MM7150-PICTAIL Motion Module PICtail on Explorer 16 Development Board User's Guide

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Signed for and on behalf of Microchip Technology Inc. at Chandler, Arizona, USA

Derek Carlson
VP Development Tools

12-Sep-14
Date

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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 & it's MM7150-PICTAIL PICtail Daughter Card with the Explorer 16 development board (Part #: 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 Motion Module PICtail with Explorer 16 Development Board to perform the demo and 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 PICtail adapter reference schematic & bill of materials information.

AUDIENCE

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

REFERENCE DOCUMENTS

- DS00001885A - SSC7150 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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- **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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Technical support is available through the web site at:
http://www.microchip.com/support

DOCUMENT REVISION HISTORY

Revision	Section/Figure/Entry	Correction
DS50002322B (02-18-15)	• Added section 3.4 for Sleep/Wake feature • Added section 3.5 for Flash Update feature, updated 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: USB-to-Serial Adapter from Staples #18762* *http://www.staples.com/Staples-USB-to-Serial-Adapter/product_837560*

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

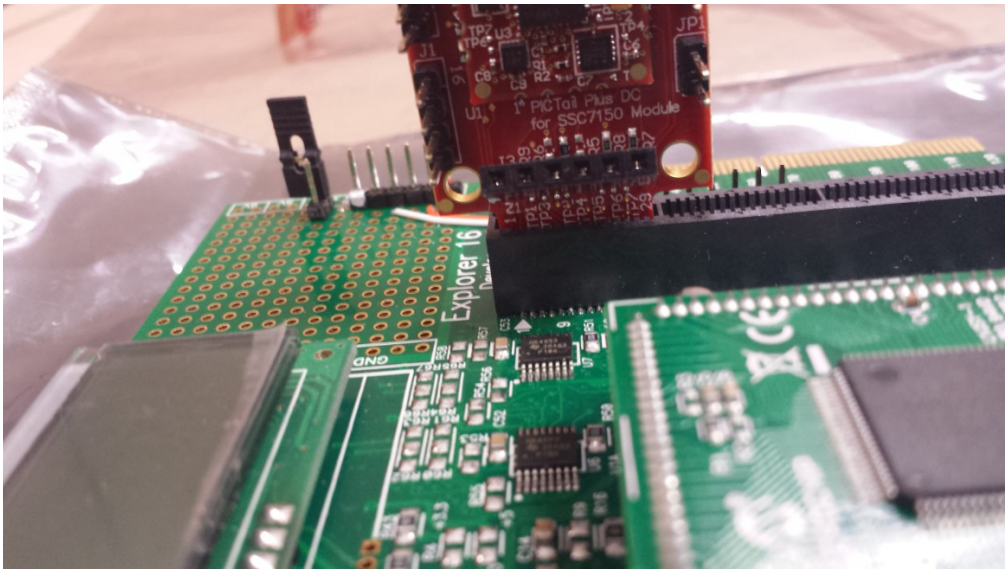
TABLE-1: CONNECTION SUMMARY BETWEEN MM7150-PICTAIL TO EXP16 BOARD

Signal Name	MM7150 Module Pin	Exp16 J6 Header Name	Exp 16 J6 Header Pin
+3.3V	7	+3.3V	21
GND	8	GND	9
HIDI2C_HOST_INT	4	RE8/INT1	18
HIDI2C_HOST_DAT	16	RG3/SDA1	8
HIDI2C_HOST_CLK	15	RG2/SCL1	6
HOST_TO_SH_WAKE	1	RE9	17

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.

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.

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



Chapter 2. Software/Firmware Setup

2.1 SOFTWARE/FIRMWARE REQUIREMENTS

- Microchip MPLABX IDE v2.06 or later
- Microchip XC16 Compiler v1.24 or later
- Explorer 16 Host Sample Code Firmware
  - Version v1.3.2 or later (older version may not support some functions like flash update and wake/sleep)

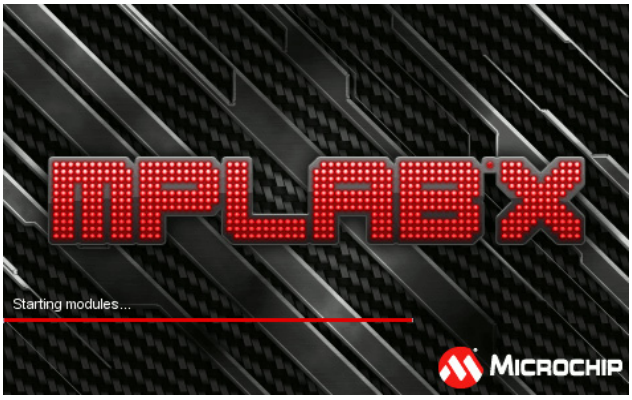
> **Note:** The latest sample code is available at *www.microchip.com/motion* or please contact your Microchip representative for more information.

- SSC7150 Motion Coprocessor Firmware
  - The firmware can be updated using the flash update feature as described in **Section 3.4 "Flash Update"**
  - The firmware binary object code is encrypted and the update process is secured.

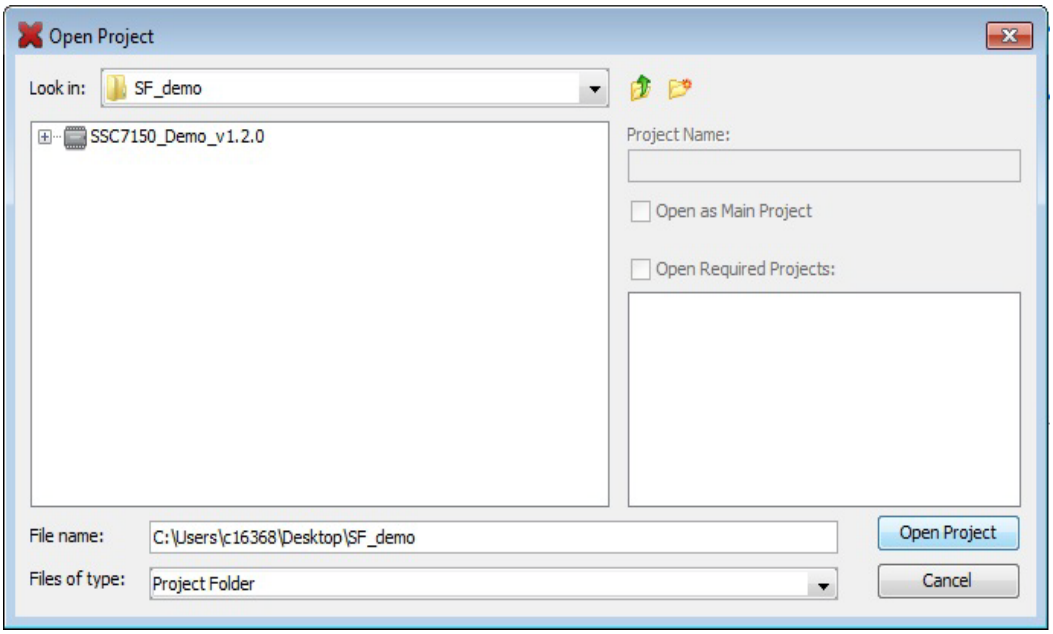
> **Note:** The latest firmware binary file is available at *www.microchip.com/motion* or please contact your Microchip representative for more information.

2.2 MPLABX PROJECT:

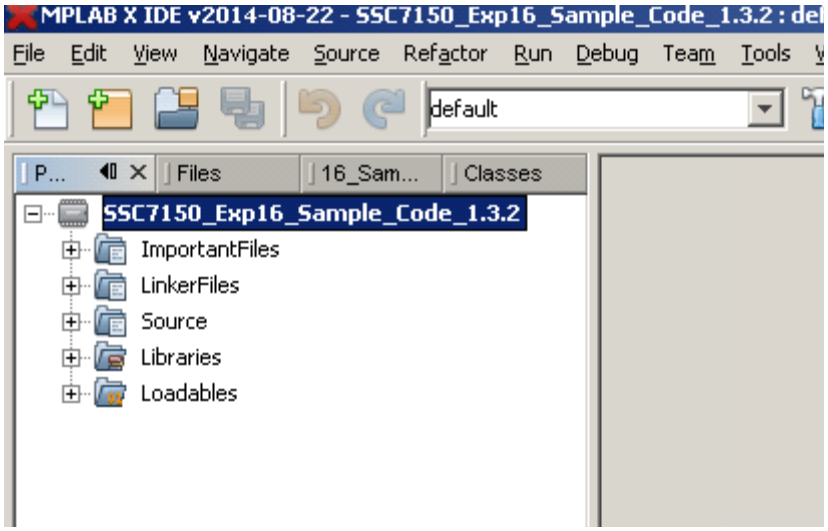
- Start MPLABX IDE



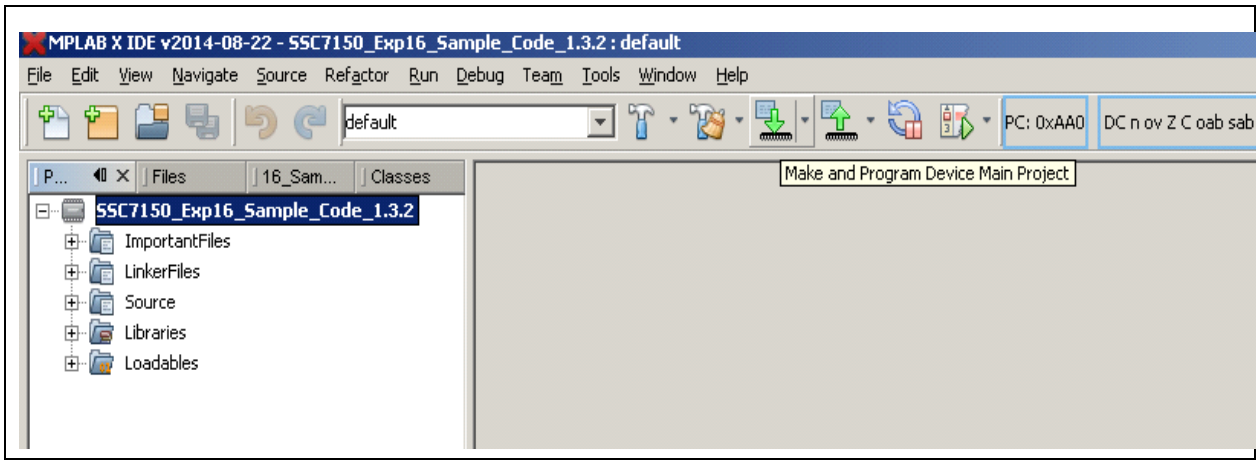
- File->Open Project Navigate to project directory and select *Open Project*



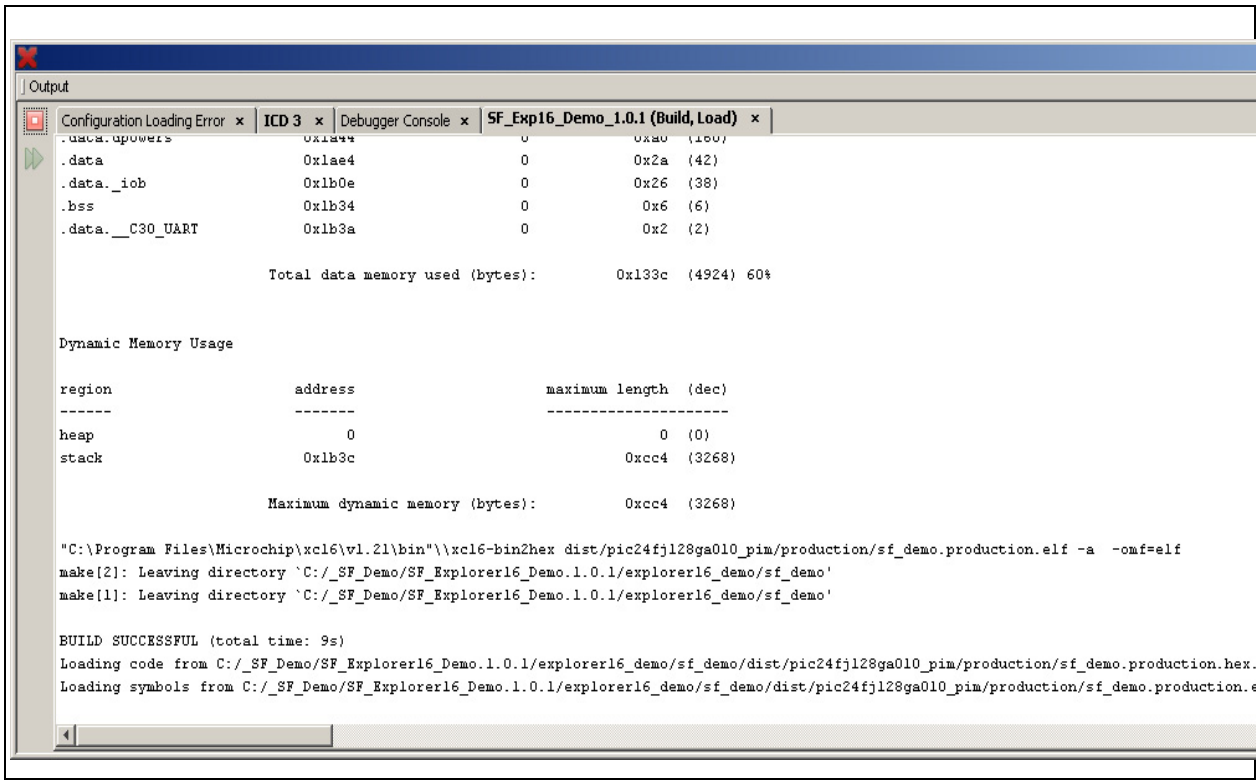
- Motion Demo Project Loaded:



- With Explorer 16 power applied, to make the project and download to Explorer 16 flash, select:



- Output screen during build process:



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.

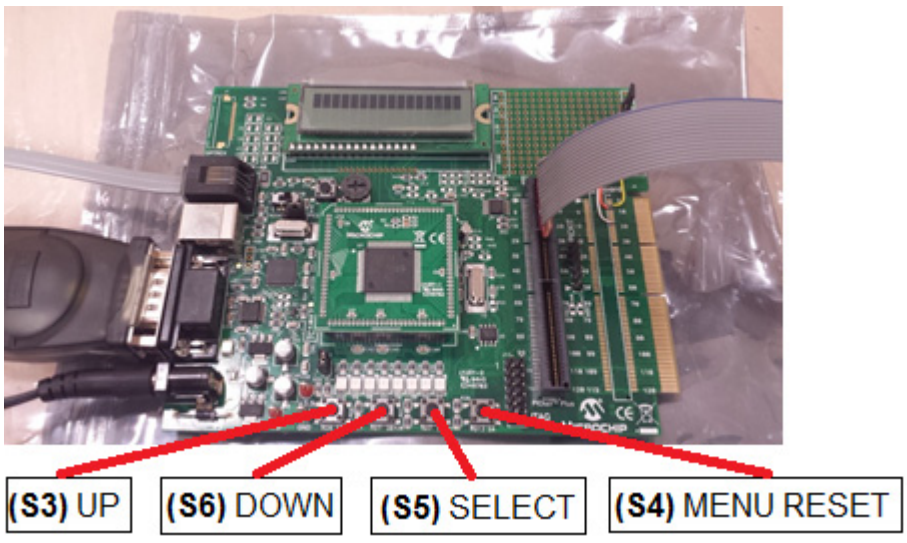
The user should then observe the following message on the Explorer 16 board's LCD screen:

SF demo: SSC7150
Select sensor:

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

Microchip Sensor Fusion Demo: SSC7150 + Explorer 16 Board v1.3.2
Select Sensor:

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:



As the UP/DOWN buttons are pressed, the Explorer 16 LCD screen will refresh and change the position of the selection cursor (">") in 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.

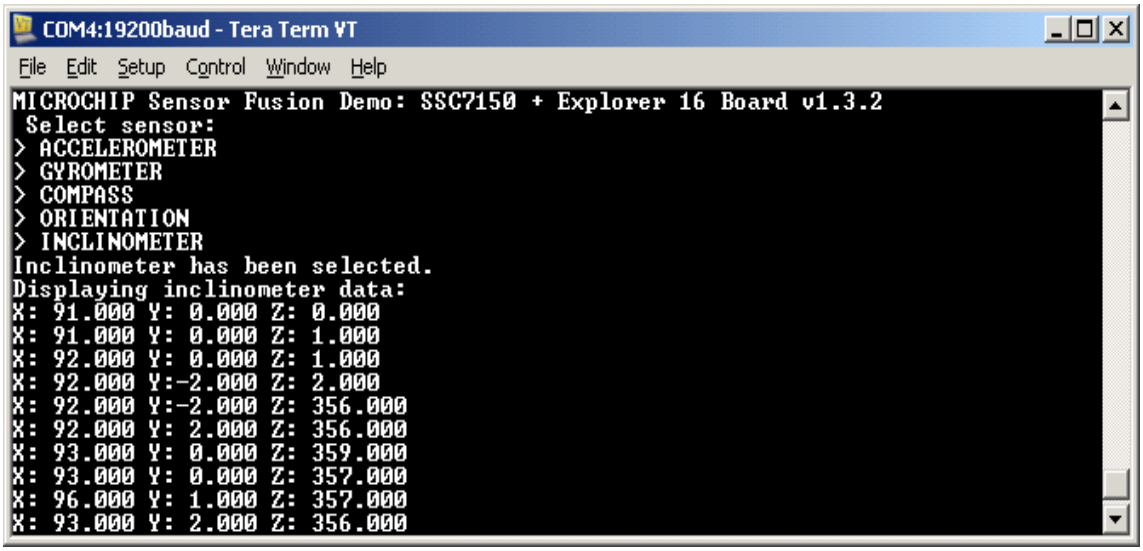
3.2 SENSOR DATA DISPLAY

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:



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

3.3 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 Table-2:).

TABLE-2: 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

3.4 FLASH UPDATE

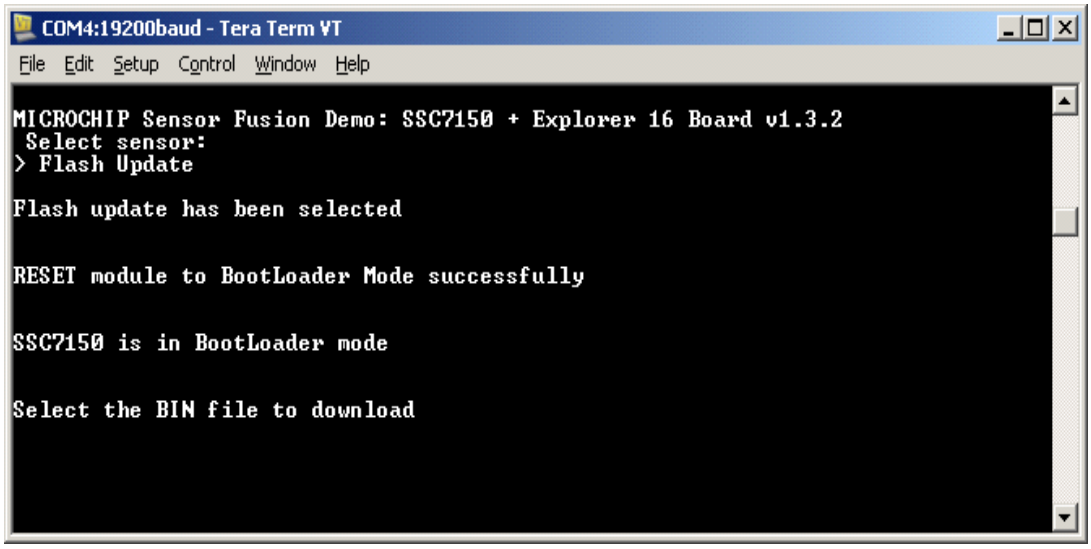
The MM7150 motion module firmware can be updated with the appropriate binary image (please refer to **Section 2.1 "Software/Firmware requirements"** for more information) by selecting Flash Update from the Explorer 16 main menu. The Explorer 16 sample code will reset the MM7150 module into a state able 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"*)**.

3.4.1 Flash Update command

Figure-2: shows the Flash Update Command from the Exp 16 sample code select menu.

FIGURE-2: FLASH UPDATE COMMAND



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

FIGURE-3: SELECT BINARY FILE

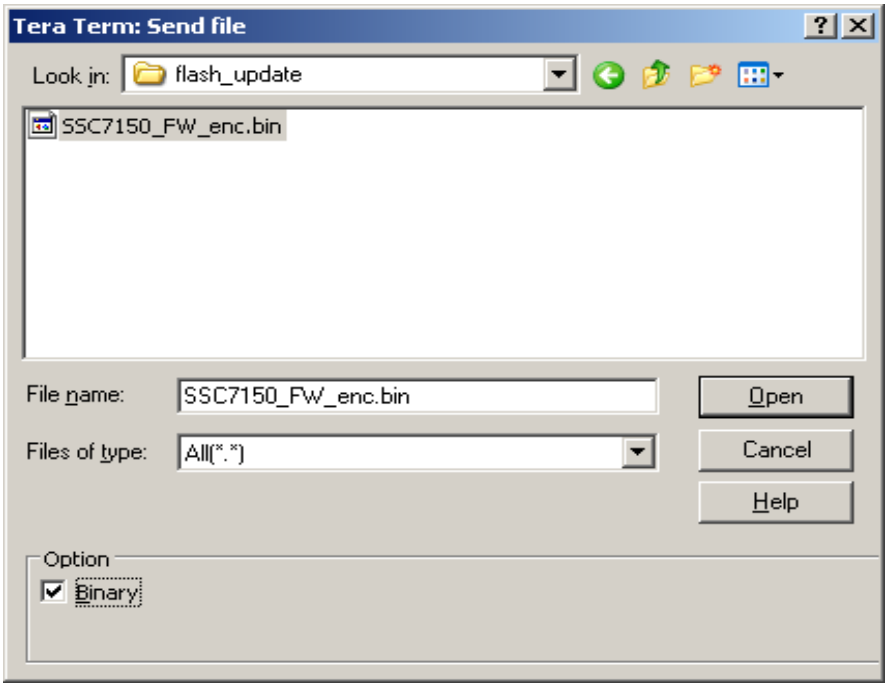


FIGURE-4: DOWNLOADING BINARY IMAGE

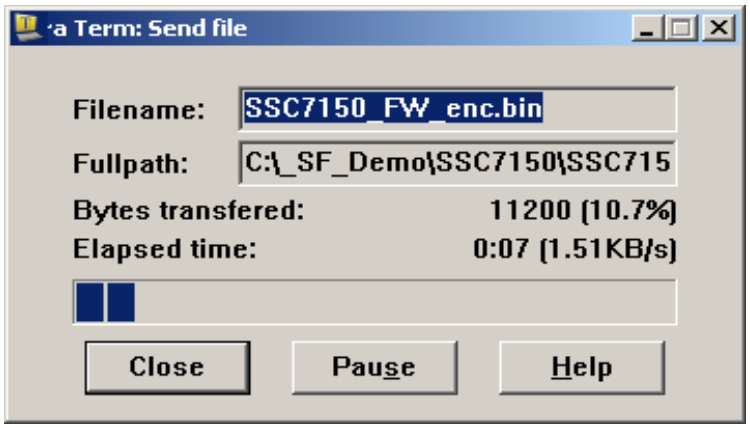
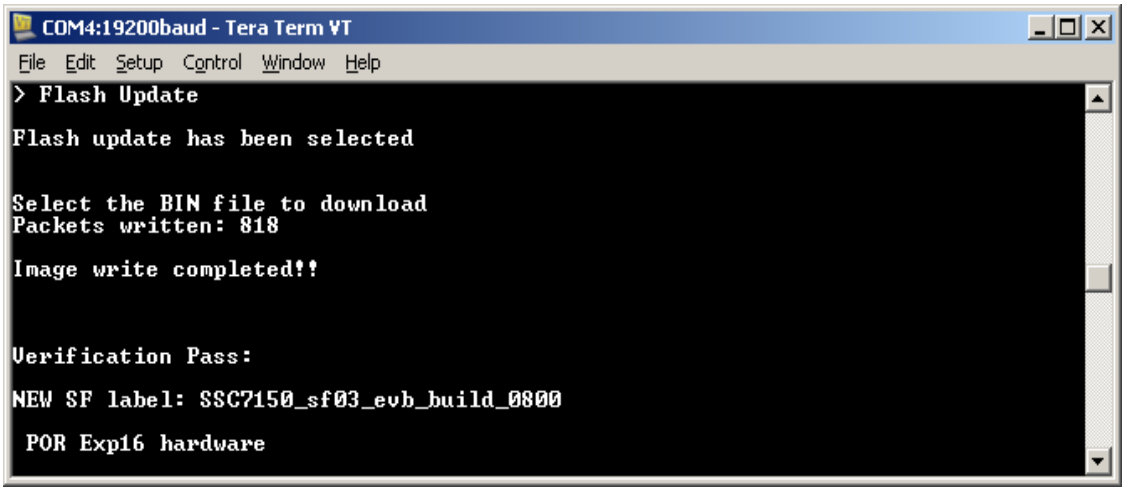


FIGURE-5: FLASH UPDATE SUCCESSFUL COMPLETION



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

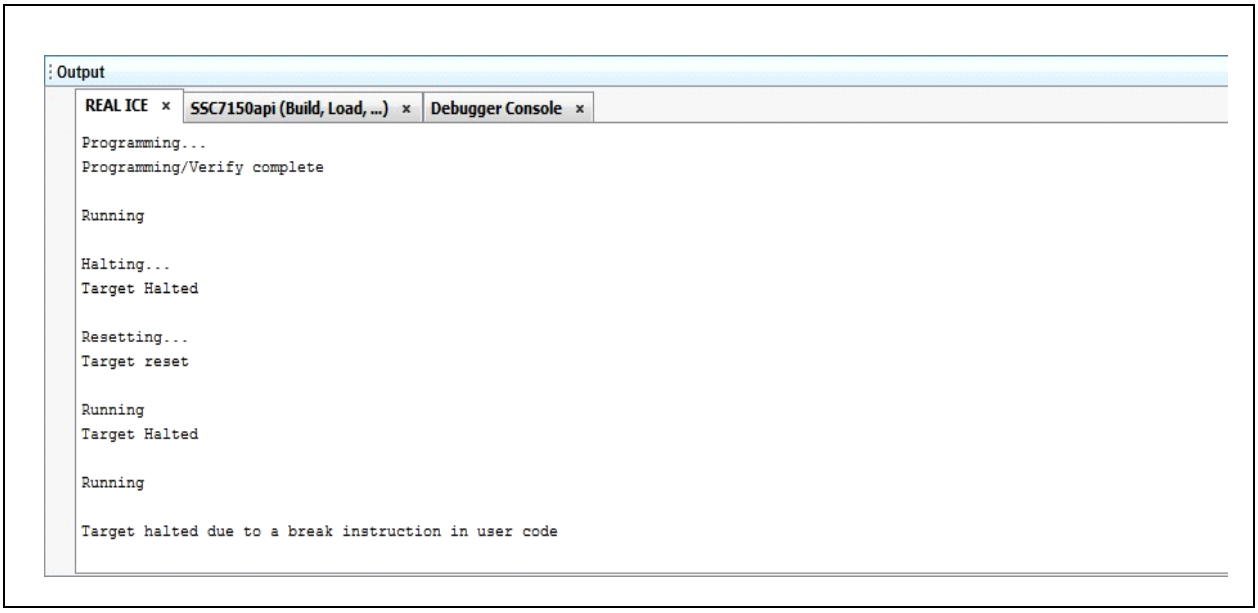
Chapter 4. Troubleshooting

This chapter describes troubleshooting potential issues and fixes.

4.1 FAILURE TO DISPLAY WELCOME SCREEN

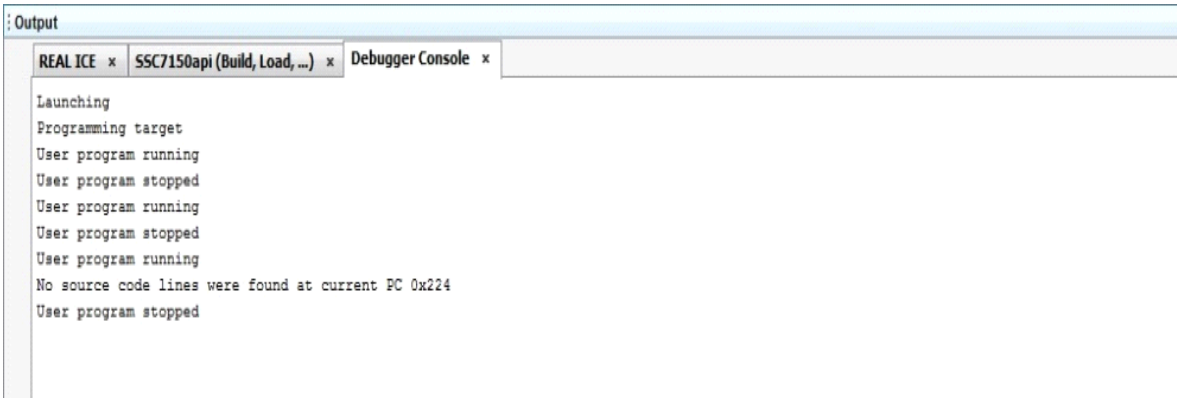
If the welcome message fails to display on the Explorer 16 LCD screen and error messages depicted below appear in the debugger's output (using Microchip ICD3 or REAL ICE debugger for instance), the most likely cause is a failure to disconnect and reconnect power to the MM7150-PICTAIL. This is accomplished by disconnecting and reconnecting power to the Explorer 16 board before restarting the demo. This process serves as a 'hard reset' for the SSC7150 on the MM7150-PICTAIL, allowing I^2C communication to reinitialize and restart.

FIGURE-6: ERROR MESSAGE IN DEBUGGER'S TAB



Note: If user is running on a different debugger (eg: ICD3, ICD2 etc.) the message would appear in that debugger's output tab.

FIGURE-7: ERROR MESSAGE IN DEBUGGER CONSOLE TAB. THIS WINDOW IS UNIVERSAL FOR ALL DEBUGGERS.



4.2 ERROR HANDLING

4.2.1 General Error Handling for VREG functions

> Note: Please refer to "*DS00001873A - Host API Design for MM7150-PICTAIL Motion Module Application Note*" for more information regarding virtual registers (VREG) defined and used in the sample code.

VREG functions which fail to complete due to certain hardware events may display error information via error handling output on the Explorer 16 board's LCD screen and on the serial terminal window on the connected computer.

For example, in the case of a VREG *Read* operation of *register 16h* which encounters a problem while reading data in response to receiving a *HIDI2C_HOST_INT* (which indicates that a MM7150 sensor has data available) the following will be displayed on the Explorer 16 board's LCD:

```
VRRd:16 err=0x31
Push S5 to cont
```

where:

VRRd:16 - Attempting a VREG Read operation on register 16h (VREG ACXD register)

err=0x31 – Error code generated *(see error code definitions in* Section 4.2.3*)*

Push S5 to cont - Press button S5 to attempt to recover from the reported error

The same error is displayed on the serial terminal window on the connected computer:

FIGURE-8: SERIAL TERMINAL GENERAL ERROR HANDLING DISPLAY

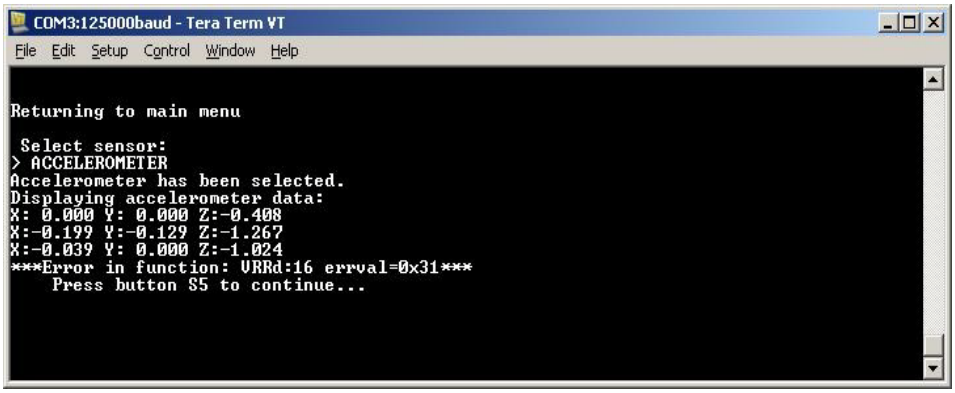


TABLE-3: GENERAL ERROR HANDLER FUNCTION ABBREVIATION

Function	Error Handler Output Abbreviation
VREG_init( )	Vini
HOST_SF_LIB_VREG_read( )	VRRd
HOST_SF_LIB_VREG_write ( )	VRWr
I2cIO( )	i2c

4.2.2 I²C Error Handling

Upper level functions which employ I²C function calls for the Explorer 16 board's PIC24 to MM7150 interface that fail to complete will display error information. The I²C error handling display is output on the Explorer 16 board's LCD screen and on the serial terminal window on the connected computer.

> Note: Most, if not all, I²C errors are hardware dependent. As this sample code is specific to the PIC24 on the Explorer 16 board, I²C errors are simply flagged as an error to illustrate where the issue was encountered. For this demo, in the rare event that a fully functional I²C interface encounters an error, the error "recovery" method will require resetting the Explorer 16 board and, hence, the connected MM7150-PICTAIL.

For example, in the case of an i2cIO operation which encounters an issue, wherein the MM7150 fails to ACK properly, the following will be displayed on the Explorer 16 board's LCD:

```
i2c   error=0x29
POR Exp16 Board
```

where:

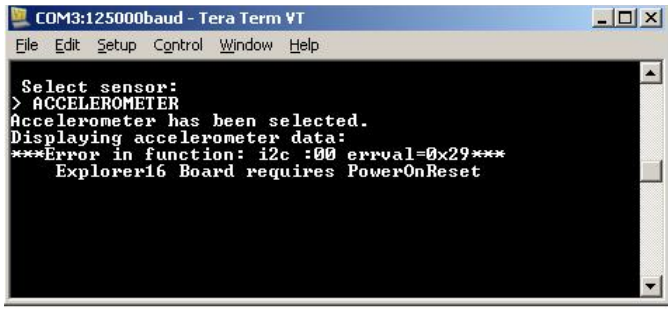
i2c - error occurred in i2cIO() function

error=0x29 – error code generated *(see error code definitions in* Section 4.2.3*)*

POR Exp16 Board - Power On Reset Explorer 16 board (and connected MM7150-PICTAIL)

The same error is displayed on the serial terminal window on the connected computer.

FIGURE-9: SERIAL TERMINAL I²C ERROR HANDLING DISPLAY



4.2.3 Error Definitions (*from source/headers/err.h*)

Error Value	Definition	Module/Type
0	SUCCESS	
10h	ID_FAIL	sf.c
11h	HID_DESC_FAIL	sf.c
12h	RPT_DESC_FAIL	sf.c
14h	REP_PARS_FAIL	sf.c
15h	NO_EOC_FAIL	sf.c
16h	GET_FEAT_FAIL	sf.c
17h	SET_FEAT_FAIL	sf.c
18h	RESET_FAIL	sf.c
19h	SET_RPT_FAIL	sf.c
1Ah	POWER_ON_FAIL	sf.c
1Bh	SLEEP_CMD_FAIL	sf.c
1Ch	HID_GET_RPT_INPT_FAIL	sf.c
1Dh	HID_GET_RPT_FEAT_FAIL	sf.c
1Eh	WAKE_CMD_FAIL	sf.c
21h	I2C_ERROR	i2cIO.c
22h	I2C_BUF_OVERFLO	i2cIO.c
23h	WRITE_COLL	i2cIO.c
24h	NOT_ACK	i2cIO.c
25h	BUS_COLL	i2cIO.c
26h	RX_OVRFLO	i2cIO.c
27h	HID_DESC_RET	i2CIO.c
28h	REP_DESC_RET	i2cIO.c
29h	I2C_TIMEOUT_ERR	i2cio.c
31h	HID_INT_FAIL	vregs.c
32h	VREG_ACCESS_ERR	vregs.c
33h	VREG_OFFSET_ERR	vregs.c
41h	FLSH_INFO_ERR	flash_update.c
42h	FLSH_WRITE_ERR	flash_update.c
43h	FLSH_VERIFY_ERR	flash_update.c
44h	FLSH_CRC_ERR	flash_update.c

Appendix A. Code Structure

A.1 DIRECTORY STRUCTURE

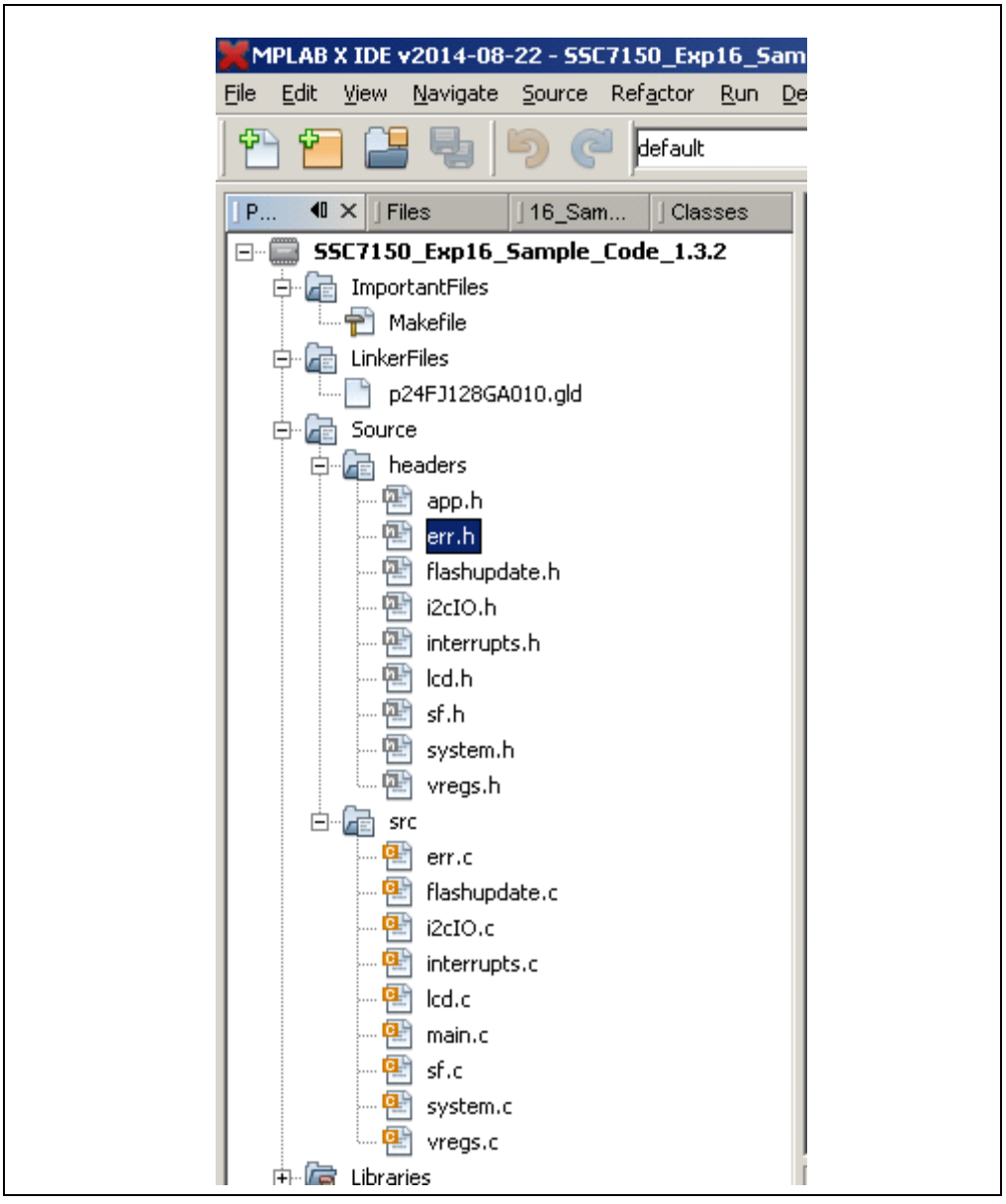


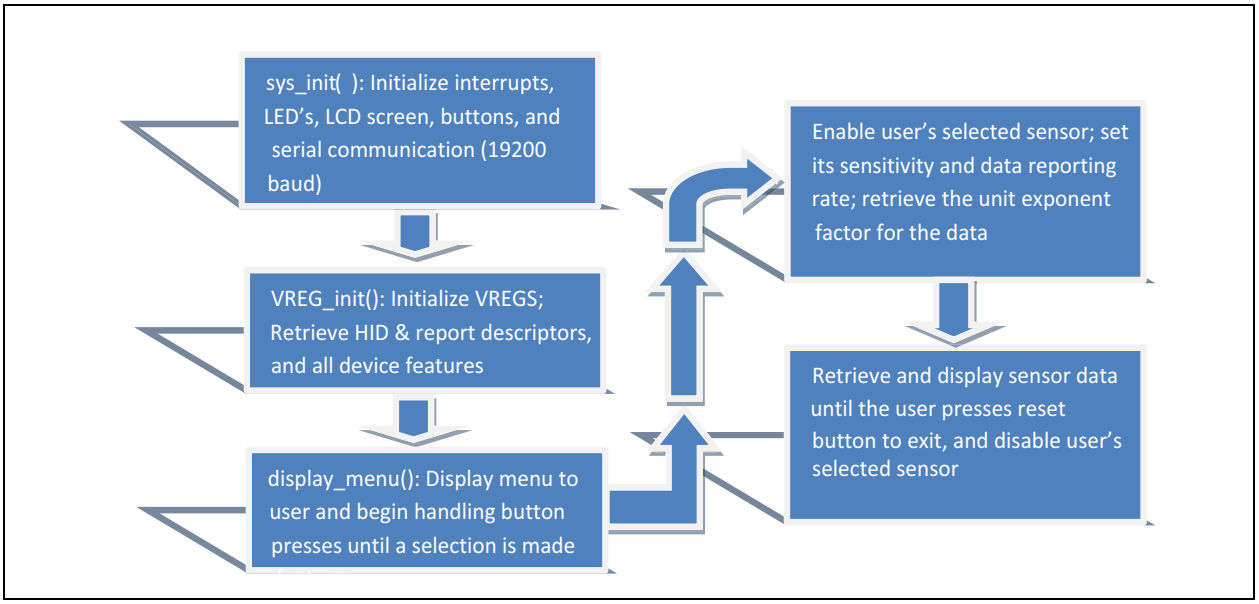
TABLE A-1: DIRECTORY STRUCTURE OF THE SENSOR FUSION SAMPLE CODE

Files	Description
\source\headers**app**.h	Include for all other underlying .h files and typedefs
\source\headers**err**.h	Functions and parameters for error handling
\source\headers**flash_update**.h	Functions for flash update
\source\headers**i2cIO**.h	Functions and parameters specific to I^2C communication with MM7150 module
\source\headers**interrupts**.h	Interrupt functions
\source\headers**lcd**.h	Functions relevant to LCD operation
\source\headers**sf**.h	Functions relevant to decoding and encoding HID commands and packets
\source\headers**system**.h	Functions relevant to running the demo
\source\headers**vregs**.h	Functions relevant to the creation of the virtual register layer of the MM7150 API library
\source\src**err**.c	Error handling functions for I^2C and VREG operations
\source\src**flash_update**.c	Functions for flash update.
\source\src**i2cIO**.c	Functions to communicate with MM7150 Module via I^2C
\source\src**interrupts**.c	Interrupt initialization and handler for INT1 (from EC-Host-interrupt), T2 (timer2 interrupt), and CN (change notification interrupt from buttons)
\source\src**lcd**.c	LCD support for Explorer 16 board
\source\src**main**.c	Functions to setup Explorer 16 board environment, COM port UART2, interrupts, timers, I^2C, HID_initialization, start HID handshaking with EC via I^2C commands
\source\src**sf**.c	Functions to get HID tables from MM7150 Module, send power and reset HID commands, get HID report descriptors, parse descriptors, get input from sensor devices
\source\src**system**.c	Initiates the motion demo by configuring LED's, LCD, Serial, and buttons
\source\src**vregs**.c	Mediator between HID-I^2C communication and user Commands (interactive layer of API)

A.2 PROGRAM FLOW

A.3.1 Main.c

FIGURE A-1: PROGRAM FLOW CHART



A.3.2 Configuring and Initializing MM7150 Motion Module

Note: For a more comprehensive explanation of the API library functions, see the Host API Design for MM7150 Application Note.

VREG_init (VREGS.c) – procedure for preparing motion module for data reporting

1. hid_i2c_descriptor_handler(GET_HID_DESC)
   - Retrieve and parse the HID descriptor table
2. hid_i2c_cmd_process (POWER_ON)
   - Wake the EC
3. hid_i2c_cmd_process (RESET)
   - Reset the EC
4. hid_i2c_descriptor_handler(GET_REPT_DESC)
   - Retrieve and parse report descriptor table
5. hid_i2c_cmd_process (HID_GET_RPT_FEAT, rept_ID)
   - Get feature reports for sensors

A.3.3 Enabling Sensors and Reading data

1. HOST_SF_LIB_write(0, 0bXXXXXXXXXX0101)
   - Enable one or multiple sensors
2. HOST_SF_LIB_write regX, sensitivity value
   - Optional - edit sensitivity per sensor
3. HOST_SF_LIB_write regX, data rate value
   - Optional - edit data rate per sensor
4. HOST_SF_LIB_write(DATA_REG)
   - Read input data from the enabled sensors

Appendix B. Reference Schematic & Bill of Materials

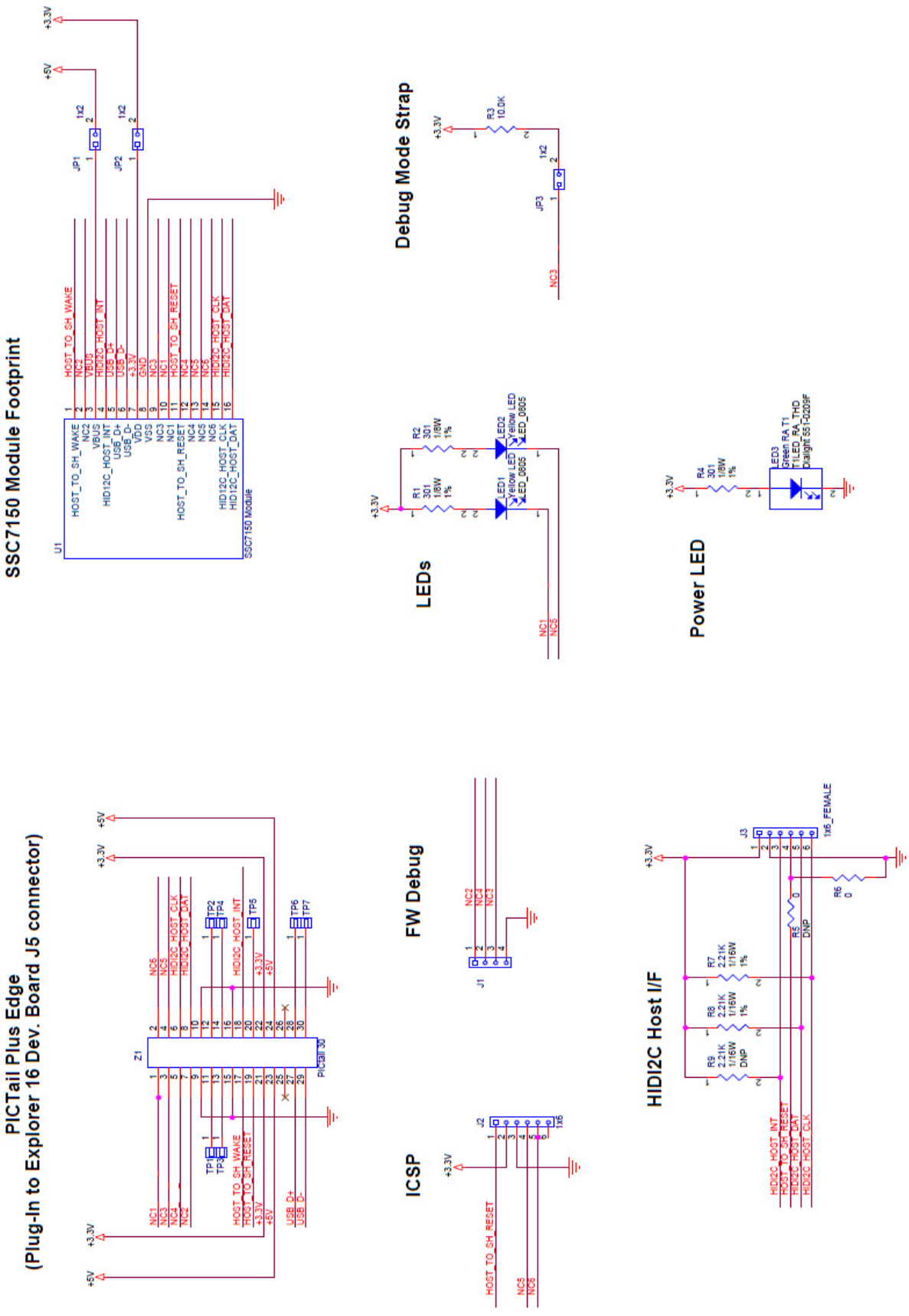
B.1 MM7150-PICTAIL DAUGHTER CARD

B.1.1 Bill of Materials

Designator	Quantity	Description	Value
J1	1	CON HDR-2.54 Male 1x4 Gold 5.84MH TH VERT	HDR-2.54 Male 1x4
J2	1	CON HDR-2.54 Male 1x6 Tin 5.84MH TH VERT	HDR-2.54 Male 1x6
J3	1	CON HDR-2.54 Female 1x6 Gold TH R/A	HDR-2.54 Female 1x6
JP1, JP2, JP3	3	CON HDR-2.54 Male 1x2	HDR-2.54 Male 1x2
LED1, LED2	2	DIO LED YELLOW 2.1V 30mA 6mcd Clear SMD 0805	YELLOW
LED3	1	LED 3MM RT ANG HI EFF GRN PC MNT - Dialight 551-0209F	GREEN
R1, R2, R4	3	RES TKF 301R 1% 1/10W SMD 0603	301R
R3, R5	2	RES TKF 10k 1% 1/16W SMD 0603, RES TKF 0R 1/10W SMD 0603	10k, DNP
R6	1	RES TKF 0R 1/10W SMD 0603	0R
R7, R8	2	RES TKF 2.21k 1% 1/10W SMD 0603	2.21k
R9	1	RES TKF 2.21k 1% 1/10W SMD 0603	DNP
U1	1	MM7150 Motion Module	

B.1.2 Reference Schematic

The MM7150-PICTAIL PICtail daughter card reference schematic is shown in the next page.



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