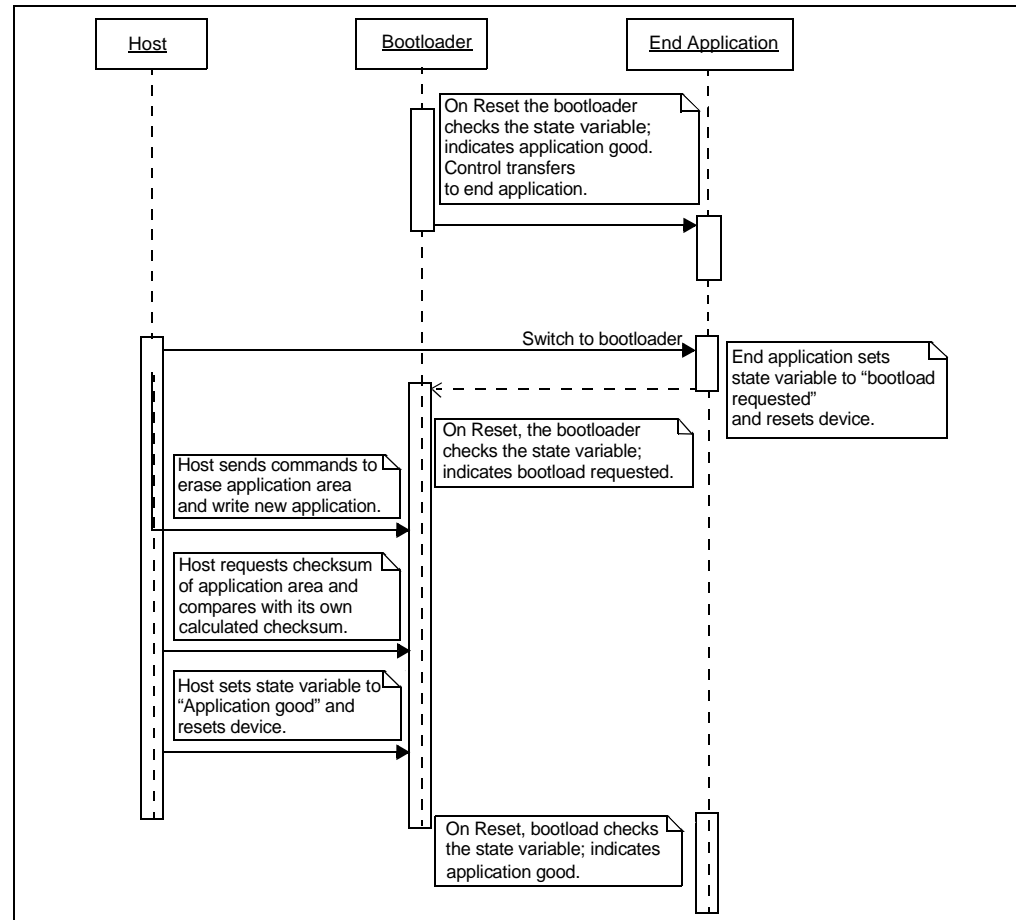
- Erased/Blank
- End-Application Valid
- Bootload requested

Example steps for this process are as follows (see [Figure 2-2](#)):

1. Host communicates to end-application a “Bootloader Request”.
2. End-application sets the nonvolatile memory variable to indicate a requested bootloader operation, and resets the device.
3. On start-up the bootloader inspect the value and finding a “Bootloader Requested” state or erased value, stays within bootloader operation.
4. The host application issues Erase command request over the end-application code range.
5. The host application loads the new firmware hex file, and issues Write command request in sections until the full end-application is updated.
6. Host calculates a checksum value of the hex file, then issues a Calculate Checksum command request to the bootloader for comparison.

7. If the two match, the host application writes a “Application Valid” state value into the nonvolatile memory location.
8. The host application issues a Reset command to bootloader.
9. After start-up the bootloader inspects the nonvolatile memory location finding “Application Valid” value, and relinquishes control to the end-application.

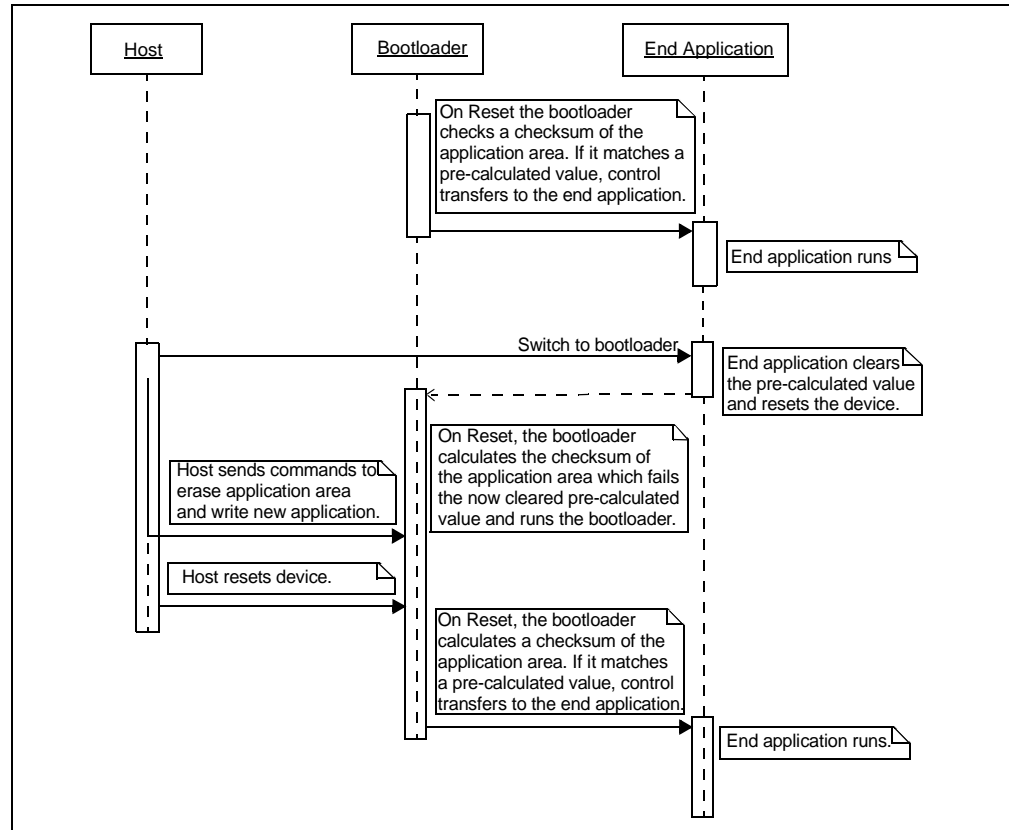
FIGURE 2-2: NONVOLATILE STATE VARIABLE



Some project designs have a requirement to check application validity on each start-up. A way to achieve this would be to calculate a checksum of the application area and compare it to a pre-calculated value (see Figure 2-3). XC8 includes a tool that can do the pre-calculation over full or a range of code space, and then store the value in a specified location in the generated hex file. See [Appendix B. “How to Calculate and Embed a Checksum Using XC8”](#) for additional details on this process.

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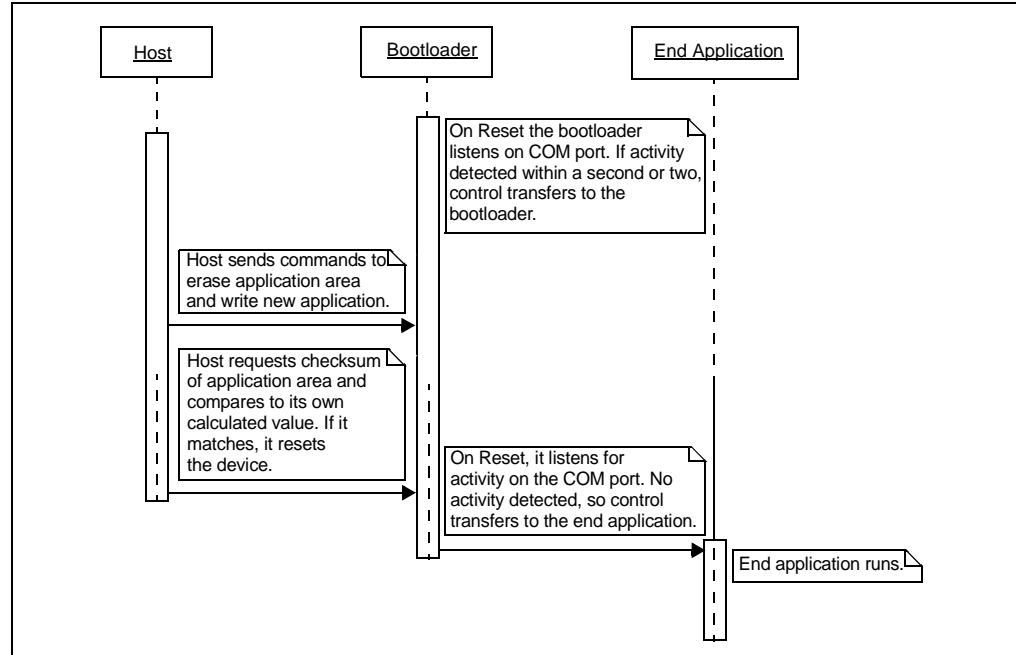
FIGURE 2-3: CALCULATE CHECKSUM ON START-UP



If the end-device does not normally connect to the host device, it is possible to modify the bootloader so that upon power-on the communication bus is monitored. On start-up, the bootloader would listen for any activity, if detected, the bootloader will remain in control instead of relinquishing to the end-application. However, if after a configured length of time no activity is observed, the end application is granted control by the bootloader (see [Figure 2-4](#)).

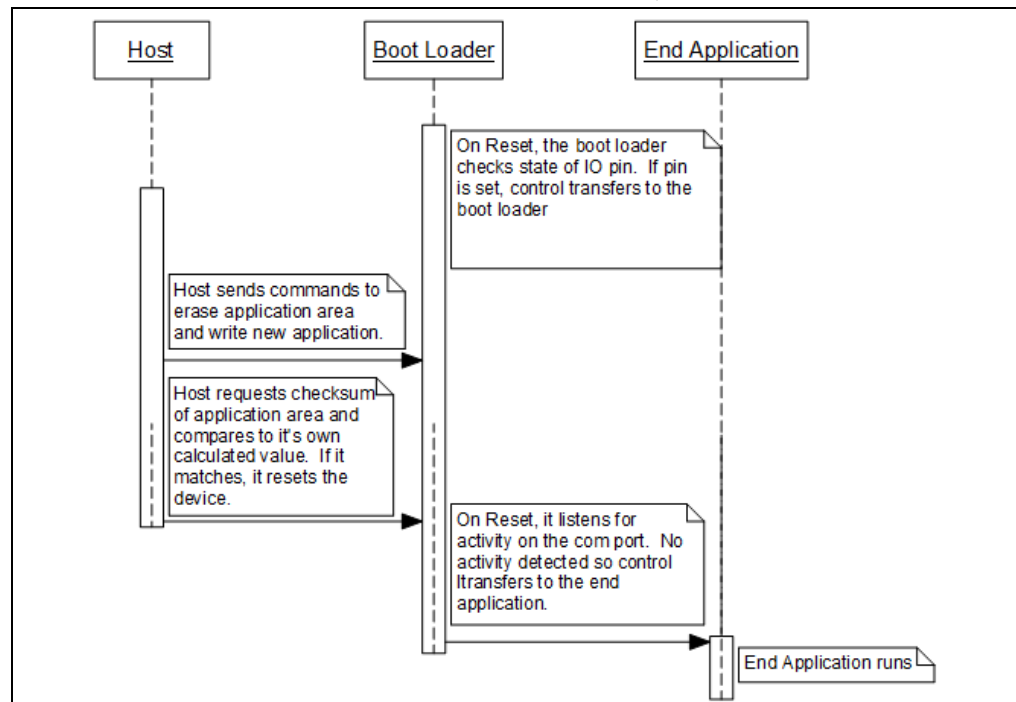
Note: This method is not supported as of publication time.

FIGURE 2-4: LISTEN FOR COM PORT ACTIVITY



In addition to one of the above bootloader entry methods, it may be beneficial to have a means to force the bootloader to run notwithstanding the state of the primary entry method. The bootloader supports checking the state of an IO line for this purpose.

FIGURE 2-5: IO PIN SET START-UP UML SEQUENCE



2.1 COMMUNICATION METHOD

Currently, the Bootloader Generator MCC software library only supports generation of UART supported code. However, in the future additional communication protocols such as I²C, SPI and USB will be added.

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At this time the host Unified Bootloader Application is capable of supporting UART and I²C protocol communication.

2.2 VERIFICATION OF BOOTLOAD INTEGRITY

It is prudent following the bootload to verify that the program memory accurately represents the application code.

If read program memory is supported, the host application may read back the memory and compare it to the original file.

The bootloader itself includes a command that calculates a 16-bit checksum of the end-application memory space. The host can then compare this to its own calculated checksum, and confirm that the write was successful.

2.3 SELF PROTECTION

The bootloader should protect itself from accidental over-write. Therefore, attempts to write into the memory where the bootloader resides should be prevented. PIC[®] microcontrollers have two methods to ensure this: hardware and software.

Write-protect Configuration bits can selectively write-protect various regions of the program memory. The advantage to hardware protection is a smaller code footprint. The downside is that the block size is fixed and may leave memory wasted.

The address protection can also be accomplished in software. Code can check the destination address of each Write/Erase command. If the address range conflicts with the bootloader region, the command request is rejected. The software requires a little more code space, but it has the advantage of additional flexibility. For example, special bootloader code could be written to allow the original bootloader to be replaced with an updated version in case a bug emerges after production has already occurred/begun. This is not possible if protected via hardware through the write-protect Configuration bit is set.

2.4 IO PIN INDICATOR

Use of an IO pin indicator is an option available to use a dedicated pin to show when if the device is in bootloader or end-application operation. Form of indication may vary depending upon the product design specification. The IO pin indicator can be simple, such as a LED used to indicate state, or as a signal connected to another device in the product circuit.

2.5 ENABLE READ FLASH

The ability to read the hex file back can represent a possible security hole for some products. As a result, the Read Flash command is optional. However, it can be used to verify the bootload by reading back the end-application memory space.

The Unified Bootloader Application does not currently support the ability to readback Flash for end-application load verification.

2.6 ENABLE READ/WRITE EEData

Read/Write EE Data commands are optional during code generation. Some devices do not have EE Data memory, so code space can be saved by omitting these commands.

2.7 ENCRYPTION

It is possible to encrypt the data which is sent to the device. In order for this encryption to be effective, a robust key management system is required to be in place.

No encryption methods are supported at this time. Customers who wish to implement an encryption scheme in their bootloader should contact Microchip for support in this regard.

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NOTES:

Chapter 3. Hex File

3.1 INTEL® HEX FILE FORMAT

EXAMPLE 3-1: HEX FILE RECORD FORMAT

```
:BBAAAAATTHHHH.....HHCC
:100F90000E1022000E1023000C1121000C1524004D
```

: Record Start Character
 BB two digit byte count specifying the number of data bytes in
 this record.
 AAAA Four digit starting address of this data record
 TT Two digit record type
 00 = data record
 01 = End of File record
 02 = Segment Address Record
 04 = Extended Linear Address record
 HH Data Bytes
 CC Two digit checksum calculated as 2's complement of all
 preceding bytes in data record except the colon.

3.2 PIC16F1XXX INTERPRETATIONS

The Intel® hex file is byte-oriented, while the PIC16 is word-oriented. The address in the hex file line is a byte address and must be divided by two to get the word address. As shown in Example 3-1 above, the address is 0x0F90. The word address is half that, 0x07C8.

Also, the word data is stored low byte first (little endian). Thus, the first two bytes make up the word at the first address. In Example 3-1 the bytes are 0x0E and 0x10; the word stored at 0x07C8 is 0x100E.

Each PIC device has several different memory regions:

- Program memory is stored at its natural word address
- ID locations are at Word Address 0x8000 through 0x8003
- Configuration Words at Word Address 0x8007 and 0x8008
- EEData is encoded at Word Address 0xF000

EEData only uses the low-order byte of each two-byte pair.

EXAMPLE 3-2: EE DATA ENCODED IN PIC16F1XXX HEX FILE

```
:020000040001F9
:10E00000080009000A000B000C000D000E000F00B4
```

The first record sets the upper 16 bits of address to 0x0001.

The second record sets the lower 16 bits of the address. The resulting 32-bit address is 0x0001E000. When divided by two, the PIC16F1XXX address of 0xF000 is obtained.

Only the low order byte of each pair is used for EEData. In this case, EEData address 0 would get 0x08, address one would get 0x09, address two would get 0x0A, etc.

3.3 PIC18 INTERPRETATIONS

PIC18F devices are byte-oriented, so the address on the line does not need any correction. EEData is encoded in the hex file at 0xF00000 and one byte per address (no skipped bytes as with the PIC16F1XXX devices).

Chapter 4. MCC Bootloader Generator

The Bootloader Generator is used to produce a separate project which will later be merged with the end-application. This user's guide will describe how to generate a new bootloader project according to operational requirements and later, how to merge with the end-application.

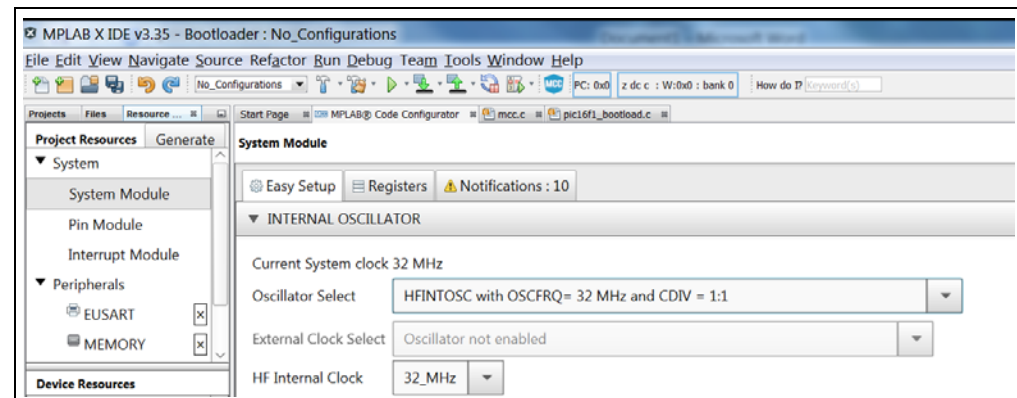
4.1 GENERATE BOOTLOADER

The bootloader generator is now fully integrated with MCC Libraries. To the maximum extent possible, the bootloader leverages MCC for configuration and peripheral usage. Thus, in addition to selecting the bootloader library, it is also required to select the memory and supported communications "Peripherals".

Here are the steps to generate a bootloader using MCC:

1. First create a bootloader project and select your device.
2. Select XC8 as the build tool (MCC generates XC8 C code).
3. Start MCC.
4. In the System Module, configure the oscillator. In general, faster is better for more reliable communications. For this example, the PIC16F18855 is selected, and configured to use the 32 MHz internal oscillator.

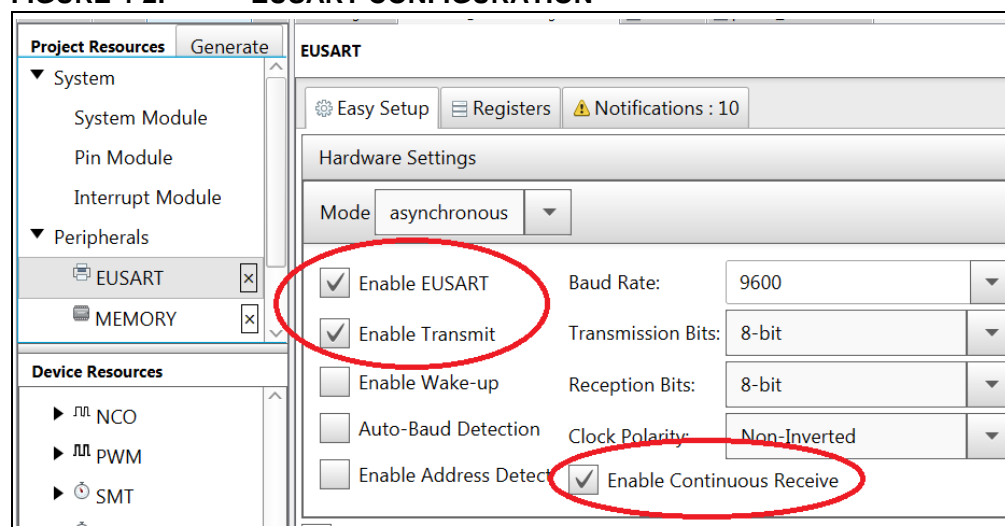
FIGURE 4-1: OSCILLATOR SELECTION



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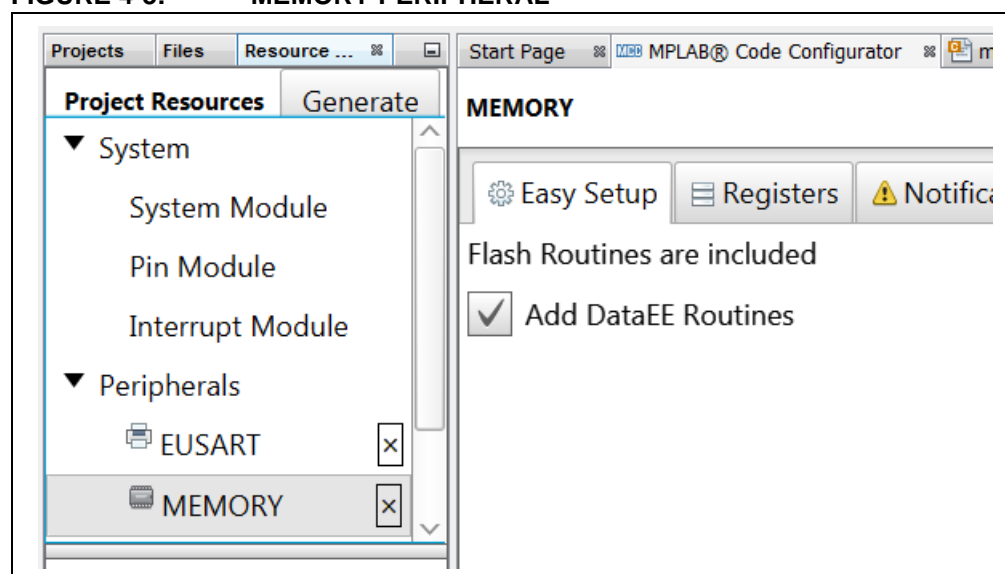
5. Select EUSART. Check “Enable EUSART”, “Enable Transmit” and “Enable Continuous Receive”. The baud rate does not matter because the bootloader code auto-bauds to detect the incoming baud rate.

FIGURE 4-2: EUSART CONFIGURATION



6. Select the Memory Peripheral. Nothing further needs to be configured. This will include a memory.h file which has #defines that specify how big the Flash memory is, write latches and erase row size.

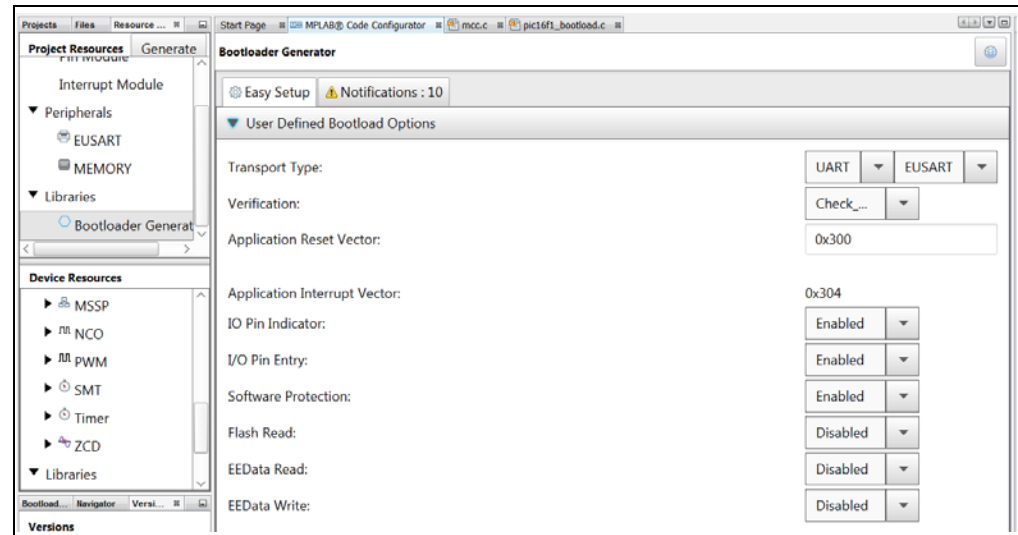
FIGURE 4-3: MEMORY PERIPHERAL



7. Select the Bootloader Generator library. Configure the bootloader for the desired operation.

Note: The Reset vector must be aligned to the beginning of an erase row. The Erase command erases the entire row. The bootloader needs to make sure it does not erase any part of the bootloader, so any Erase command not starting on a row boundary will be disallowed.

FIGURE 4-4: BOOTLOADER GENERATOR



8. Open the Pin Manager Grid View. Configure pin selections for the bootloader operation behavior. As shown below, the lab RA0 is used for the Bootloader Indication pin (output), RA5 is the Bootloader entry pin (input), Tx and Rx are on RC0 and RC1.

FIGURE 4-5: PIN MANAGER GRID VIEW

Output - MPLAB® Code Configurator			Hardware Stack		Configuration Bits		Search Results		File Registers		SFRs		Program Memory		Hardware														
Pack...	SOL...	▼	Pin No:		Port A ▼								Port B ▼								Port C ▼								...
Module	Function	Direction	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	3		
Bootloader...	BL_ENTRY	input																											
	BL_INDI...	output																											
EUSART ▼	RX	input																											
	TX	output																											

9. Select Pin Module from the Project Resources, “System” option. Configure applicable pins to be digital by deselecting the analog check box option on all pins used.

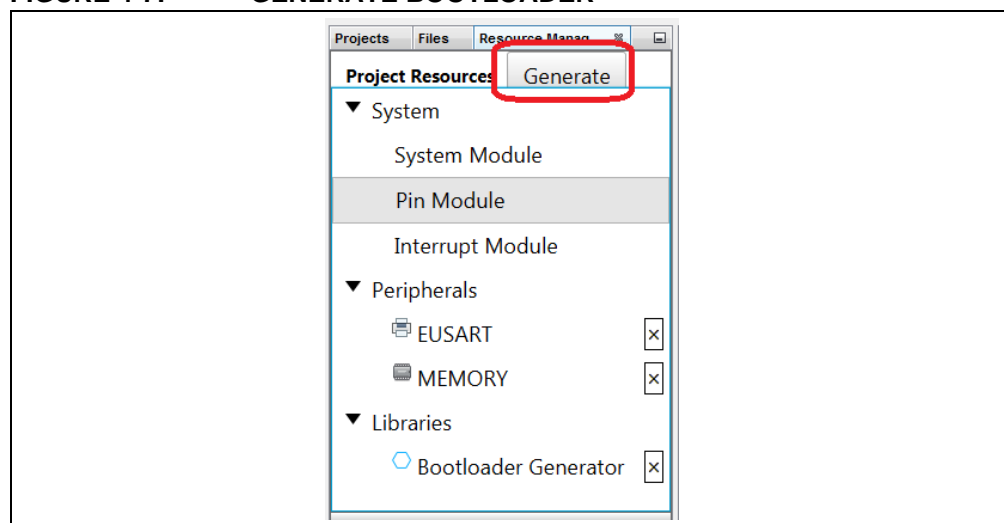
FIGURE 4-6: CONFIGURE PINS AS DIGITAL

Project Resources		Generate	Pin Module									
System			Easy Setup									
Pin Module			Registers									
Interrupt Module			Notifications : 4									
Peripherals												
EUSART												
MEMORY												
Device Resources												
MSSP												
Pin No...	Module	Function	Custom ...	Start High	Analog	Output	WPU	OD	IOC			
RA0	Bootload...	BG_INDI...		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		...			
RA5	Bootload...	BG_ENTRY		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>		...			
RC0	EUSART	TX		<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		...			
RC1	EUSART	RX		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>		...			

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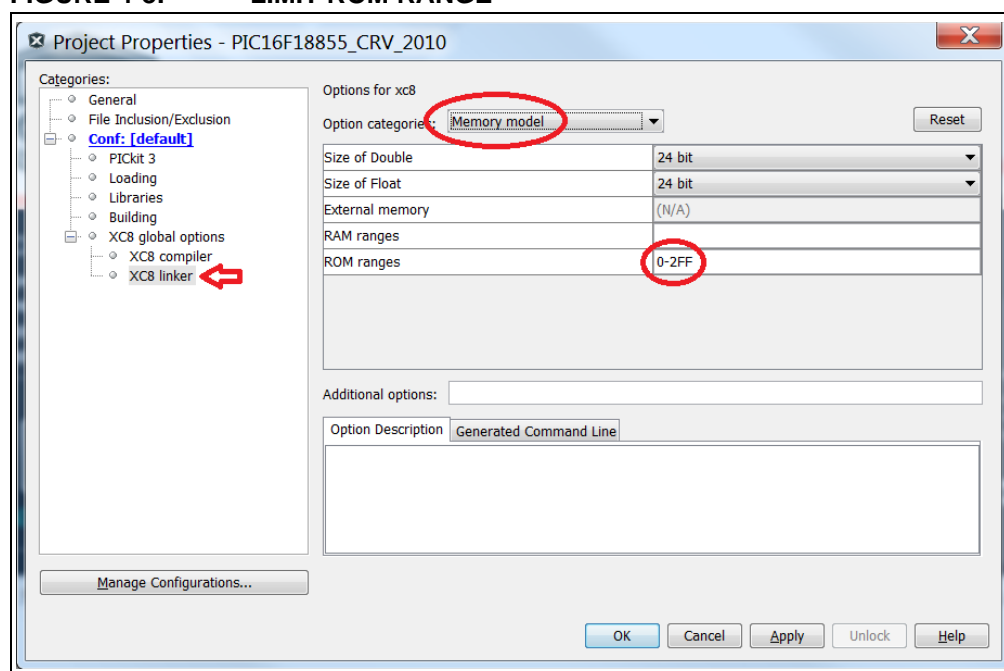
10. Press **Generate** button.

FIGURE 4-7: GENERATE BOOTLOADER



11. For the final step, configure to only build within a specified memory space. Open the Project Properties window; this can be done by right clicking on a project and selecting properties. Select XC8 Linker, under the XC8 global options. Select "Memory Model" under the Option Categories combo box. For example, entering the value of 0-2FF would restrict the generated code to the first 0x300 words of ROM when compiling project code. Refer to code size for appropriate ROM reservation size. To best understand the required ROM range, after a successful build of the Bootloader project, refer to the "PIC Memory Views" --> "Program Memory"; or at the Window --> "Dashboard", Memory Section.

FIGURE 4-8: LIMIT ROM RANGE



12. The bootloader should now be ready to build and test.

At this time only the EUSART is supported as a peripheral. MSSP and USB support will be added in the future.

Chapter 5. Merge Bootloader with the Application

5.1 MPLAB X PROJECT CONFIGURATIONS

The MPLAB X IDE allows for a project to be built in many different configurations. Merging projects into a single unified hex file is very useful when going to production, or debugging interactions between application and bootloader.

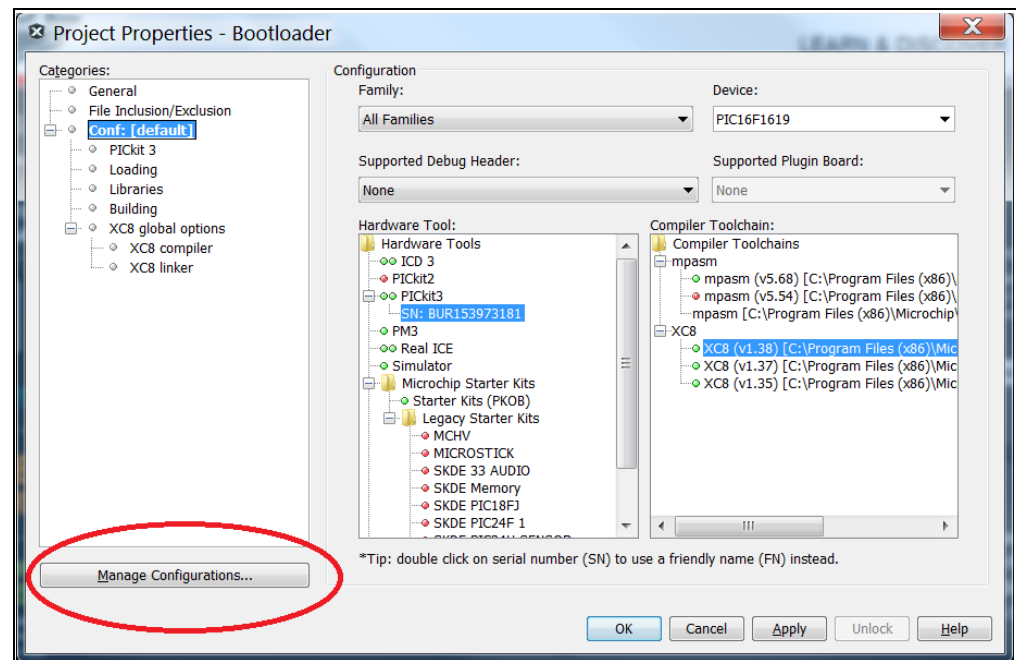
The bootloader needs to have Configuration Words declarations when programmed stand-alone or during the development purposes; however, if Configuration Words do not match when attempting to merge with the end application, the linker will give a "(944) data conflict error at..." This occurs when it tries to put two different values into a location. This most often occurs when the Configuration Words are included both in the bootloader and end application. Thus it is advantageous to have a means to have them included while developing, but omitted when incorporating with the end application.

MPLAB X project configurations provide a solution to this issue. A project configuration can be created which includes Configuration Word in the stand-alone bootloader project compilation, while another can omit the settings from the bootloader project build, allowing the merged end application settings to be used for both projects. The first is useful when debugging, or learning bootloader operation while the second is useful during end application development building a production ready unified hex file.

Here is how to create the two bootloader project configurations:

1. Open the Project Properties window.
2. Click on the **Manage Configurations** button.

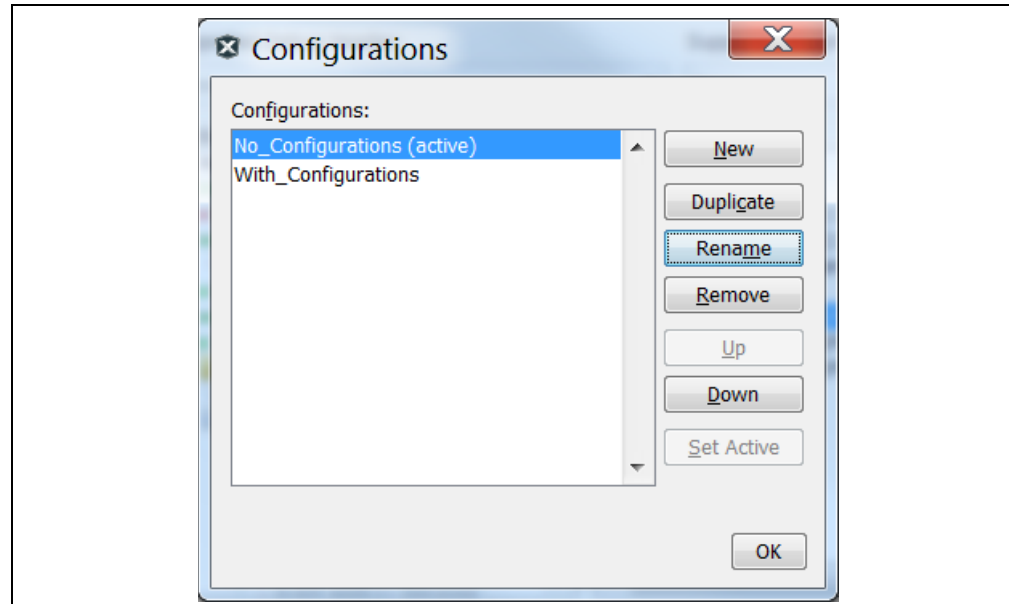
FIGURE 5-1: MANAGE CONFIGURATIONS



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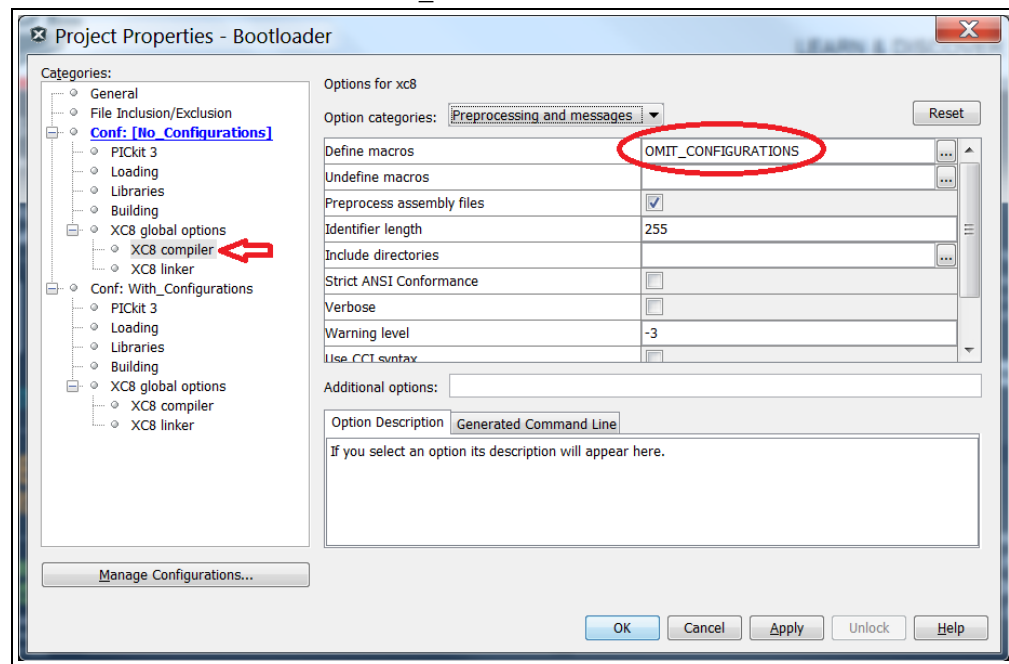
3. Duplicate the “default” project configuration; rename one to With_Configurations, and the other No_Configurations.

FIGURE 5-2: BOOTLOADER CONFIGURATIONS



4. From the Conf: [No Configurations] select the “XC8 Compiler” under “XC8 global options”. The first field is labeled as “Define a macros”, double click inside the blank field or press on the icon. Add the Text, “OMIT_CONFIGURATIONS” to the field.

FIGURE 5-3: #define OMIT_CONFIGURATIONS



Merge Bootloader with the Application

5. Go to the generated MCC.C source file where Configuration bits are defined for the bootloader project.
6. Add a `#ifdef OMIT_CONFIGURATIONS/#else/#endif` around the Configuration Words as shown below:

EXAMPLE 5-1: `#ifdef OMIT_CONFIGURATIONS`

```
#ifdef OMIT_CONFIGURATIONS
#info "Configuration bits are not generated with the code. If you
need them switch to the 'WITH_CONFIGURATIONS' Configuration."
#else
#info "Configuration bits are generated with the code. If you get a
linker
CONFIG1
#pragma config FOSC = INTOSC      // Oscillator Selection Bits->INTOSC
oscillator: I/O function on CLKIN pin
#pragma config PWRTE = OFF        // Power-up Timer Enable->PWRT
disabled
#pragma config MCLRE = ON         // MCLR Pin Function Select->MCLR/VPP
pin function is MCLR

...

#endif
```

Using OMIT instead of INCLUDE means the Configuration bits will be generated by default. This is to great advantage when merging the bootloader with the application.

5.2 END – APPLICATION PROJECT CONFIGURATIONS

There are three configurations useful for the end application when being combined with the generated bootloader:

“Stand-Alone” is the normal configuration where the end-application begins at the start of program memory. This configuration is useful when beginning initial development, or doing debugging without interference from the bootloader.

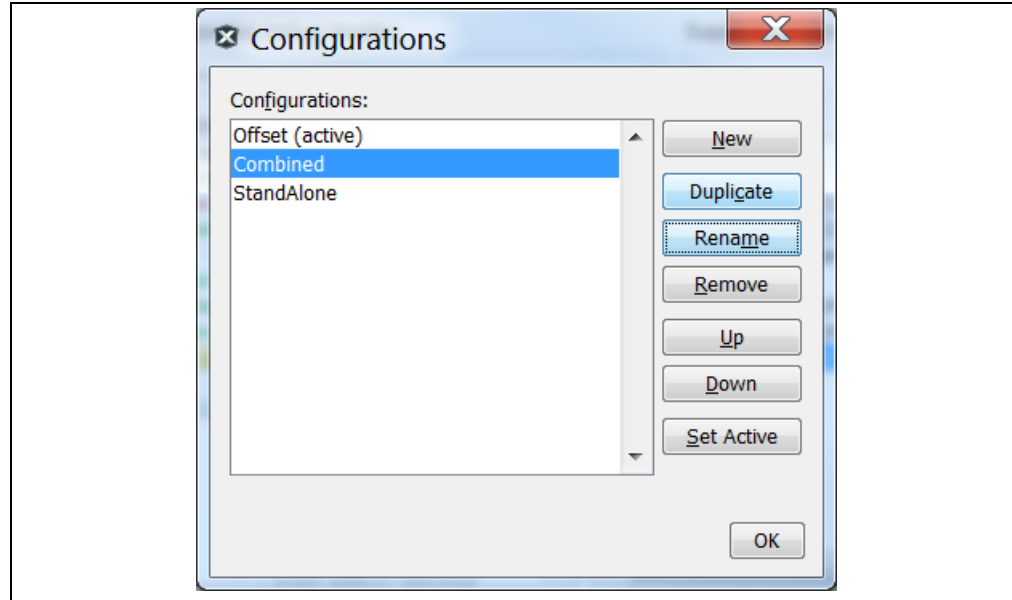
“Offset” configuration shifts the end-application to start at the defined offset location in the devices program memory. This configuration is done to reserve the beginning of the bootloader. This is the configuration used when developing incremental updates to the end-application which are intended to be bootloaded on to the device.

“Combined” is the final configuration, and is used to merge the offset end-application project with the bootloader included into a single unified hex file. This is the code that would be initially programmed into the device at the factory.

MPLAB X makes it easy to set up and switch between these configurations. As done with the bootloader configurations, go to the Project Properties window, then manage configurations. Duplicate the default configuration twice, rename one to Stand-Alone, another to Offset and the third to Combined.

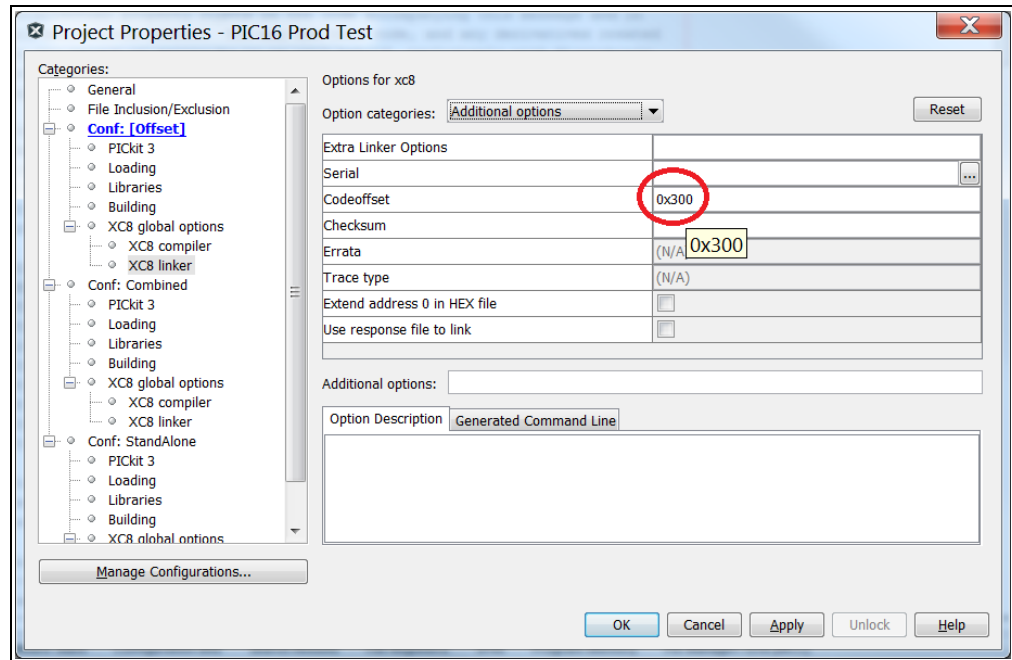
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FIGURE 5-4: END APPLICATION PROJECT CONFIGURATIONS



From Conf: [Offset] select “XC8 Linker” under “XC8 global options”. Select the “Additional Options” from the “Option categories” combo box. Enter into the “Codeoffset” field the program memory Flash value where the application will start while leaving room to not occupy the bootloader code space. This will automatically remap the Reset, and interrupt vectors to appropriate locations, respectively. For example, a value of 0x300 on a PIC16 will offset the Reset Vector to 0x300 and Interrupt Service Routine to 0x304; on a PIC18 Interrupt Service Routines would be located at 0x308 and 0x318. Apply the same offset to the “Combined” configuration.

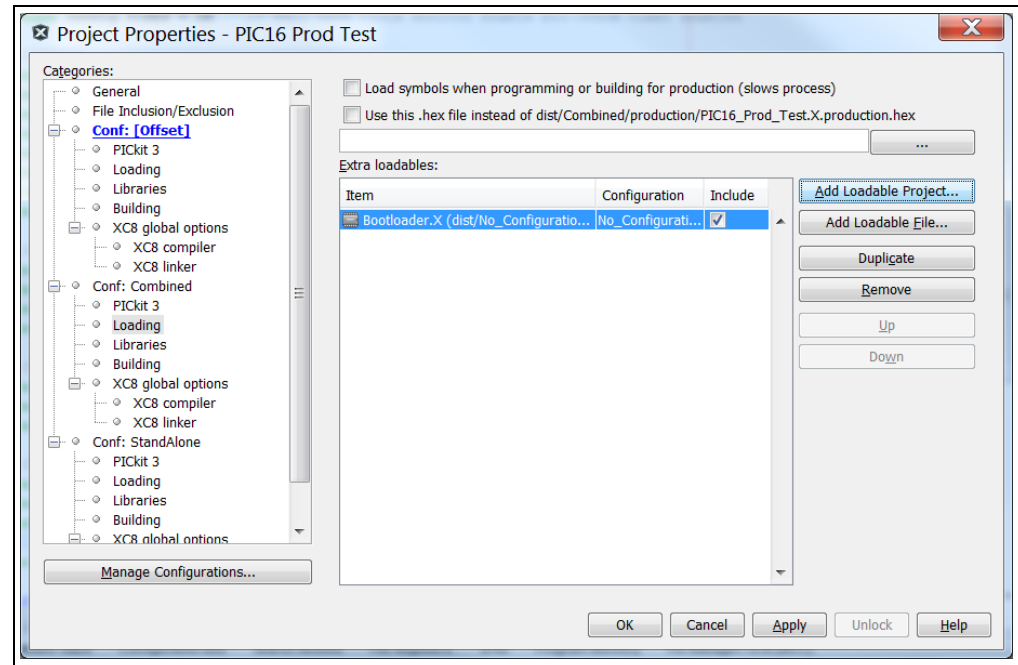
FIGURE 5-5: CODE OFFSET



Merge Bootloader with the Application

From the Conf: [Combined] configuration selected, select the “Loading” option within the combined configuration. Click the **“Add Loadable Project”** push button. Navigate to the bootloader project directory and add it as a loadable project. Select the No_Configurations option under the “Configuration” column; clicking in this column will supply a combo box of configuration options for the loaded project. Confirm the “Include” check box is toggled only for the [Combined] configuration and click apply.

FIGURE 5-6: MERGE BOOTLOADER WITH END APPLICATION



The application is now ready to be built in any of the three configurations.

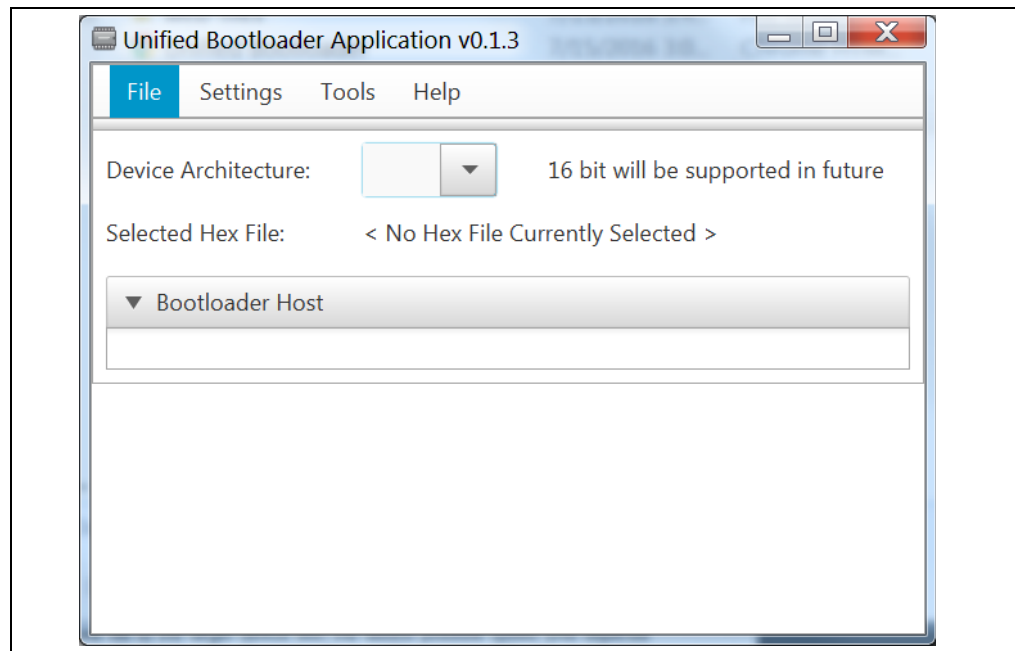
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NOTES:

Chapter 6. Bootloader Host Application

The bootloader host application is responsible for transferring an embedded application program (the .hex file) from the host machine (development host) to a target device (a device running the embedded application). It talks to the bootloader present on the target device by sending appropriate commands, and it transfers data (the embedded application program) using UART communication. It can be used to program the Flash memory for PIC16 and PIC18 devices. EEPROM writes are also supported.

FIGURE 6-1: BOOTLOADER HOST APPLICATION



6.1 OVERALL WORKING STRATEGY

The application requires the user to select the device family and the COM port used for communication. Once this is selected, the user has to configure the program memory and offset values on the GUI screen. As soon as the user clicks the **Program Device** button, the application prompts the user to select a .hex file, after which it tries to write (transfer) the file to the target device with the fastest possible speed (this depends massively on the baud rate). Once the file is written successfully, the application calculates a checksum over the entire .hex file and verifies data integrity. A checksum match resets the target device and the embedded application program starts to execute.

In case of a communication failure, the application retries three times after which it relinquishes control over the COM port and stops the communication giving an error.

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6.2 PREREQUISITES

Make sure that the MPLAB X IDE or MPLAB communication libraries are installed on the machine. If any problems arise while starting the application, try re-installing MPLAB X.

The values to be entered in the text fields for the “Program Memory size” and “Bootloader offset” must be in hex format. By default, the application is set to have an offset of 300 (hex) with program memory size as 4000 (hex).

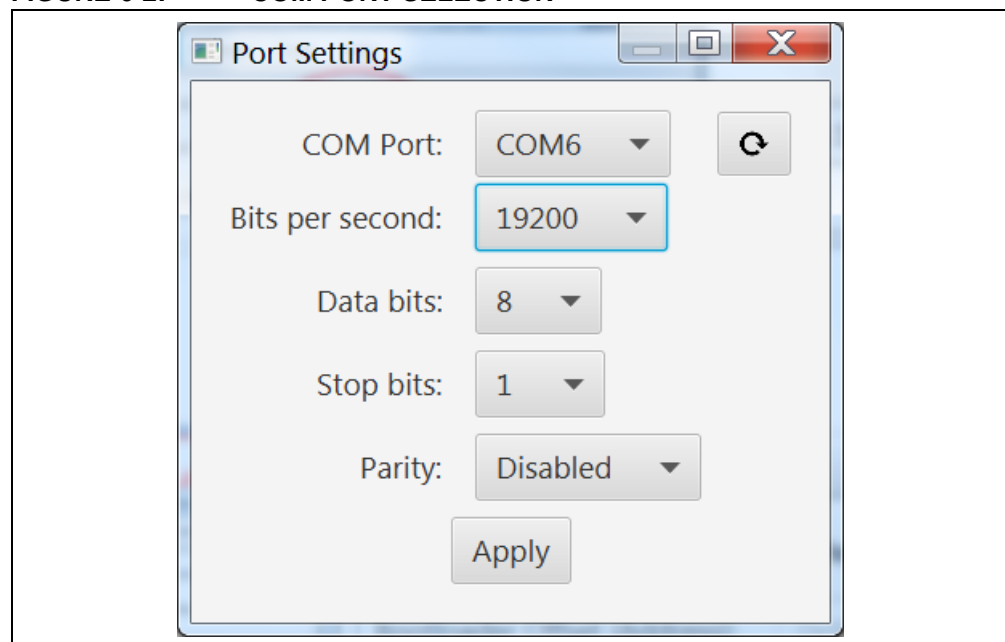
Version 1.0 of the application performs “Program Memory and EEPROM” writes only with UART interface.

6.3 DETAILED STEPS

As soon as the application is launched, there are several inputs that need to be provided, as listed below.

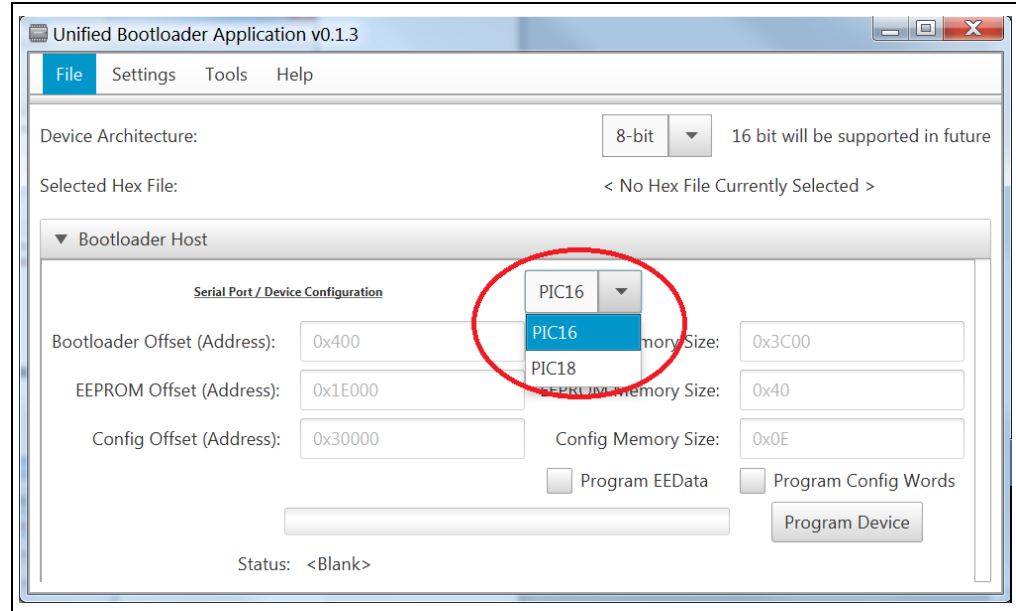
1. Select the device architecture to bootstrap.

FIGURE 6-2: COM PORT SELECTION



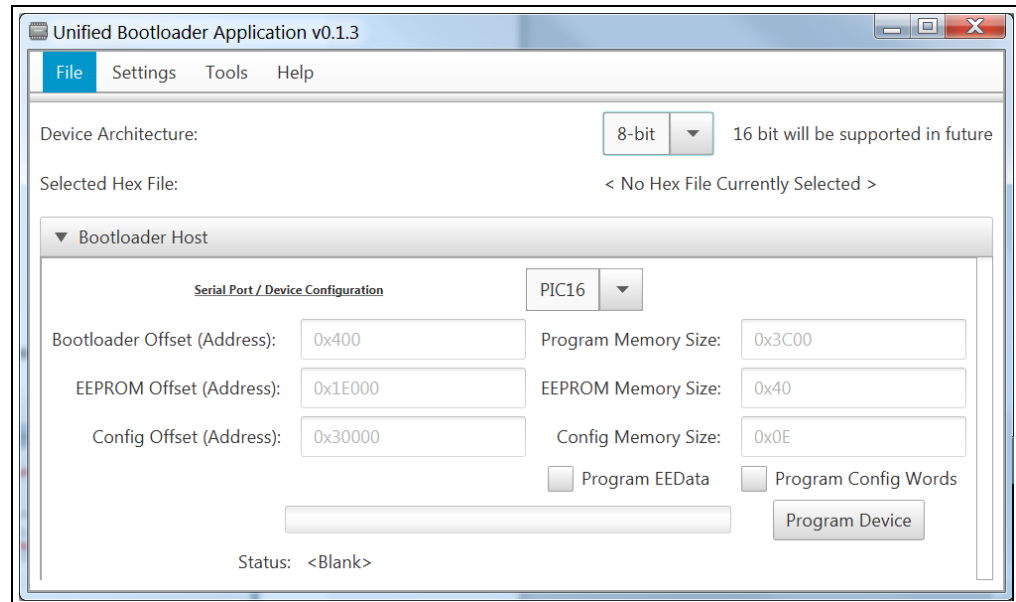
2. Pick the device family (PIC16 or PIC18) from the other drop-down menu (see Figure 6-3).

FIGURE 6-3: DEVICE FAMILY SELECTION



3. Select and configure the COM port.

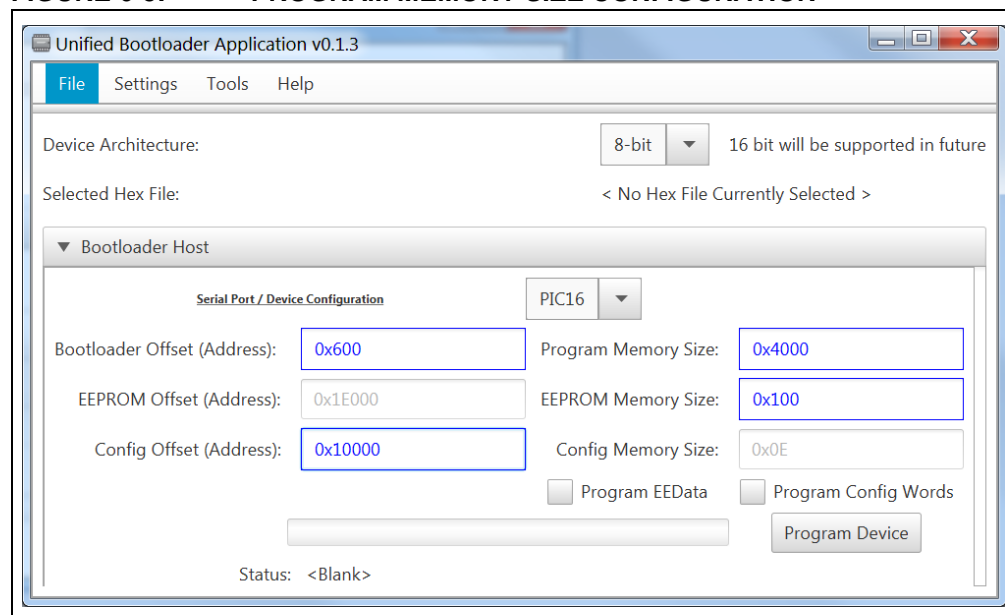
FIGURE 6-4: BOOTLOADER OFFSET CONFIGURATION



4. Set the program memory size depending on the target device (see Figure 6-5). Be aware that the program memory size is the number of locations. For example, if the target device has program memory starting from 0-3FFF, then 4000 should be entered in the text field. The size of every location depends on the target device. Some devices have word-addressable Flash and others have it byte-addressable.

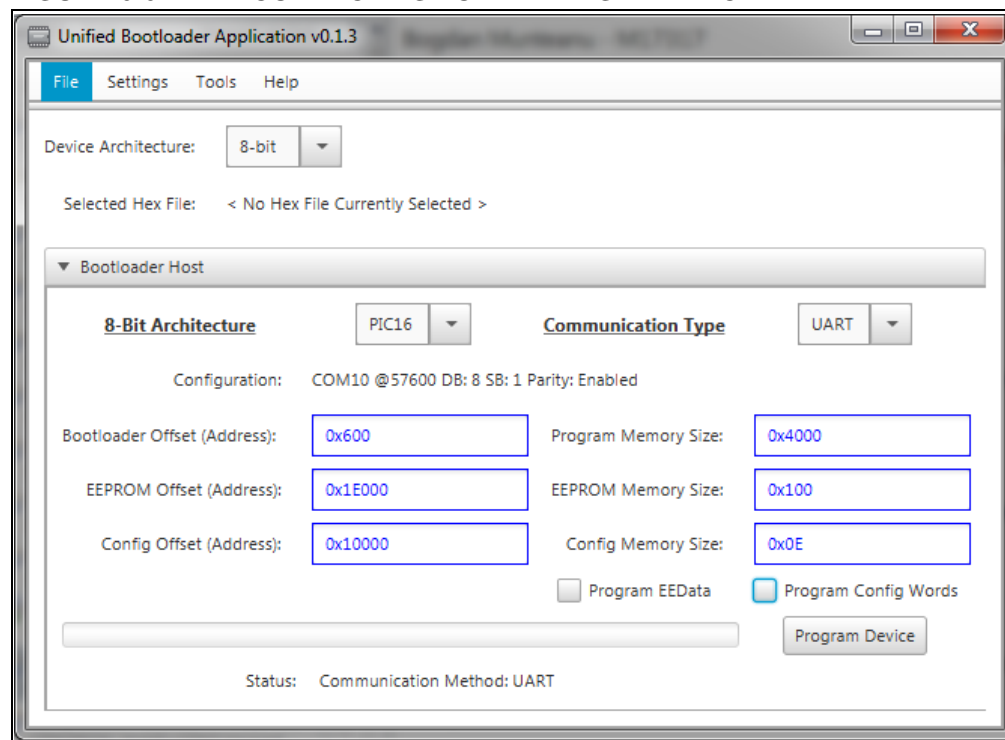
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FIGURE 6-5: PROGRAM MEMORY SIZE CONFIGURATION



5. Click the **Program Device** button (see Figure 6-6 through Figure 6-8).

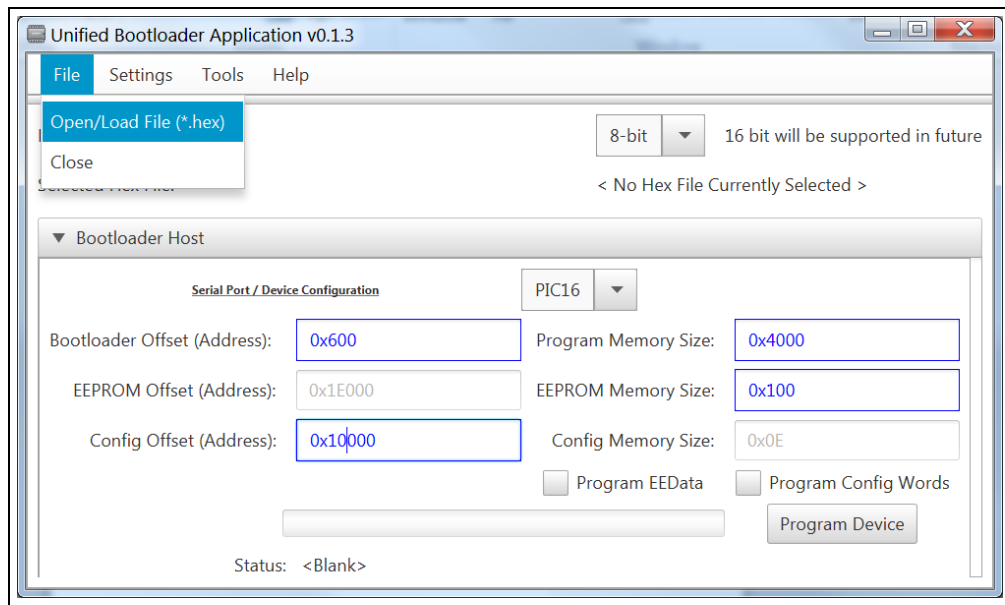
FIGURE 6-6: CONNECTING TO THE TARGET DEVICE



6. Select the File then Open/Load file to select the hex file to load.

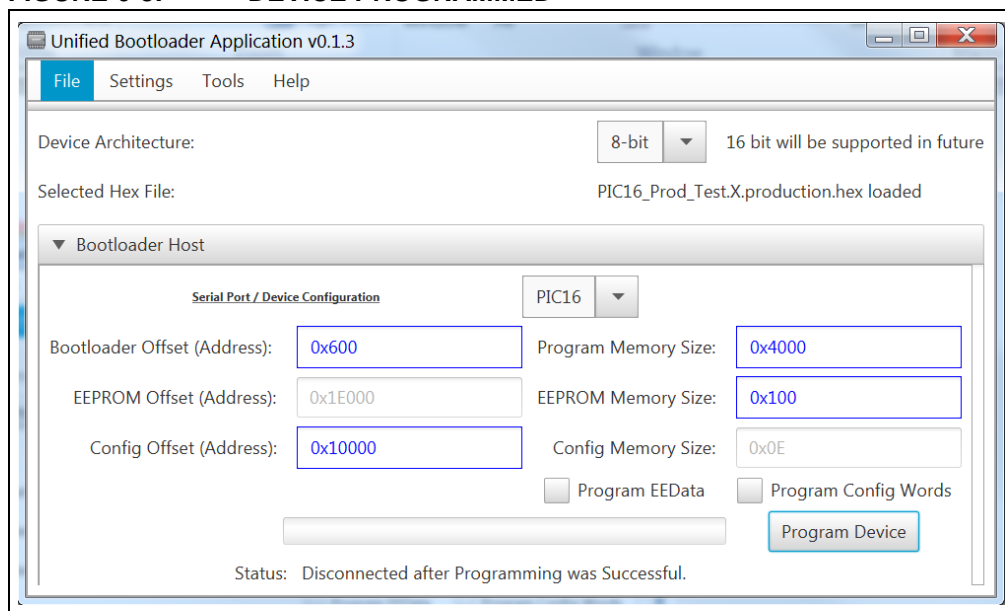
Bootloader Host Application

FIGURE 6-7: DISPLAYING A FILE CHOOSER DIALOG



7. Once the device is programmed, the bootloader will disconnect from the COM port.

FIGURE 6-8: DEVICE PROGRAMMED



6.4 MENU BAR OPTIONS

There are additional options that can be used if needed. The **Program Device** button should take care of connecting to the target device and popping up a file selection dialog. However, if the user wants to connect or load the file externally, options have been provided in the menu. If the user needs to close the application, this can be done under the menu.

Ensure that the Console window is pulled up when programming a device. This window will provide step-by-step visibility into the bootloading process.

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6.5 TROUBLESHOOTING

If the application fails to connect, close the application, unplug the target device, plug it back in and start the application again. If the device is connected while the application is running, click the **Refresh** option under the menu to pull up the COM port. Pull up the Console window to check the nature of the error. There is a status label above the progress bar which displays messages appropriately.

6.6 EXTERNAL DEPENDENCIES

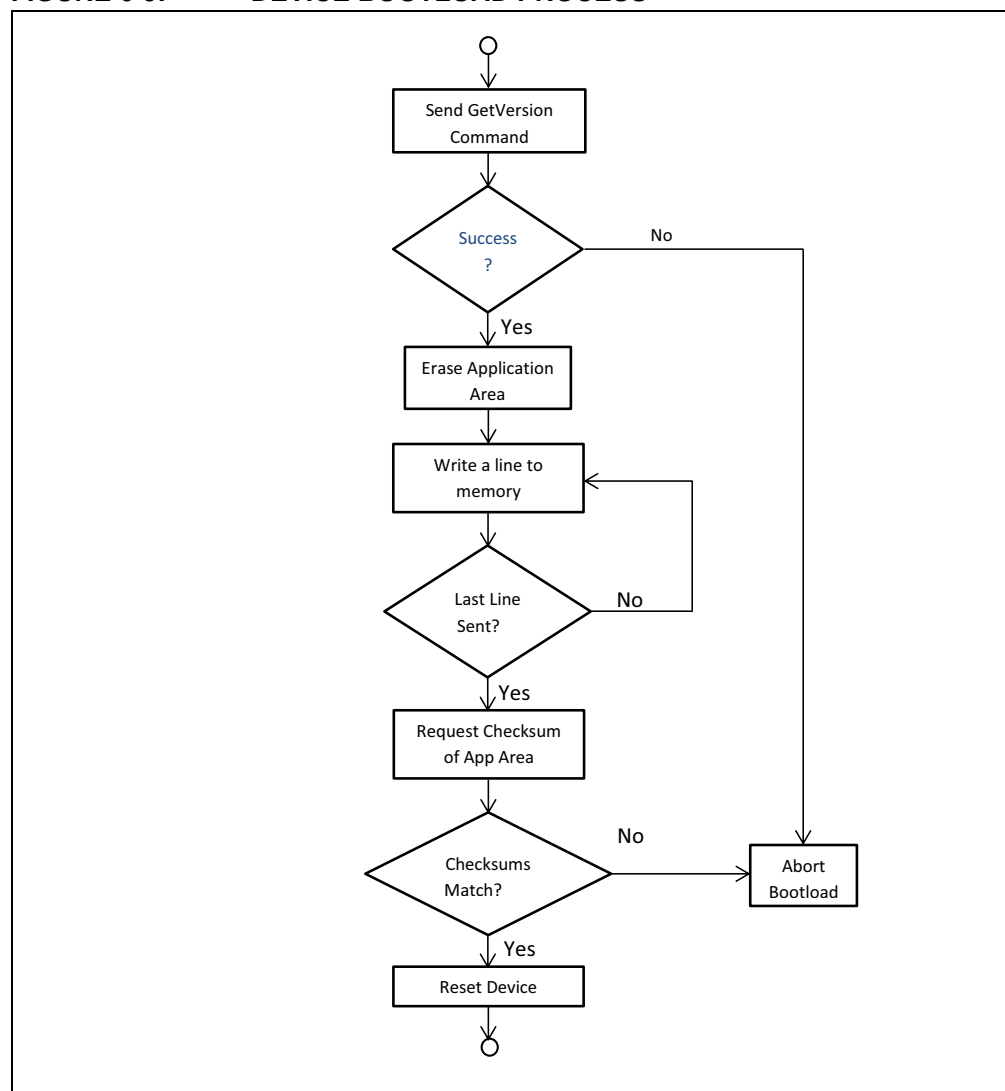
The application uses a hex file parser and MPLAB X communication to parse and store the hex file to be programmed and to communicate to the target device, respectively. Both of these are provided in the form of libraries (.jar) with the application.

Another common reason for the lack of communications is that one or more of the comms line has analog functions enabled. (See [Figure 4-6](#) "Disable Analog"). At this point it may be easier just to change the ANSEL registers in the code.

6.7 THE HOST APPLICATION

Here is the process used to bootstrap a device:

FIGURE 6-9: DEVICE BOOTLOAD PROCESS



Chapter 7. Bootloader Protocol

7.1 COMMAND SET

It is important to note that the success status code returned by the bootloader upon reception of a command only implies it met the proper format, and the bootloader code accomplished execution. Write commands are not read back and compared with the RAM copy. This could be custom added after generation, but has been intentionally omitted in favor of small and lite code. It is recommended that the host keep a running checksum as the device is programmed. After completion of the entire write, issuing the Calculate Checksum command [0x08] request the bootloader code to calculate a checksum over the specific application area and return the value for comparison with the host's expected result.

TABLE 7-1: COMMAND LIST

Hex Value	Command	Description
0	Read Version	Confirms Communication and Exchanges Bootloader Version Info
1	Read Flash	Reads Program Memory range as specified
2	Write Flash	Writes Program Memory range as specified
3	Erase Flash	Erases Program Memory range as specified
4	Read EE Data	Reads EEPROM Memory range as specified
5	Write EE Data	Writes EEPROM Memory range as specified
6	Read Config	Reads current Configuration Words programmed values
7	Write Config*	Writes Configuration Words reprogramming over stored values
8	Calculate Checksum	Calculates and returns computed Checksum over Memory Range
9	Reset Device	Informs the Bootloader to do a software Reset

Note: Most PIC16F1 devices can only change Configuration Words via an external programmer, not via a bootloader.

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7.2 THE HOST APPLICATION

Command Descriptions:

All commands sent to the bootloader device contain at minimal [9] bytes. General format is described below:

[AutoBaud(1)] [Command] [Data Length(2)] [Unlock Sequence(3)] [Address(4)]
[Data(5)]

Notes*:

1. Required only for EUSART
2. [2] Bytes – [Low] [High]
3. [0x55] [0xAA] for Write and Erase commands, [0x00] [0x00] for non-write
4. [4] Bytes – [Low] [High] [Upper] [Extended]
5. [0 – 64] Bytes – Based upon [Data Length]

All command examples for a PIC18F25K50:

Return Code Values:

- [0x01] – Command Successful
- [0xFF] – Command Unsupported
- [0Xfe] – Address Error

Get Version: [0x00]

Establishes communication with the device and returns useful information such as:

- bootloader version
- Max Packet size
- Device ID
- Erase row size
- Write latch size
- Config words

Tx to device: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00

Description: Request bootloader version information.

Rx from device:

Command string: 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00

Bootloader Version: 0x06 0x00

Max Packet size: 0x00 0x01 (0x100)

Not Used: 0x00 0x00

Device ID: 0xA1 0x5C

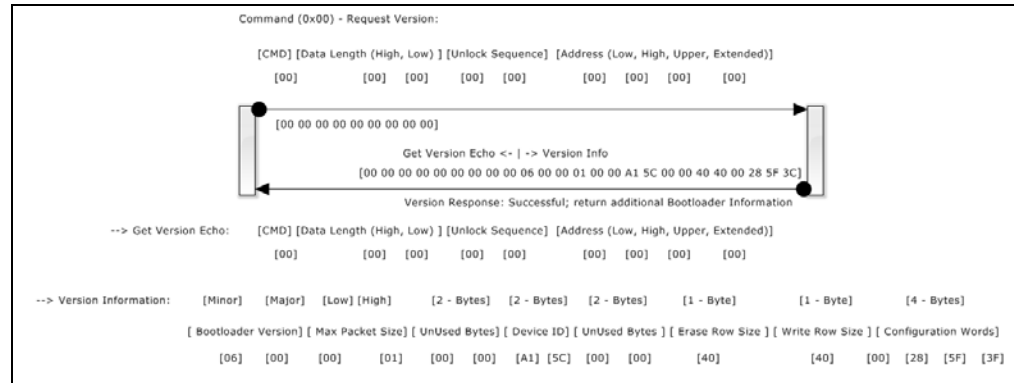
Not Used: 0x00 0x00

Erase Row Size: 0x40

Write Latches: 0x40

Config Words: 0x00 0x28 0x5F 0x3C

FIGURE 7-1: REQUEST VERSION COMMAND



Erase Flash: [0x03]

Tx to device: 0x03 0xEC 0x00 0x55 0xAA 0x00 0x05 0x00 0x00

Erase 0xEC rows starting at 0x500.

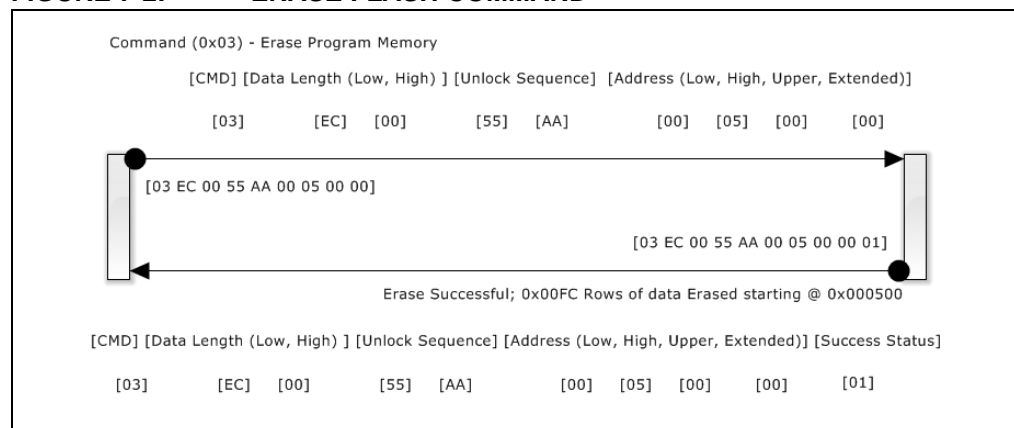
Rx from Device:

Command String: 0x03 0xEC 0x00 0x55 0xAA 0x00 0x05 0x00 0x00

Success Code: 0x01

Note: The erase address must be aligned to the first address of an erase row. Any attempt to erase with an address not at the beginning of a row will be rejected with an address error code.

FIGURE 7-2: ERASE FLASH COMMAND



Write Flash Memory:

Tx to Device: 0x02 0x40 0x00 0x55 0xAA 0x00 0x05 0x00 0x00 {64 bytes of data to be written}

Description: Write (0x40 bytes starting at address 0x500)

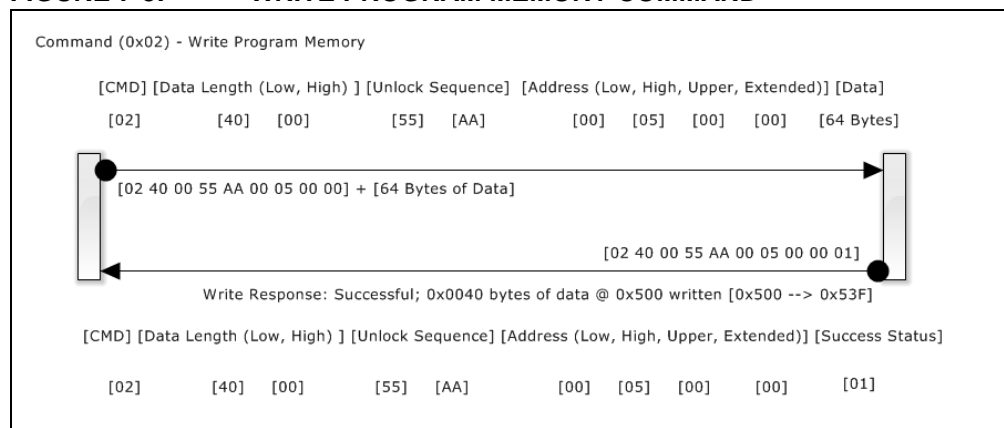
Rx from Device:

Command String: 0x02 0x40 0x00 0x55 0xAA 0x00 0x05 0x00 0x00

Success Code: 0x01

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FIGURE 7-3: WRITE PROGRAM MEMORY COMMAND



Calculate Checksum: [0x08]

Tx to Device: 0x08 0x00 0x3B 0x00 0x00 0x00 0x05 0x00 0x00

Description: Calculate checksum from 0x500 to 0x3FFF.

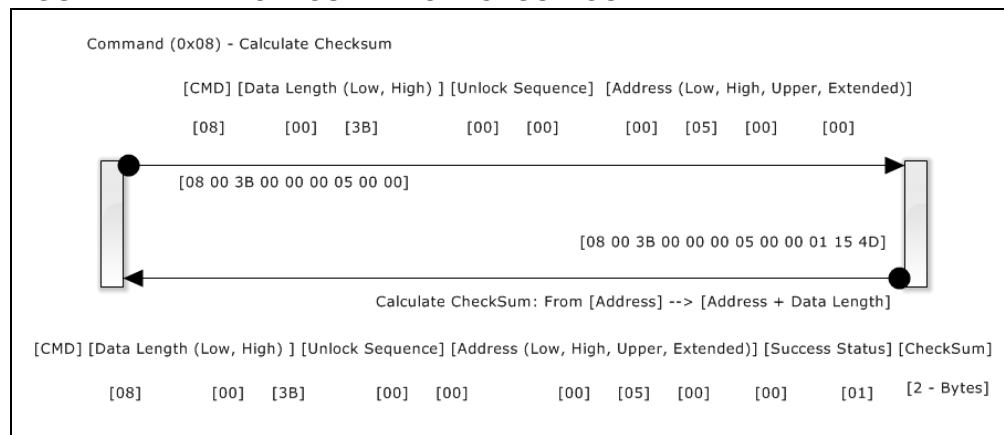
Note: It is recommended the host program calculates an independent checksum as the hex file is written to the device. This can later be compared to the checksums calculated on the device and supply confidence the memory array was correctly written.

Rx from Device:

Command String: 0x08 0x00 0x3B 0x00 0x00 0x00 0x05 0x00 0x00

Checksum: 0x15 0x4D

FIGURE 7-4: CALCULATE CHECKSUM COMMAND



Reset Device: [0x09]

Tx: to Device: 0x09 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00

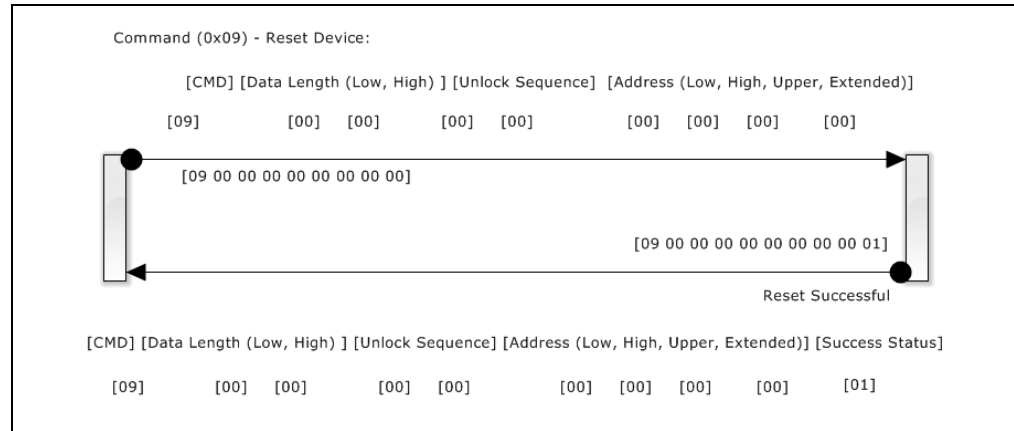
Description: Allows bootloader to process a soft-reset on the device.

Rx from Device

Command String: 0x09 0x00 0x00 0x00 0x00 0x00 0x00 0x00 0x00

Success Code: 0x01

FIGURE 7-5: RESET DEVICE COMMAND



7.3 ADDITIONAL COMMANDS

Read Flash: [0x01]

Tx to Device: 0x01 0x40 0x00 0x00 0x00 0x00 0x05 0x00 0x00

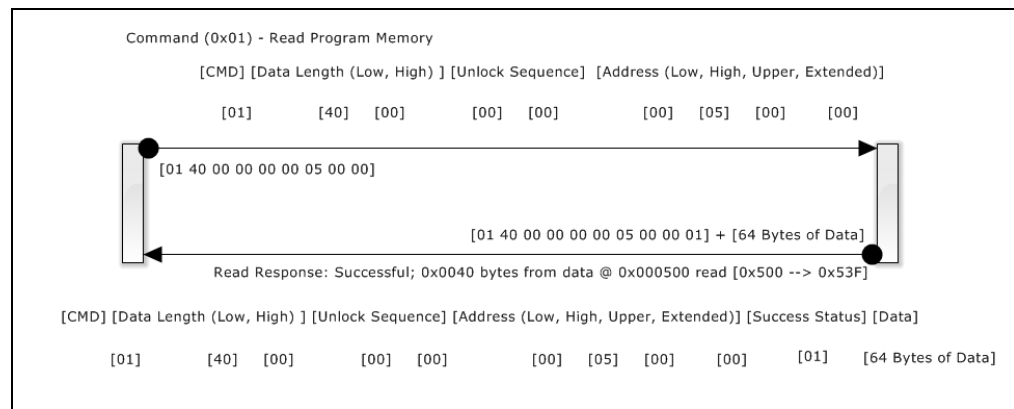
Description: Read 0x40 bytes starting at address 0x500.

Rx from Device:

Command String: 0x01 0x40 0x00 0x00 0x00 0x00 0x05 0x00 0x00

Flash Memory: { 64 bytes from Flash program memory from 0x500-0x53F }

FIGURE 7-6: READ FLASH COMMAND



Write EE Data: [0x05]

Tx to Device: 0x05 0x05 0x00 0x55 0xAA 0x00 0x00 0xF0 0x00 0x11 0x22 0x33 0x44 0x55

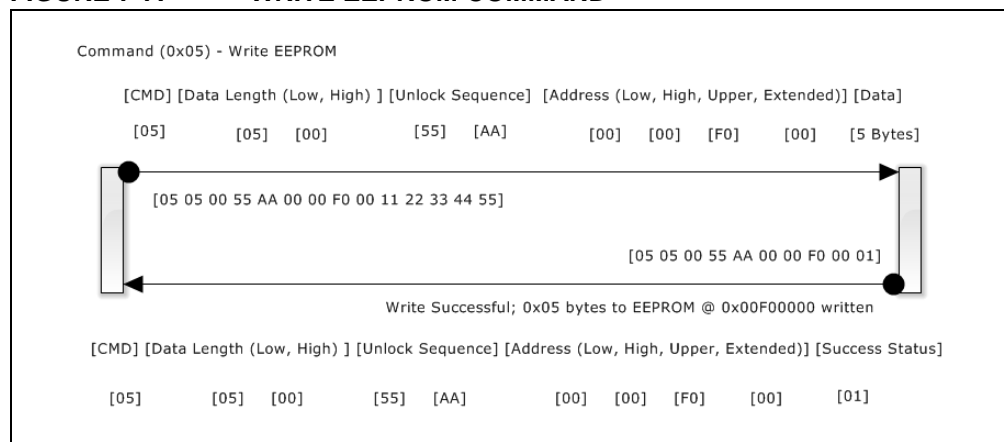
Description: Writes 0x05 bytes to EE Data starting at address 0x00F00000

Command String: 0x04 0x5 0x00 0x55 0xAA 0x00 0x00 0xF0 0x00

Success Code: 0x01

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FIGURE 7-7: WRITE EEPROM COMMAND



Read EE Data: [0x04]

Tx to Device: 0x04 0x05 0x00 0x00 0x00 0x00 0x00 0x00 0xF0 0x00

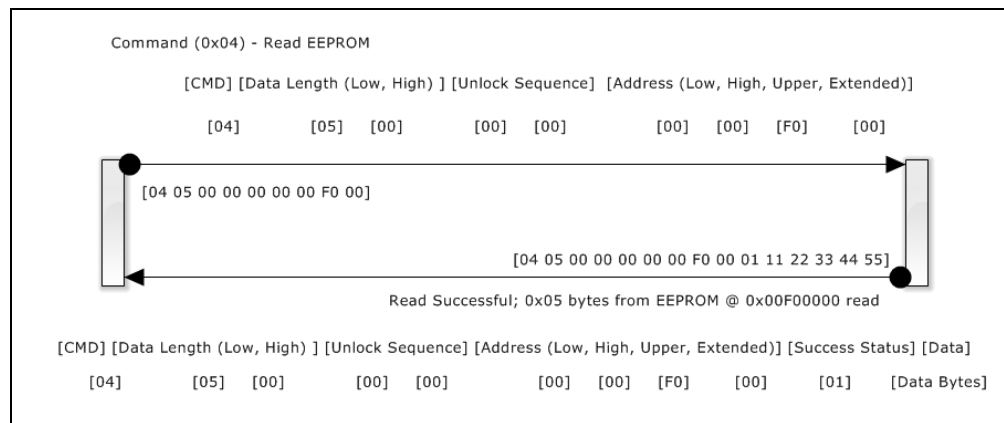
Description: Read five bytes from EE Data starting at address 0x00F00000.

Rx from device:

Command String: 0x04 0x05 0x00 0x00 0x00 0x00 0x00 0x00 0xF0 0x00

Returned Data: 0x11 0x22 0x33 0x44 0x55

FIGURE 7-8: READ EEPROM COMMAND



Read Config Words: [0x06]

Tx to Device: 0x06 0x0E 0x00 0x00 0x00 0x00 0x00 0x00 0x30 0x00

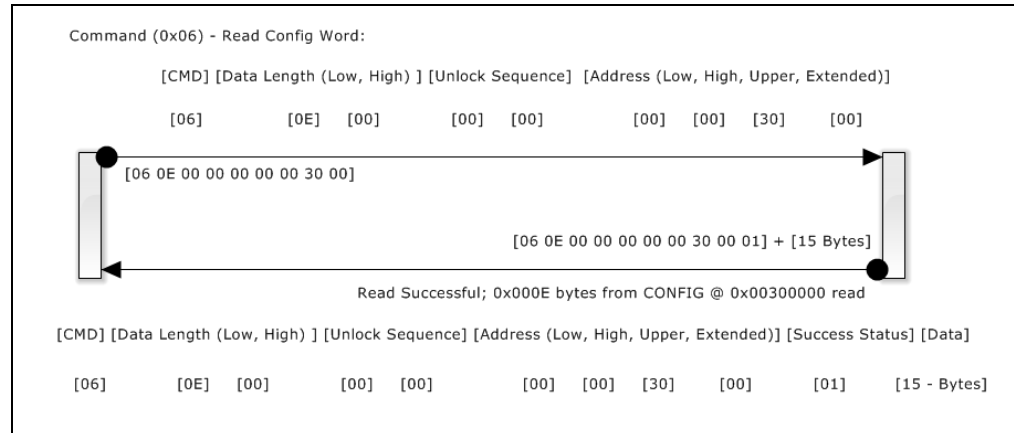
Description: Read 14 bytes from Config Words (mapped at 0x00300000).

Rx from Device:

Command String: 0x06 0x0E 0x00 0x00 0x00 0x00 0x00 0x00 0x30 0x00

Returned Data: {14 bytes representing Config bytes from 0x300000-30000E}

FIGURE 7-9: READ CONFIG COMMAND



Write Config Words: [0x07]

Tx to Device: 0x07 0x0E 0x00 0x55 0xAA 0x00 0x00 0x30 0x00 {14 additional bytes to be programmed to Config bytes}

Description: Write 14 bytes from Config Words (mapped at 0x00300000).

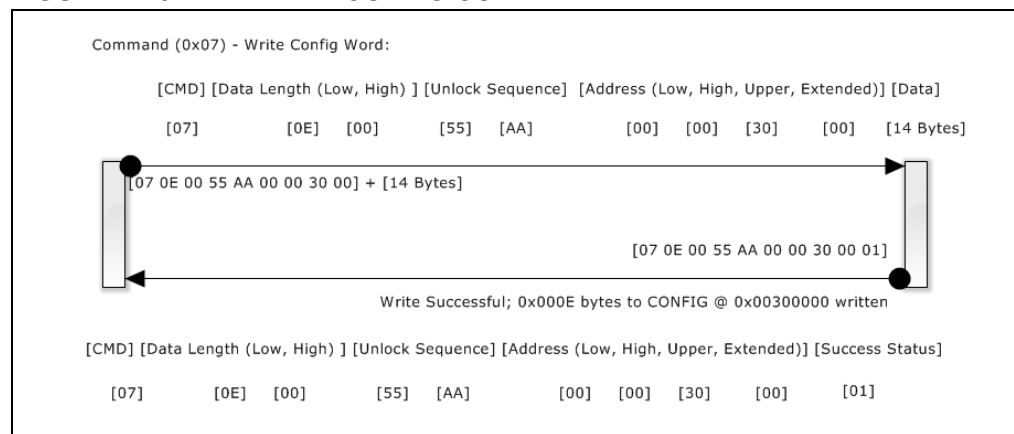
Rx from Device:

Command String: 0x07 0x0E 0x00 0x55 0xAA 0x00 0x00 0x30 0x00

Returned Data: 0x07 0x0E 0x00 0x55 0xAA 0x00 0x00 0x30 0x00

Success Code: 0x01

FIGURE 7-10: WRITE CONFIG COMMAND



Switching between Application and bootloader:

There are two methods for switching from the device's end-application back to bootloader:

- Jump to the Reset vector
- Reset the device

Resetting the device has the advantage that it clears the stack, reducing the chance for a Stack Overflow. However, if the MCU is engaged in some activity that cannot be stopped for the Reset, a jump to the Reset vector is another choice. Also, newer MCUs allow stack access under program control so extraneous stack levels can be manually popped before transferring control back to the user application.

The simplest method to switch control from the end-application to the bootloader is to execute a goto back to the top of the bootloader code. There must also be a means to indicate to the bootloader not to relinquish control to the end-application.

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Another way is to have the end-application invalidate the “application valid” indicator checked by the bootloader upon start-up, then reset the device. The normal start-up checks will return no valid application when loaded, and continue to run the bootloader application. This method has the additional benefits of resetting the call stack and also that it will continue to run the bootloader until a valid application has been re-loaded, even if a previous bootload process was interrupted.

However, this method is not always possible. For example, if the MCU is running a process which cannot be stopped during operation, such as running an active power supply consumed by the device, the method of executing a goto back to the bootloader vector should be used.

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