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MM7150 Motion Module PICtail™ Plus Evaluation Board (#AC243007) with Explorer 16 Development Board User's Guide

Object of Declaration: MM7150 Motion Module PICtail™ Plus Evaluation Board (#AC243007) with Explorer 16 Development Board

EU Declaration of Conformity

Manufacturer: Microchip Technology Inc.
2355 W. Chandler Blvd.
Chandler, Arizona, 85224-6199
USA

This declaration of conformity is issued by the manufacturer.

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This development/evaluation tool complies with EU RoHS2 Directive 2011/65/EU.

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ISBN: 9781632775498

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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 web site (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 "DSXXXXXA", where "XXXXX" 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 MM7150 Motion Module PICtail™ Plus Evaluation Board (#AC243007) with the Explorer 16 development board (#DM240001) to run the demo and sample code. Items discussed in this chapter include:

- Document Layout
- Audience
- Reference Documents
- Glossary
- The Microchip Web Site
- Development Systems Customer Change Notification Service
- Customer Support
- Document Revision History

DOCUMENT LAYOUT

This document describes how to use the MM7150-PICTAIL with Explorer 16 Development Board to perform the demo and modify sample code. The manual layout is as follows:

- **Chapter 1. "Hardware Setup"** – Provides hardware setting information.
- **Chapter 2. "Software/Firmware Setup"** – Provides software and firmware setting and build information.
- **Chapter 3. "Demo Setup"** – Includes demonstration procedures.
- **Chapter 4. "Troubleshooting"** – Provides troubleshooting information.
- **Appendix A. "Code Structure"** – Provides sample code structure information.

- **Appendix B. "Reference Schematic & Bill of Materials"** – Provides MM7150-PICTAIL adapter reference schematic & bill of materials information.
- **Appendix C. "Extension Cable for Explorer 16"** – Provides signals connection information for building a custom extension cable to use with MM7150-PICTAIL.

AUDIENCE

This document is written for developers who are familiar with 9-axis motion sensor applications. The purpose of this document is to describe the functions and use of the MM7150-PICTAIL with Explorer 16 Development Board to perform the demos and modify sample code functions as described in the Host API Design for MM7150 Application Note.

REFERENCE DOCUMENTS

- DS00001885A - MM7150 Motion Coprocessor Data Sheet
- DS00001888A - MM7150 Motion Module Data Sheet
- DS00001873A - Host API Design for MM7150 Motion Module Application Note

Note: Please contact your Microchip representative for the above documents and availability.

GLOSSARY

This section describes glossary terms and acronyms used in this document.

TERM	DEFINITION
EVB	Evaluation Board
HID	Human Interface Device
I^2C	Inter-Integrated Circuit
USB	Universal Serial Bus
EC	Embedded Controller
SF	Sensor Fusion

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- **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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- **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.
- **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 PIC-kit 2 and 3.

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- Field Application Engineer (FAE)
- Technical Support

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Technical support is available through the web site at:
http://www.microchip.com/support

DOCUMENT REVISION HISTORY

Revision	Correction
DS500002322C (07-02-15)	• Added section 3.2 “Calibrating Sensors” • Added section 3.5.2 “Flash Configuration Update” feature • Added Appendix C “Extension Cable” info • Updated all pictures with latest production MM7150-PICTAIL • Updated all figures for sample code v1.3.3
DS50002322B (02-18-15)	• Added section 3.4 for Sleep/Wake feature • Added section 3.5 for Flash Update feature, update corresponding sections • Changed UART baud rate from custom 125000 to standard 19200 • Updated all the figures to show the v1.3.2 sample code • Updated the correct Document Numbers in the Reference Section • Added section 1.1 for hardware requirements • Added section 2.1 for software/firmware requirements • Section 3.2 “Calibrating Sensors” removed
DS50002322A (11-07-14)	Initial Release

Chapter 1. Hardware Setup

1.1 HARDWARE REQUIREMENTS

- Microchip Explorer 16 Development Board
- Microchip MM7150-PICtail Motion Module PICtail Board
- Microchip PICKit3 or ICD3 or RealICE debugger
- Null-Modem Serial Cable
- USB-to-Serial Adapter

1.2 PREPARING THE EXPLORER 16 DEVELOPMENT BOARD

- Insert PIM PIC24FJ128GA010 at Explorer 16 U1A socket
- Insert strap J7 for PIC24
- S2 switch selected for *PIM*
- Connect MPLAB ICD3 (or REAL ICE) In-Circuit Debugger module from HOST PC to JP1
- Connect USB-to-Serial Adapter capable of 19200 baud rate from HOST USB Port to Explorer 16 P1
  - *USB-to-Serial Adapter such as Microchip MCP2200 USB to RS232 Demo Board (Microchip part#: MCP2200EV-VCP)*

> **Note:** Configure Terminal Emulation Software (ex. Tera Term) for 19200 baud, 8 bits, No Parity, 1 Stop Bit, No Flow Control.

- Power Supply (+9V) at J12

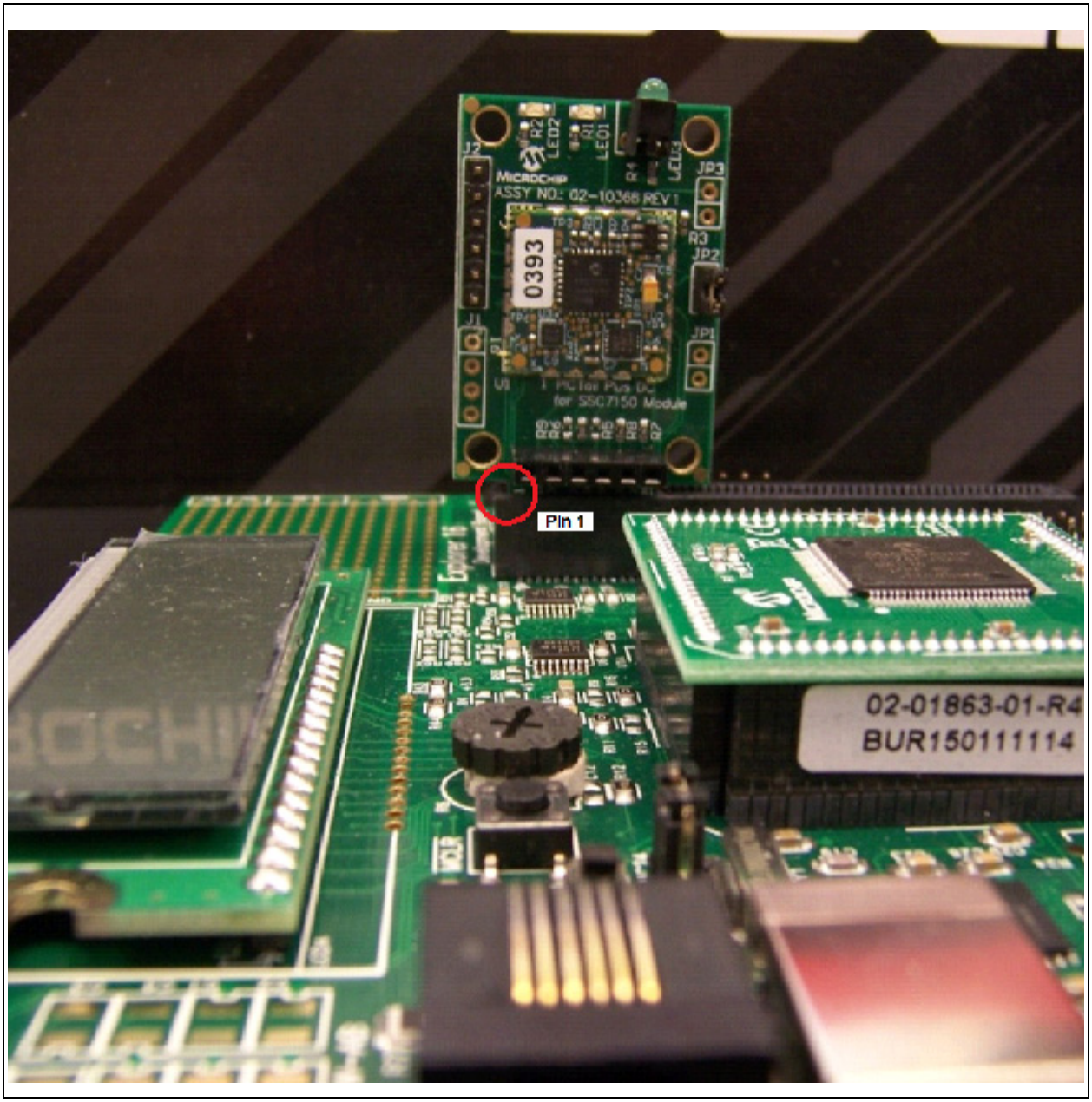
1.3 HARDWARE CONNECTIONS FOR MM7150-PICTAIL TO EXPLORER 16 DEVELOPMENT BOARD

> **Note:** Before attempting to connect the MM7150-PICTAIL with PICtail™ Plus Edge connector module to the Explorer 16 board, it is crucial that the power supply to the Explorer 16 be disconnected. Failure to do so may damage the MM7150 Motion Module.

1.3.1 Direct Plug-In

The MM7150-PICTAIL can be installed directly into the Explorer 16 Board. Insert the MM7150-PICTAIL into the PICtail™ header J5 with pin 1 of the module lining up with pin 1 of the header, as seen in Figure 1-1.

FIGURE 1-1: DIRECT CONNECTION OF MM7150-PICTAIL TO THE EXPLORER 16 PICTAIL™ HEADER.



1.3.2 Using Extension Cable

The MM7150-PICTAIL motion module can be connected to the Explorer 16 development board via a custom extension cable. Using an extension cable will allow freedom of movement compared with directly inserting the MM7150-PICTAIL board into the PICtail header on the Explorer 16 board.

Please see **Appendix C. "Extension Cable for Explorer 16"** for more information.

Chapter 2. Software/Firmware Setup

2.1 SOFTWARE/FIRMWARE REQUIREMENTS

- Microchip MPLABX IDE v2.06 or later
- Microchip XC16 Compiler v1.24 or later
- MM7150_Exp16_Sample_Code_v1.3.3

> **Note:** The latest sample code is available at *www.microchip.com/motion* or please contact your Microchip representative for more information.

- SSC7150 Motion Coprocessor Firmware Binary
  - The firmware can be updated using the flash update feature as described in **Section 3.5.1 "Flash Update command"**.
  - The firmware binary object code is encrypted and the update process is secured.

> **Note:** The latest firmware binary file is available at *www.microchip.com/motion* or please contact your Microchip representative for more information.

- MM7150 Module Configuration Firmware Binary
  - The configuration data can be updated using the update feature as described in **Section 3.5.2 "Flash Configuration Update Command"**.

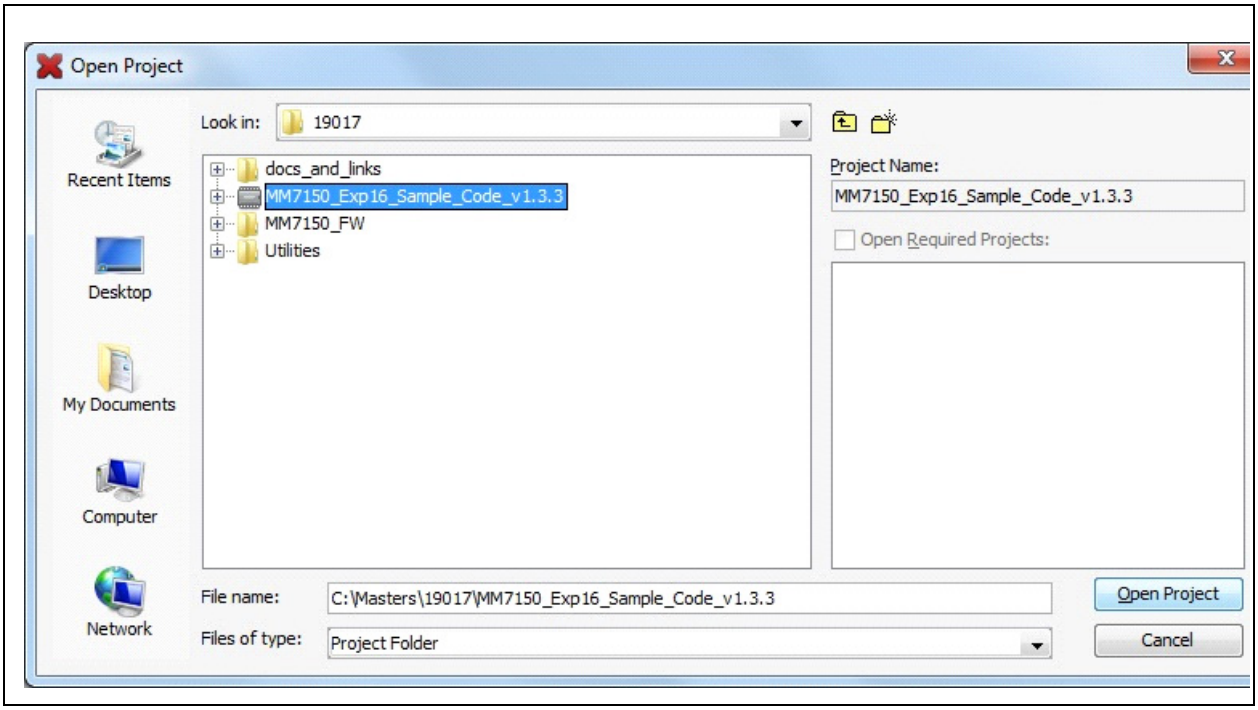
2.2 MPLABX PROJECT:

- Start MPLABX IDE as shown in Figure 2-1.

FIGURE 2-1: MPLABX IDE STARTUP SCREEN

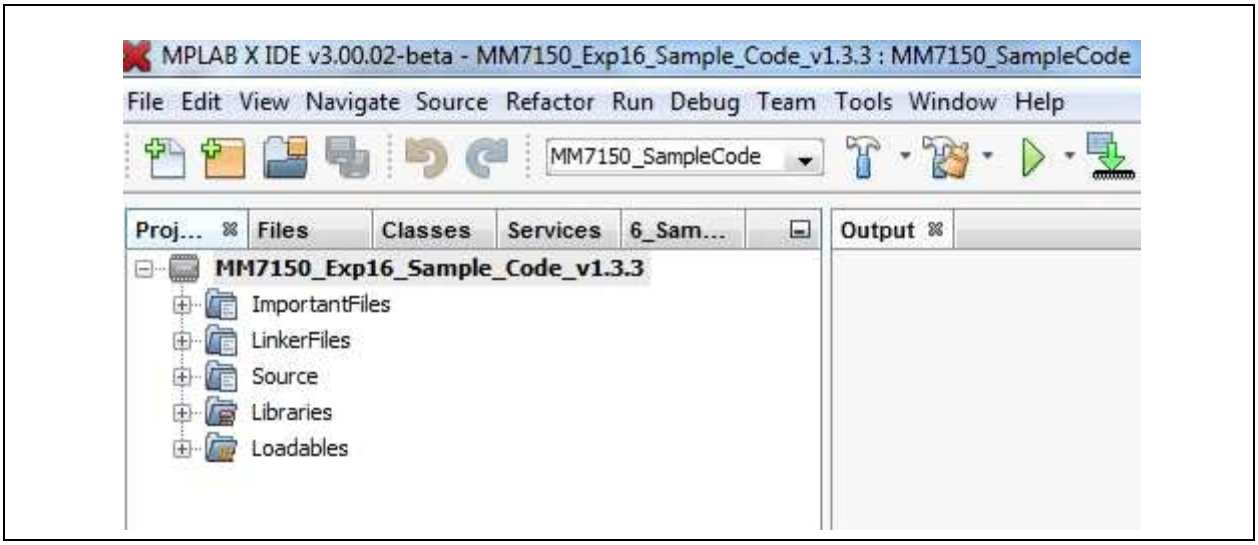
- File->Open Project Navigate to project directory and select *Open Project* as shown in Figure 2-2.

FIGURE 2-2: OPEN PROJECT



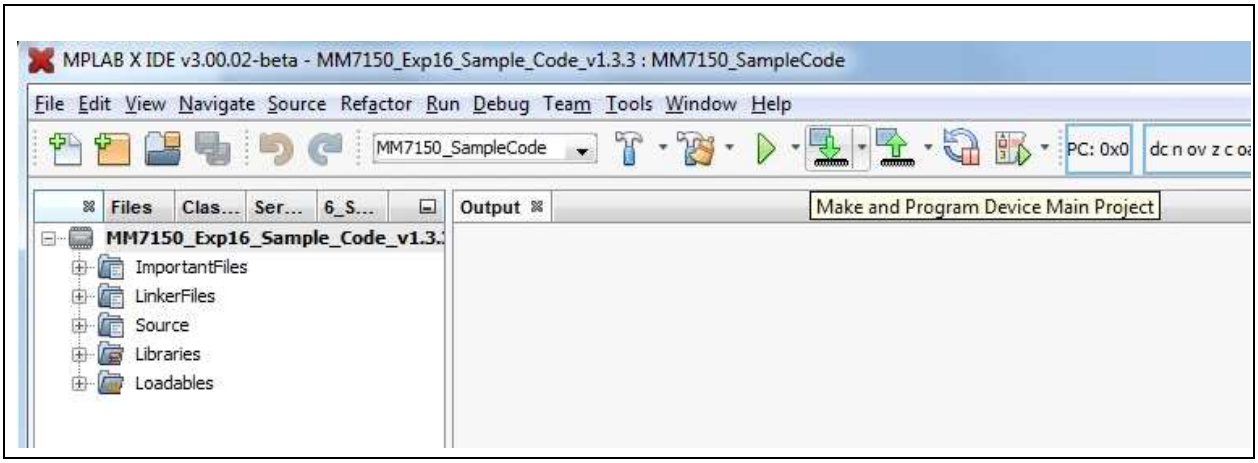
- Motion Demo Project Loaded as shown in Figure 2-3:

FIGURE 2-3: PROJECT IS OPENED



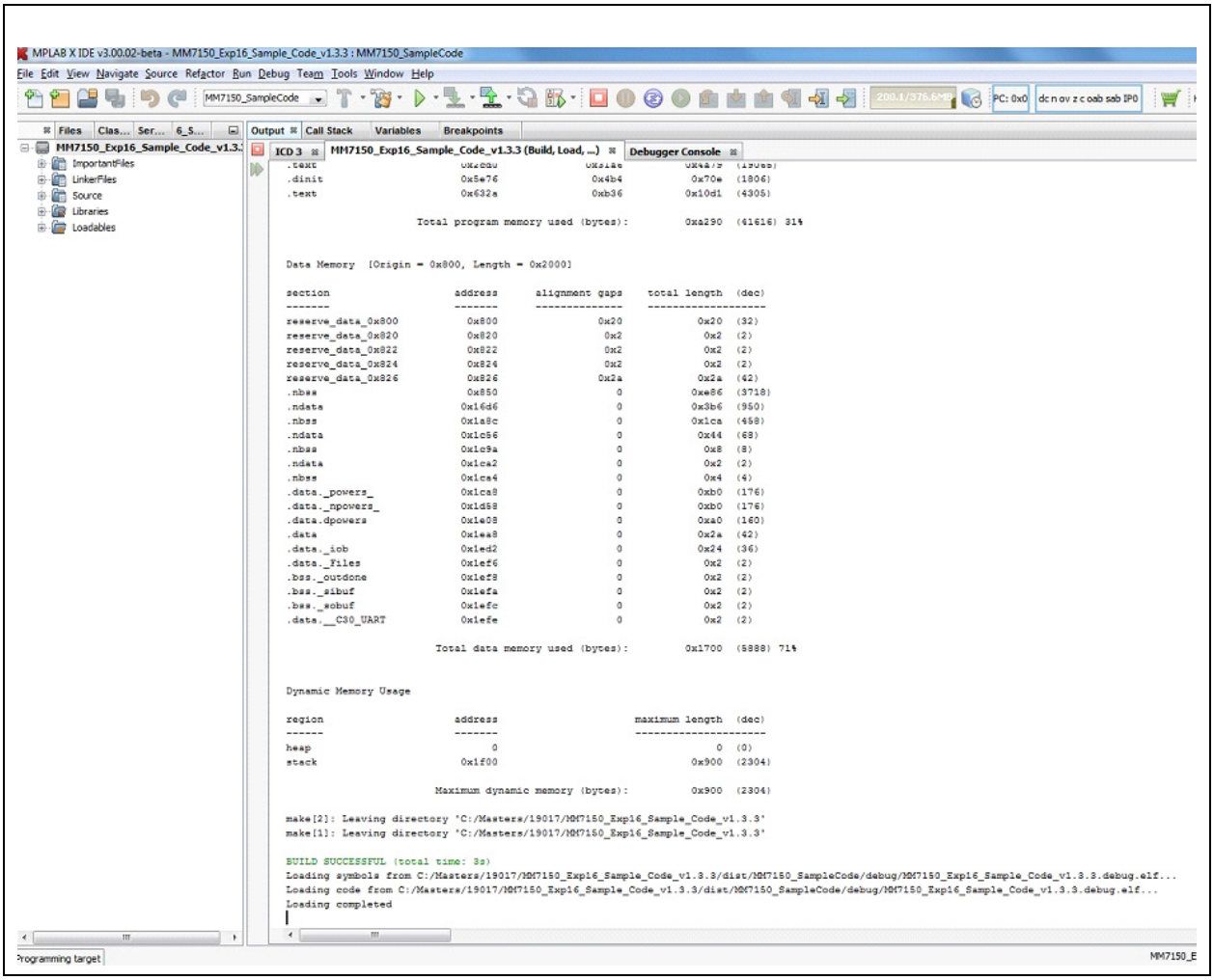
- With Explorer 16 power applied, make the project and download to Explorer 16 flash as shown in Figure 2-4:

FIGURE 2-4: SELECT DOWNLOAD OPTION



- Output screen during build process as shown in Figure 2-5:

FIGURE 2-5: BUILD PROCESS OUTPUT



Chapter 3. Demo Setup

3.1 RUNNING THE MOTION DEMO

Note: Using a debugger will necessitate cycling power to the connected MM7150-PICTAIL to reset its onboard EC (embedded controller). The easiest way to accomplish this while debugging code is to remove/install power to the Explorer 16 Development board with the MM7150-PICTAIL installed in J5 header. DO NOT attempt to unplug the MM7150-PICTAIL while power is applied to it through its connection to the Explorer 16 Development board. This can cause a power spike to the MM7150-PICTAIL and cause it to become inoperative.

Once the program has been built and downloaded/programmed successfully to Explorer 16 Flash, the user should observe a sequence of LED flashes on the Explorer 16 board's LED panel.

The user should then observe the following message on the Explorer 16 board's LCD screen:

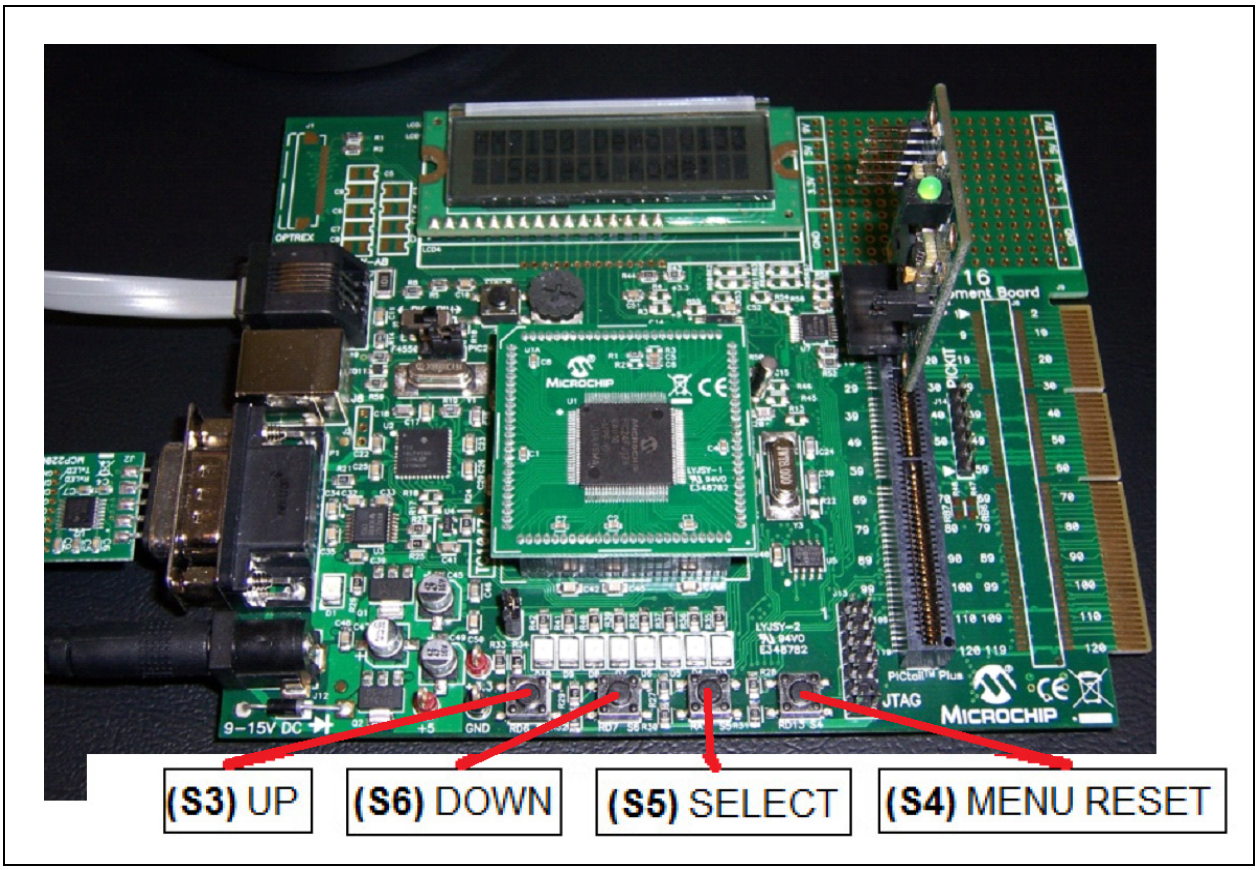
MM7150 Demo v133
Select mode:

Additionally the following message will appear in the serial terminal window on the connected computer:

Microchip Motion Module Demo: MM7150 + Explorer 16 Board v1.3.3
Select mode:

Once this message has been displayed, the user can begin navigating the user menu using the Explorer 16 push buttons (S3/S6/S5/S4). The buttons are coded as follows:

FIGURE 3-1: MM7150-PICTAIL ON EXP16 OVERVIEW

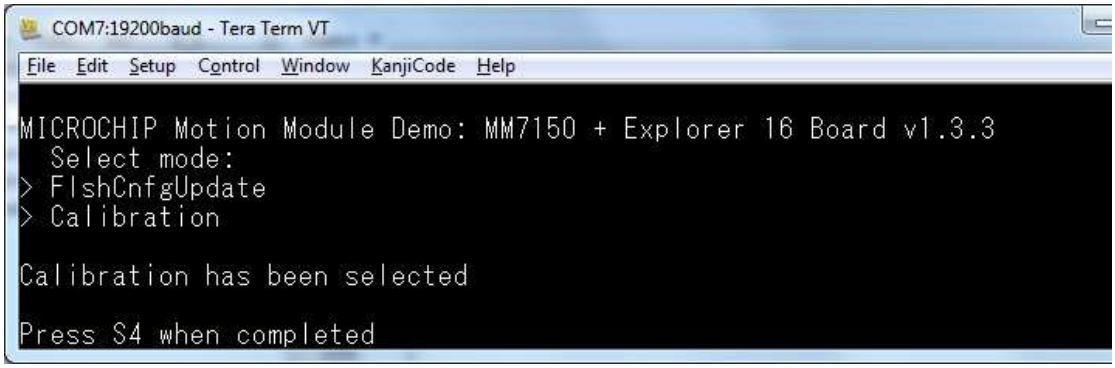


As the UP/DOWN buttons are pressed, the Explorer 16 LCD screen will refresh and change the position of the selection cursor (">") to a list of available sensor types. The output to the serial monitor will also change to indicate the current sensor type which can be selected by pressing the (S5) SELECT button. Once the user selects a sensor from the menu, the sensor data output will be displayed and updated on both the LCD and serial monitor.

3.2 CALIBRATING SENSORS

In order for the sensors to function properly and indicate accurate data the user will need to calibrate the MM7150 each time power has been removed. This calibration is done by selecting the "Calibration" mode as shown in Figure 3-2, holding the MM7150-PICTAIL which is attached via an extension cable (see *Appendix C. "Extension Cable for Explorer 16"* for more information), or if not using an extension cable, by holding the entire Explorer 16 board with MM7150-PICTAIL installed, and moving it through space a few times (~ 5 seconds) to make an "infinity" symbol or a "figure 8".

FIGURE 3-2: CALIBRATION MODE



3.3 SENSOR DATA DISPLAY

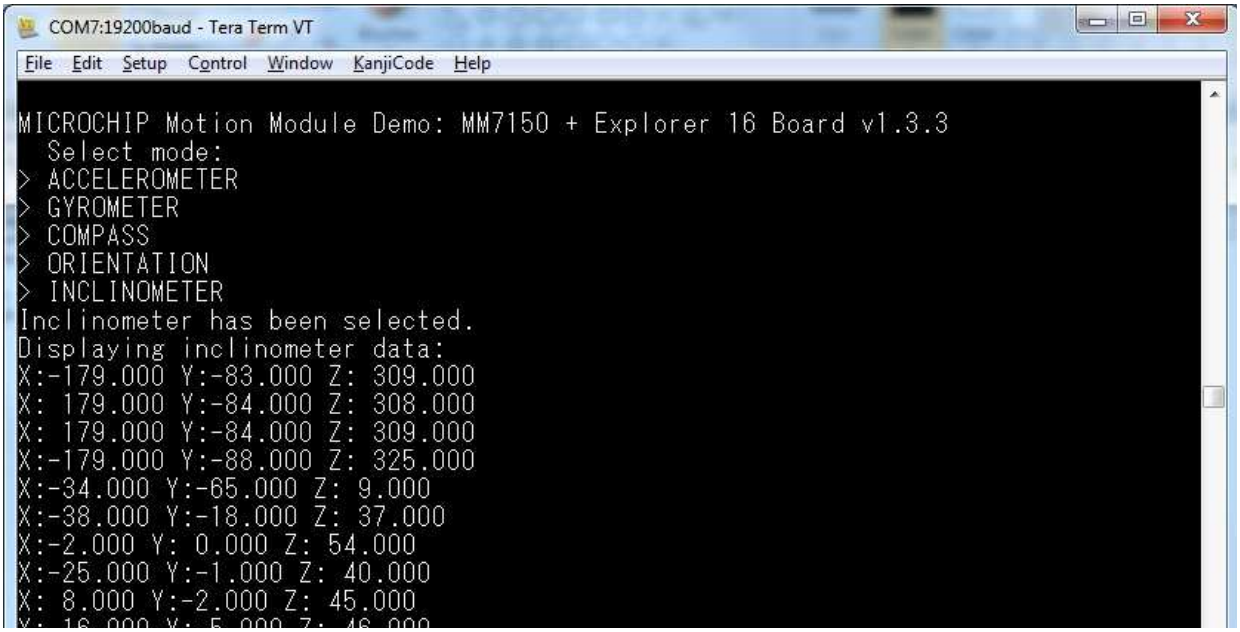
Once calibrated the active sensors on the MM7150 motion module will send updates to the PIC24 on the Explorer 16 board running the application program via I^2C in the form of HID packets including all relevant dimensions of data to be retrieved from the device. These sensor readings will be displayed on the LCD (as well as the COM port in a 'linear' formatting):

1D data:	*79.0*			
3D data:	*X: 50.3*	*Y: 75.6*	*Z: -32.9*	
4D data:	*X: 1.021*	*Y:-.642*	*Z:-.458*	*W: .348*

Note: Significant digits will vary based on resolution of specific sensor. This resolution can be determined by the *unit exponent scaling factor.* Serial data will always be displayed to 3 significant digits.

Sample output to COM port running Tera Term serial emulator:

FIGURE 3-3: DISPLAY INCLINOMETER DATA



The sensor data is updated to the display every time a data register has changed since the previous update.

3.4 SLEEP/WAKE

The MM7150 motion module can be set to enter deep sleep to achieve its lowest power consumption. In the Explorer 16 sample code this can be accomplished by selecting the SLEEP command from the main menu. The Explorer 16 host will send a POWER_OFF command through the I^2C interface. As a result of this SLEEP command the MM7150 motion coprocessor is halted and the I^2C interface is stopped.

Select the WAKE command from the Explorer 16 main menu to wake the MM7150 motion module. This command will toggle the HOST_TO_SH_WAKE signal to alert the MM7150 to wake, send the POWER_ON command via I^2C interface, and wait the required time to allow the MM7150 to fully wake and allow sensor activity to resume.

The sleep/wake process requires that certain timing constraints must be observed (shown below in Figure 3-1).

TABLE 3-1: SLEEP / WAKE TIMING CONSTRAINTS

		Delay period	Reason
1	Required delay between sending the SLEEP command & toggling WAKE	70ms	This is required for the coefficient write in flash during D3 plus other housekeeping activities to go into D3 state
2	Required delay between toggling (3 µs min) the wake signal and sending power ON command	11ms	This is required for clock source switching after coming out of D3 state
3	Required delay between D3 wake and enumeration sequence start	30ms	This is required for sensor initialization after D3 state

3.5 FLASH UPDATE

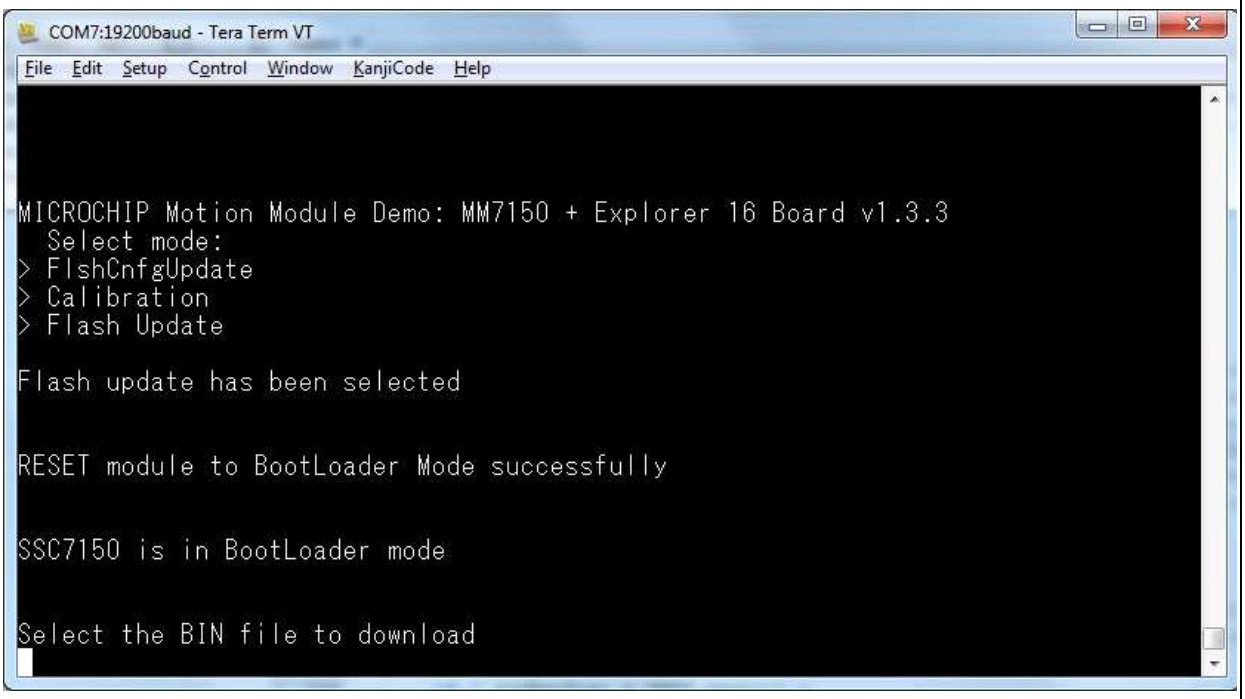
The MM7150 motion module firmware can be updated with the appropriate binary image (please refer to *Section 2.1 "Software/Firmware requirements"* for more information) by selecting Flash Update from the Explorer 16 main menu. The Explorer 16 sample code will reset the MM7150 module into a state able to accept the new binary image, download and CRC-check a valid binary image, program new MM7150 firmware binary via I^2C interface, and finally perform image verification.

> *Note:* The Explorer 16's UART connection will be used to download the flash update binary and, as such, must be connected to a HOST PC running a terminal emulator (such as *Tera Term* as described in *Section 1.2 "Preparing the Explorer 16 Development Board"*).

3.5.1 Flash Update command

Figure 3-4 shows the Flash Update Command from the Exp 16 sample code select menu.

FIGURE 3-4: FLASH UPDATE COMMAND



Select "*File->Send file…*" from Tera Term utility (NOTE: Select *Binary Option*).

FIGURE 3-5: SELECT BINARY FILE

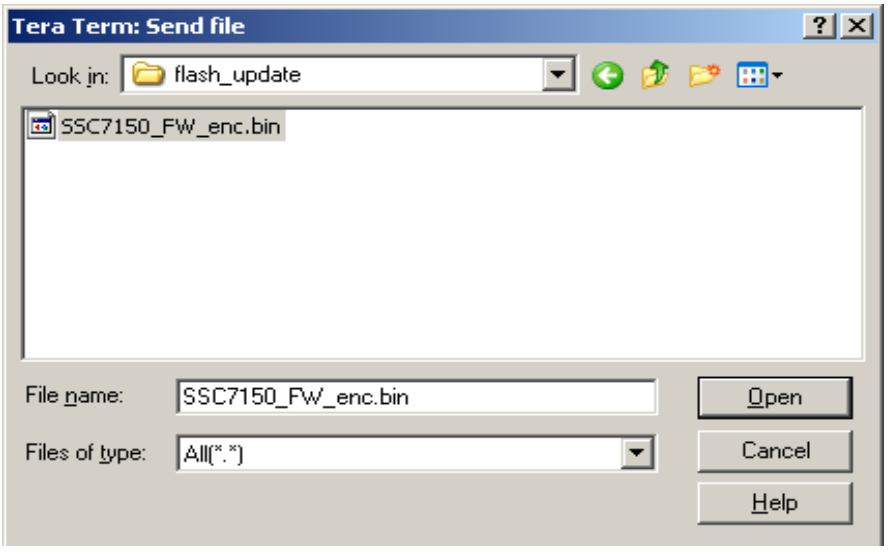


FIGURE 3-6: DOWNLOADING BINARY IMAGE

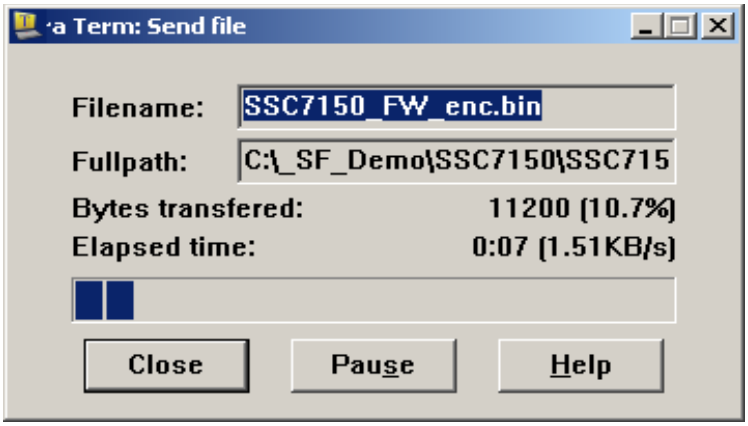
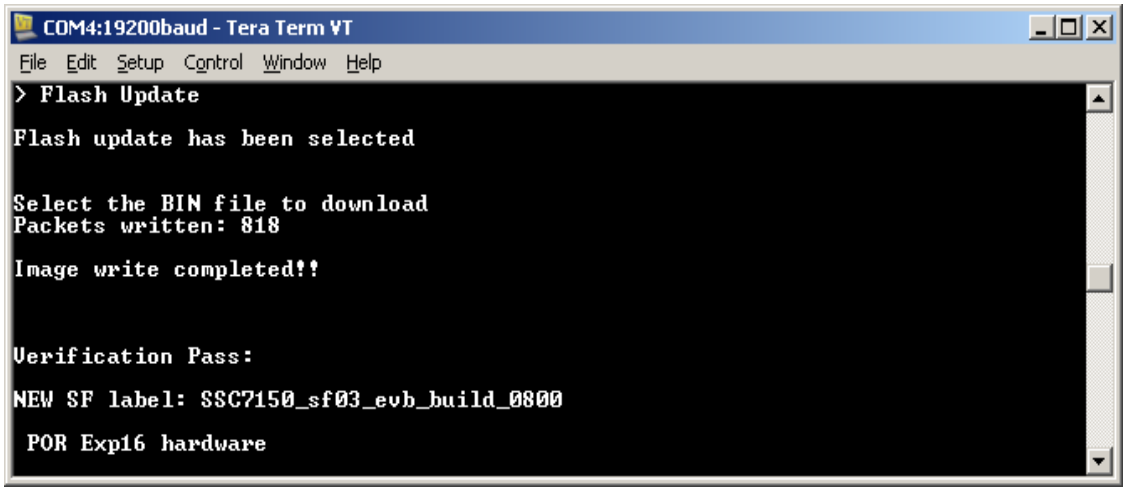


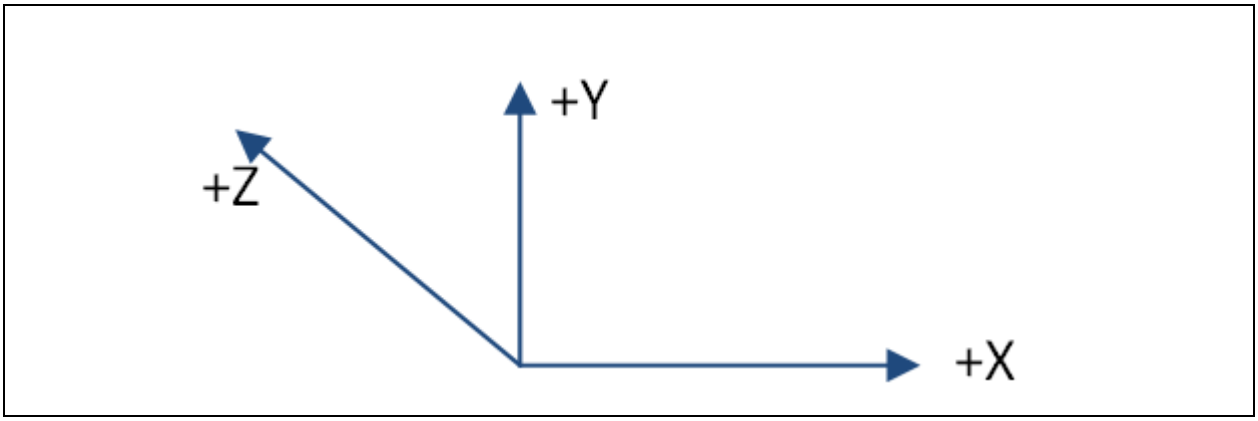
FIGURE 3-7: FLASH UPDATE SUCCESSFUL COMPLETION



Following successful completion of the flash update procedure (or if *any* error is encountered), the Explorer 16 must be power cycled.

3.5.2 Flash Configuration Update Command

The X/Y/Z orientation of the MM7150 module on the customer's design can be modified and saved to the MM7150's flash. The default orientation of the A/M/G sensors of MM7150 (placed horizontally) is:



For this case, the inputs to the motion algorithm (running in MM7150 firmware) can be represented by the following 3x3 matrix (Accelerometer for example):

Matrix[3, 3] = [A00, A01, A02; A10, A11, A12; A20, A21, A22];

where Axx could be 0, 1, or -1.

So, for the horizontal orientation shown above and assuming that X/Y/Z are data read from the hardware sensor and X'/Y'/Z' are data input to the motion algorithm:

X' = A00*x + A01*y + A02*z

Y' = A10*x + A11*y + A12*z

Z' = A20*x + A21*y + A22*z

Since the input matrix corresponds one to one in X/Y/Z to the output matrix, we obtain the following:

X' = 1*x + 0*y + 0*z

Y' = 0*x + 1*y + 0*z

Z' = 0*x + 0*y + 1*z

i.e. Resulting matrix[3, 3] = [1,0,0; 0,1,0; 0,0,1;]

This orientation configuration data must be sent to the appropriate sector in the MM7150 firmware in the following format:

TABLE 3-2: CONFIGURATION DATA FORMAT FOR HORIZONTAL

Name	Values
Header	A5A5A5A5
Serial_num	00000000
ACC_matrix	010000000100000001
MAG_matrix	010000000100000001
GYR_matrix	010000000100000001
Reserved	00
ACC_config	01010110
MAG_config	02010112
GYR_config	03010168
Reserved	04010144
Reserved	05010177
Reserved	06000000
Reserved	07000000
Reserved	08000000
Reserved	09000000
Reserved	0A000000
Chk_sum	23040000 (see Note 1)
Padded	FF's for 128 byte packet

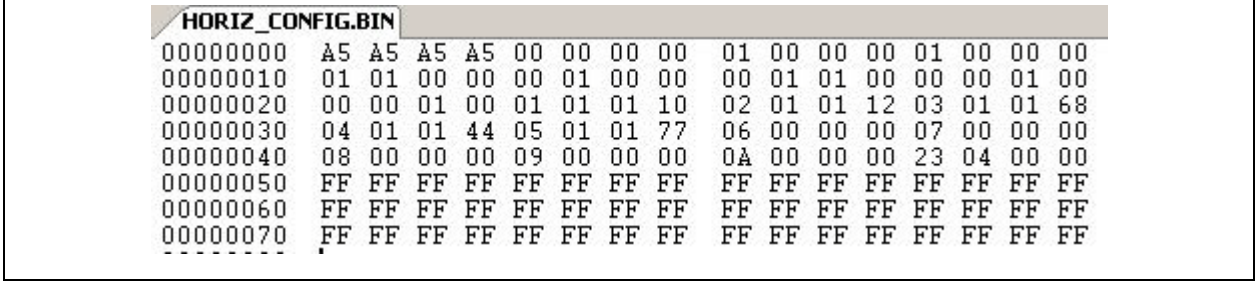
Note 1: Check sum will be calculated by the sample code flash configuration update command, as a result this field will be ignored and can be: 00000000.

For example, the XYZ matrix result for the accelerometer (acc_matrix) takes the form of:

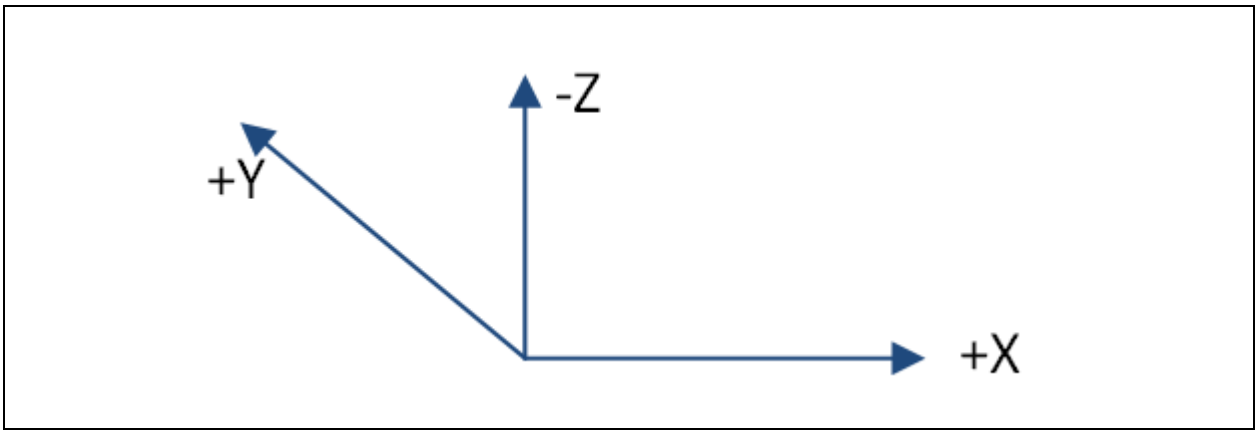
ACC_matrix = 01 00 00 *(X=1,0,0)* 00 01 00 *(Y=0,1,0)* 00 00 01 *(Z=0,0,1)*

For MM7150_Exp16_Sample_Code_v1.3.3, the flash configuration data needs to be in the following *binary* file format (derived from the above text file):

FIGURE 3-8: CONFIGURATION DATA BINARY FOR HORIZONTAL



Similarly, for the A/M/G sensors of the MM7150 placed vertically (such as when plugged into the Explorer 16 card):



For the vertical orientation shown above and assuming that X/Y/Z are data read from the hardware sensor and X'/Y'/Z' are data input to the motion algorithm with respect to the default X/Y/Z settings:

X' = A00*x + A01*y + A02*z

Y' = A10*x + A11*y + A12*z

Z' = A20*x + A21*y + A22*z

Since, for this case, the input matrix does not correspond one to one in X/Y/Z to the output matrix, we obtain the following translations:

X' = 1*x + 0*y + 0*z

Y' = 0*x + 0*y - 1*z

Z' = 0*x + 1*y + 0*z

i.e. Resulting matrix[3, 3] = [1,0,0; 0,0,-1; 0,1,0;]

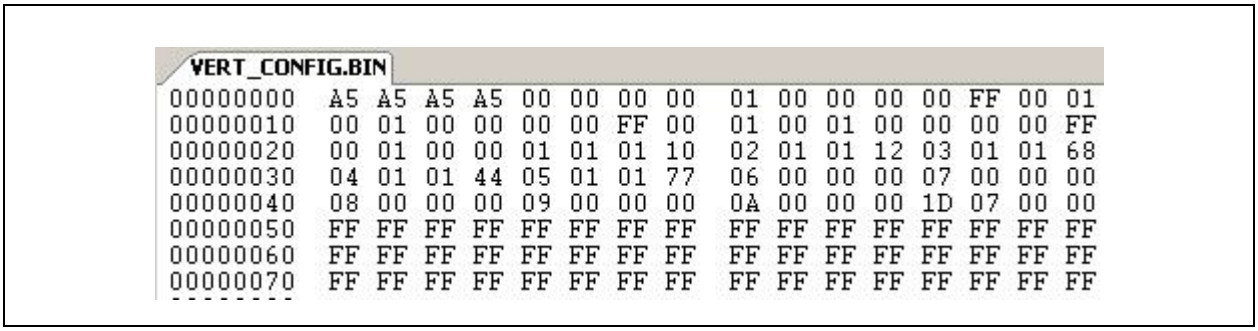
This vertical configuration data can be sent to the appropriate sector in the MM7150 firmware in the following format:

TABLE 3-3: CONFIGURATION DATA FORMAT FOR VERTICAL

Name	Values
Header	A5A5A5A5
Serial_num	00000000
ACC_matrix	0100000000FF000100
MAG_matrix	0100000000FF000100
GYR_matrix	0100000000FF000100
Reserved	00
ACC_config	01010110
MAG_config	02010112
GYR_config	03010168
Reserved	04010144
Reserved	05010177
Reserved	06000000
Reserved	07000000
Reserved	08000000
Reserved	09000000
Reserved	0A000000
Chk_sum	1D070000 (see Note 1)
Padded	FF's for 128 byte package

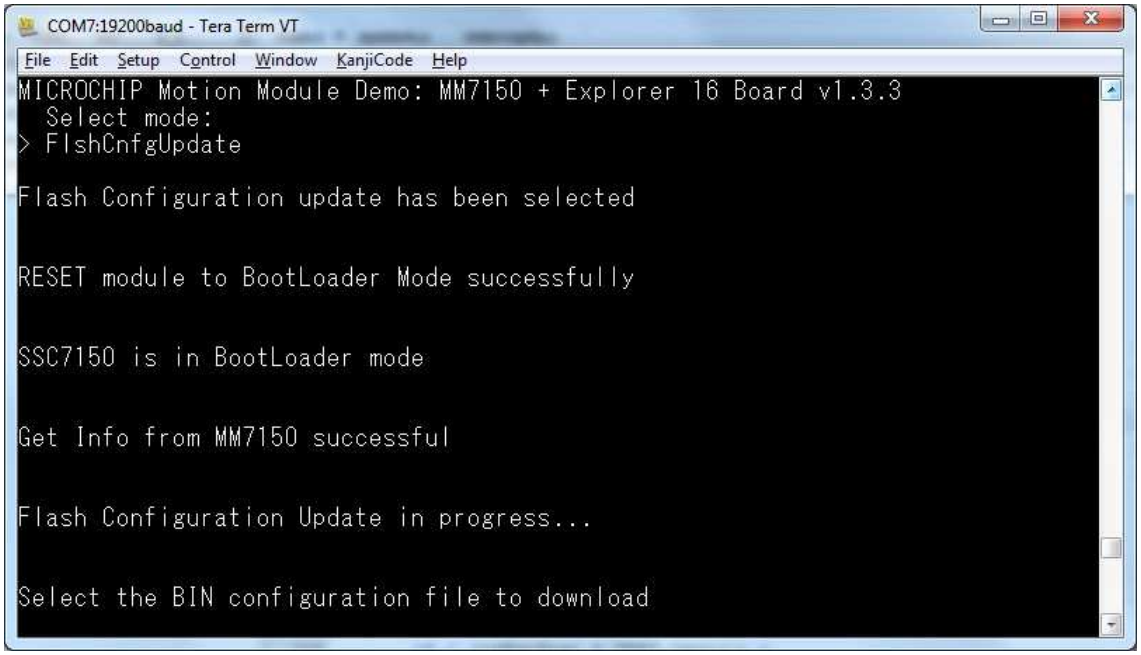
For MM7150_Exp16_Sample_Code_v1.3.3 the flash configuration data must adhere to the following *binary* file format:

FIGURE 3-9: CONFIGURATION DATA BINARY FOR VERTICAL



Using the sample code's Flash Configuration Update mode:

FIGURE 3-10: FLASH CONFIGURATION DATA MODE



Select "File->Send file..." from TeraTerm utility: (NOTE: Select *Binary Option*).

FIGURE 3-11: SELECT BINARY FILE