ISM400

Multimetric Imote2 Sensor Board

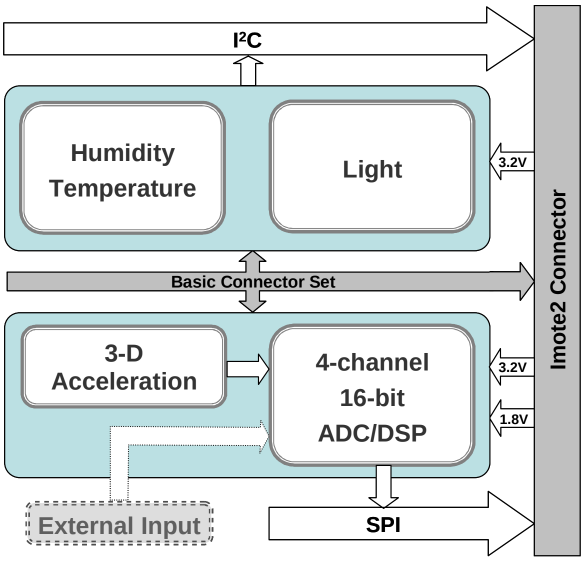
Datasheet and User's Guide

Overview

Developed as part of the Illinois Structural Health Monitoring Project, the ISM400 (formerly SHM-A) sensor board is designed to interface with the Imote2 smart sensor platform. This versatile sensor board is tailored to structural health monitoring (SHM) applications and is capable of providing the information required for comprehensive infrastructure monitoring. The sensor board provides three axes of acceleration as well as light, temperature and humidity measurements. The 4-channel analog to digital converter (ADC) can accommodate the addition of one external analog input signal, e.g. strain measurement.

Features

- Three axes of acceleration measurement
- Temperature and relative humidity measurement
- Single-channel external analog input to 16-bit ADC
- User-selectable sampling rates and cut-off frequencies
- Customizable digital filters
- Open-source software available for operation with the Imote2



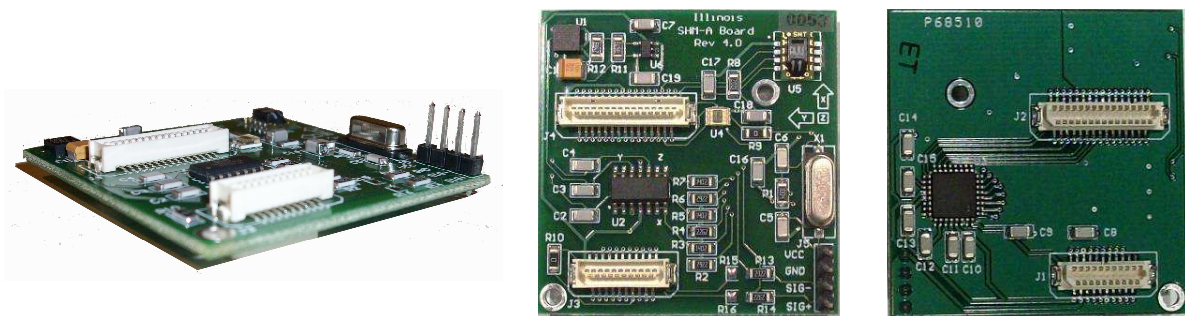


Figure 1. ISM400 sensor board: perspective (left), top (middle), and bottom (right).

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1 Block Diagram and Pin Descriptions

1.1 Block Diagram

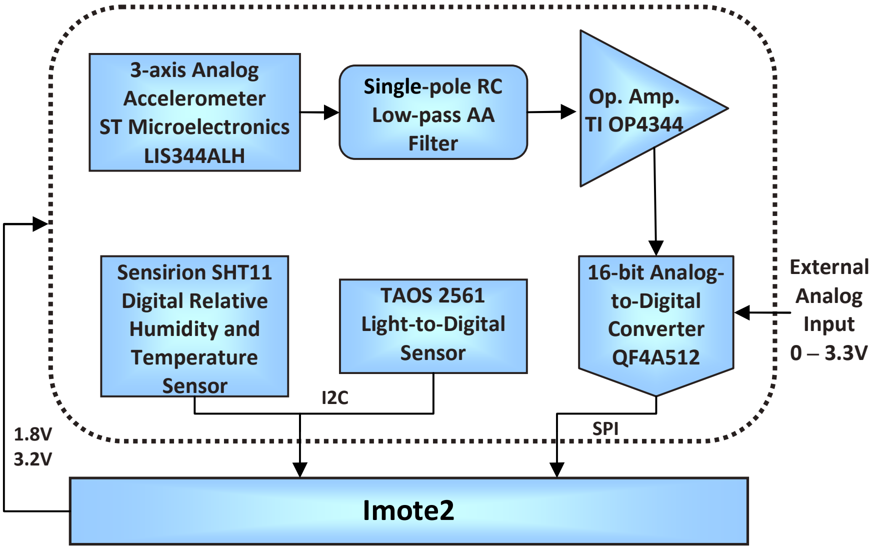

Figure 2. ISM400 block diagram

1.2 Pin descriptions

The ISM400 board connects to the Imote2 via two connectors located on the bottom of the board. In addition, the ISM400 board provides two connectors on the top of the board to allow the stacking of additional boards to interface with both the ISM400 board and the Imote2. Figure 3 gives the dimensions of the ISM400 sensor board, indicates the location of the connectors on both the top and bottom of the board, and shows the acceleration measurement directions. The pin descriptions are given in Tables 1, 2 and 3.

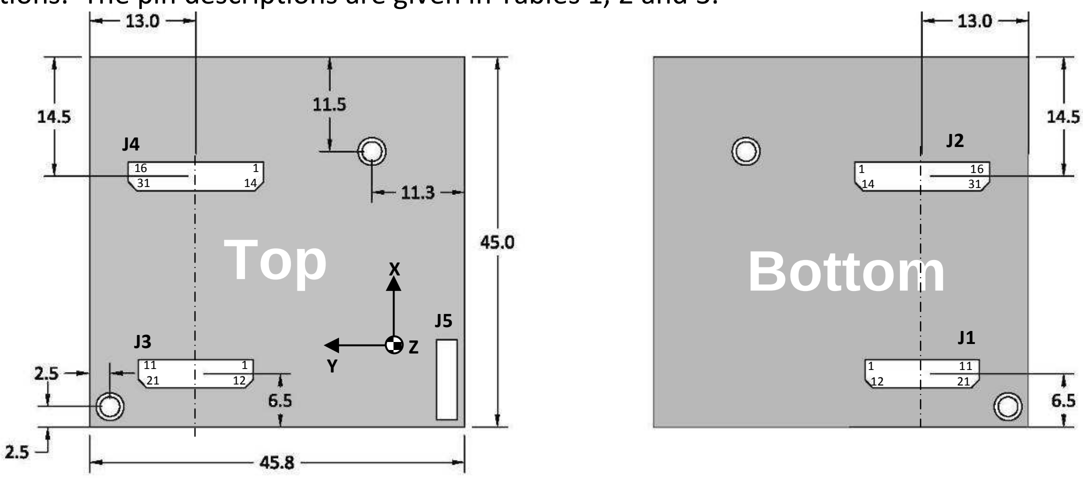

Figure 3. ISM400 dimensions (all dimensions in mm).

Table 1. Imote2/ISM400 31-pin connector (J2 and J4) pin descriptions.

Pins	Group	Imote2 Description	ISM400 Functionality
1	UART1	Serial port communication or General Purpose I/O	none
2			none
3			SHT11 (Temp. and Hum.) data[1]
4			SHT11 (Temp. and Hum.) clock[1]
5-8	UART2	Serial port communication or General Purpose I/O	none
9	GND	Ground	GND
10	SPI2	SSPCLK2– SPI Clock	none
11		SSPFRM2 – Chip Select	none
12		SSPTxD2 – SPI Serial Data Input	none
13		SSPRxD2 – SPI Serial Data Output	none
14	GPIO94	General purpose I/O	TAOS2561 (Light Sensor) interrupt
15,16	Reserved	Reserved	none
17	I^2C	SCL – I^2C Serial Clock	TAOS2561 (Light Sensor) clock
18		SDA – I^2C Serial Data	TAOS2561 (Light Sensor) data
19	SPI1	SSPCLK1– SPI Clock	QF4A512 (ADC) SPI Clock
20		SSPFRM1 – Chip Select	QF4A512 (ADC) Chip Select
21		SSPTxD1 – SPI Serial Data Input	QF4A512 (ADC) Serial Data Output
22		SSPRxD1 – SPI Serial Data Output	QF4A512 (ADC) Serial Data Input
23	GPIO10	General Purpose I/O	QF4A512 (ADC) Data Ready Interrupt
24	GND	Ground	GND
25	SDIO	MMCLK	none
26		MMCMD	none
27		MMD0	none
28		MMD1	none
29		MMD2	none
30		MMD3	none
31	GPIO93	General Purpose I/O	QF4A512 (ADC) Chip Reset

[1]The humidity and temperature sensor cannot be accessed when the Imtoe2 is connected to the debug board (IIB2400) since it uses the same pins as the one of the two serial ports used by the debug board.

Table 2. Imote2/ISM400 21-pin connector (J1 and J3) pin descriptions.

Pins	Group	Imote2 Description	ISM400 Functionality
1-2	VBAT	Drives power to processor (3.2 – 4.7V input)	none
3	GND	Ground	GND
4	PMIC_TBAT	PMIC battery temperature input	none
5-9	Reserved	Reserved	none
10		Available for expansion	Negative external analog input (0-3.3V) **J3 (top) only**[1]
11			Positive external analog input (0-3.3V) **J3 (top) only**[1]
12	Power	1.8V (programmable 1.8 – 3.3V)	1.8V supply
13		3V (programmable 1.8 – 3.3V)	3.2V supply
14	Reserved	Reserved	none
15	ALARM	Alarm input to PMIC	Connected to VRTC (18)[2]
16	RESET	Reset – manual reset	none
17	GND	Ground	GND
18	VRTC	Imote2 processor powered indicator - high if on or asleep	Connected to Alarm (15)[2]
19	nCHARGE_EN	Battery select (primary or rechargable)	none
20	STDUart	STD_RxD – Debugging with BLUSH	none
21		STD_TxD – Debugging with BLUSH	none

[1]The external input can come from either J5 or from J3. Populate R13 and R14 for connection via J5 OR populate R15 and R16 for connection via pins 10 and 11 of J3.
[2]VRTC is connected to the PMIC Alarm if R10 is populated. This connection causes the Imote2 to power on if a USB plug power source is inserted or the Imote2 is connected to a powered battery board without the need to press the reset button.

Table 3. ISM400 4-pin external analog input pin descriptions.

Pin	Label	Description
1	VCC	Power supplied by ISM400 board to external device (typically 3.2V)
2	GND	Ground
3	SIG-	Negative external analog input (0-3.3V)[1]
4	SIG+	Negative external analog input (0-3.3V)[1]

[1]See note 1 on Table 2.

2 Mechanical and electrical specifications

2.1 Mechanical characteristics

Table 4. Acceleration characteristics @ V_{SB} = 3.2V, T = 25°C unless otherwise noted.

Parameter	Min	Typ.	Max.	Units
Acceleration Range[1]		±2		g
Least significant bit (LSB)	0.133	0.143	0.152	mg
Sensitivity	6600	7000	7500	LSB/g
Zero-g offset	13300	14000	14600	LSB
Temperature sensitivity, all axes[2]	-0.08		0.02	%/°C
Zero-g change vs. temperature, x & y axes[2]		-1.25		mg/°C
Zero-g change vs. temperature, z axis[2]		-2.75		mg/°C
Noise floor, x & y axes	0.2	0.3	0.7	mg
Noise floor, z axis	0.3	0.7	1.2	mg
Maximum Frequency[1,3]	1158	1448	1736	Hz

[1]According to STMicroelectronics LIS344ALH Datasheet:
http://www.st.com/stonline/products/literature/ds/14337/lis344alh.htm.
[2]Before on-board temperature correction
[3]This is represents the maximum analog frequency prior to digital filtering that results from 1nF capacitors on the output of the accelerometer

Table 5. Environmental sensor characteristics

Parameter	Min	Typ.	Max.	Units
Light Range[1]	0.1		40000	Lux
Light Resolution[1]		16		bit
Temperature Range[2]	-40		123.8	°C
Temperature Resolution[2]	0.04	0.01	0.01	°C
Temperature Accuracy[2]		±0.4		°C
Temperature Response Time[2]	5		10	s
Humidity Range[2]	0		100	%RH
Humidity Resolution[2]	0.4	0.05	0.05	%RH
Humidity Accuracy[2]		±3.0		%RH
Humidity Response Time[2]		3		s

[1]From TAOS Light-to-Digital Converter (TS2561) Datasheet: http://www.taosinc.com/getfile.aspx?type=press&file=tsl2560-e58.pdf. Not specifically tested on the ISM400 board.
[2]From the Sensirion SHT11 – Digital Humidity Sensor Datasheet: http://www.sensirion.com/en/pdf/product_information/Datasheet-humidity-sensor-SHT1x.pdf. Not all characteristics were specifically tested on the ISM400 board.

2.2 Electrical characteristics

Table 6. ISM400 electrical characteristics.

Parameter	Condition	Min.	Typical	Max.	Units
Supply voltage			1.8		V
		3.2	3.2	3.3	V
ISM400 current draw[1]	3.2V, QF4A512 operating, 3-ch.		12.8	13.2	mA
	1.8V, QF4A512 operating, 3-ch.		79.6	82	mA
ISM400 + Imote2 current draw	ISM400 powered down + Imote2 @ 13MHz		41	56	mA
	ISM400 operating (3 ch.) + Imote2 @ 104MHz		169	184	mA
Analog external input voltage		0		3.3	V

[1]From the QF4A512 Programmable Signal Conditioner Datasheet: http://www.quickfiltertech.com/files/QF4A512revD7.pdf.

3 Typical performance characteristics

The following plots are intended to give a range of expected performance of the sensor boards. Unless otherwise noted, the boards were tested at ~25°C with V_{SB} = 3.2V.

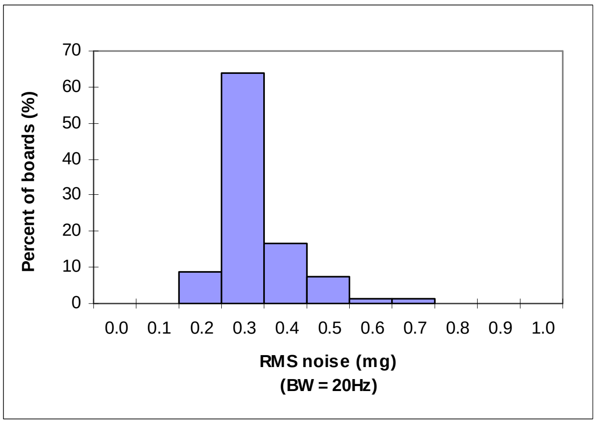

Figure 4. RMS noise for 20-Hz bandwidth, x and y axes.

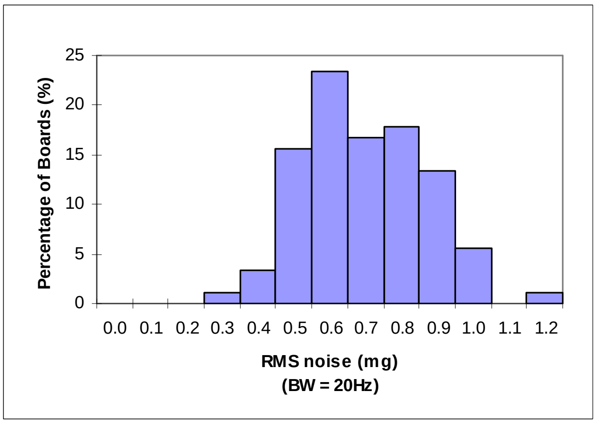

Figure 5. RMS noise for 20-Hz bandwidth, z axis.

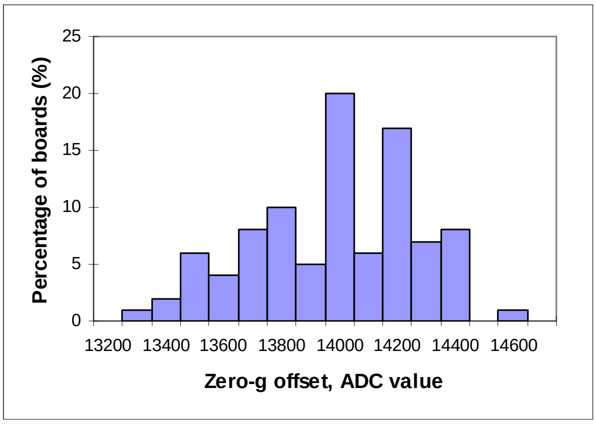

Figure 6. Zero-g offset ADC value.

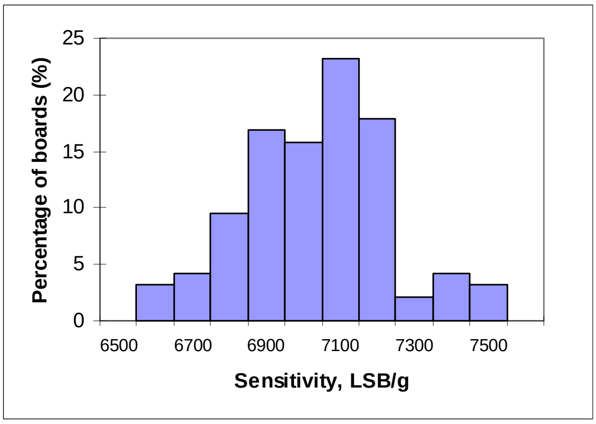

Figure 7. Sensitivity in LSB (ADC value)/g.

During sensing the ISM400 board self-heats (primarily due to the ADC). To account for the effects of this self-heating, as well as any changes in the ambient temperature, on the mean values (zero-g offsets) of the acceleration output, the temperature measurements are used to provide on-board correction. The following plots show the typical change in the zero-g levels and sensitivity without temperature correction.

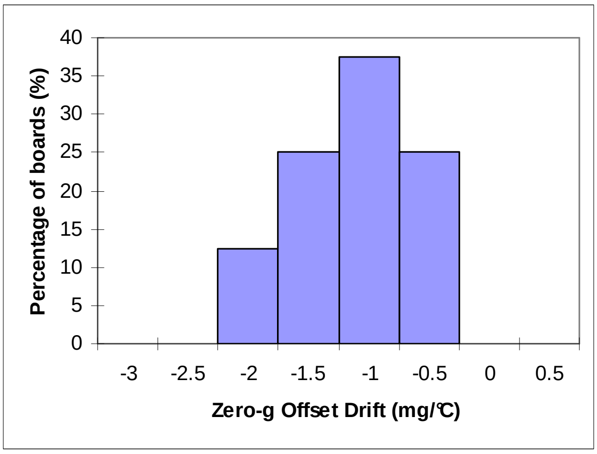

Figure 8. X-axis zero-g drift vs. temperature.

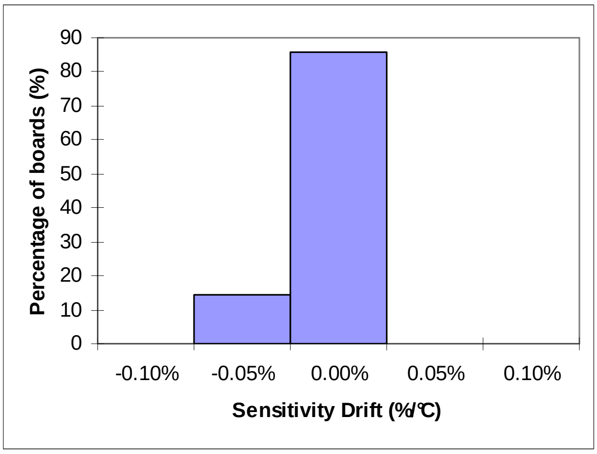

Figure 9. X-axis sensitivity drift vs. temperature.

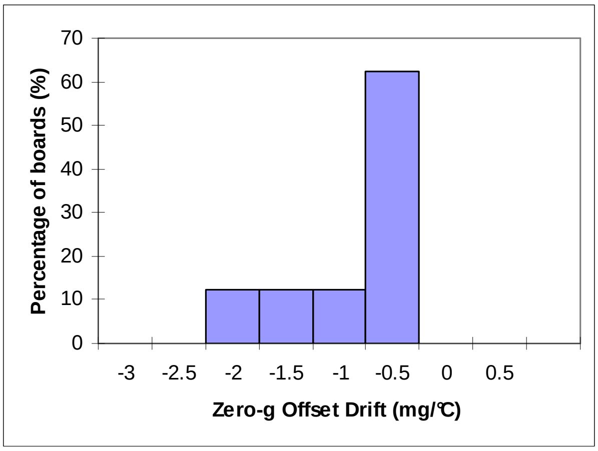

Figure 10. Y-axis zero-g drift vs. temperature.

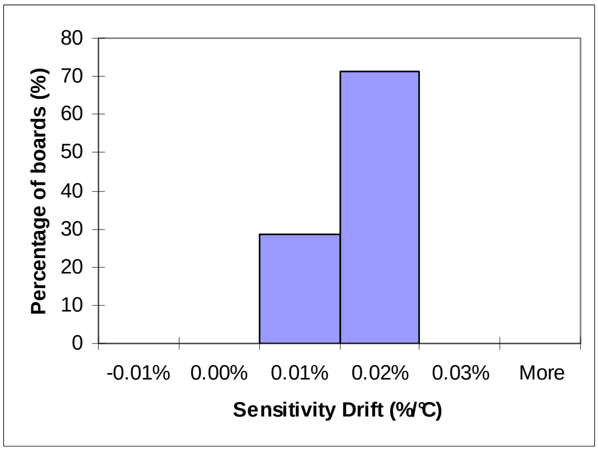

Figure 11. Y-axis sensitivity drift vs. temperature.

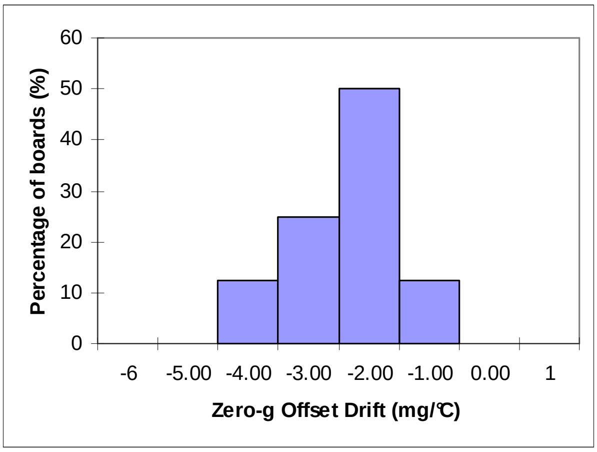

Figure 12. Z-axis zero-g drift vs. temperature.

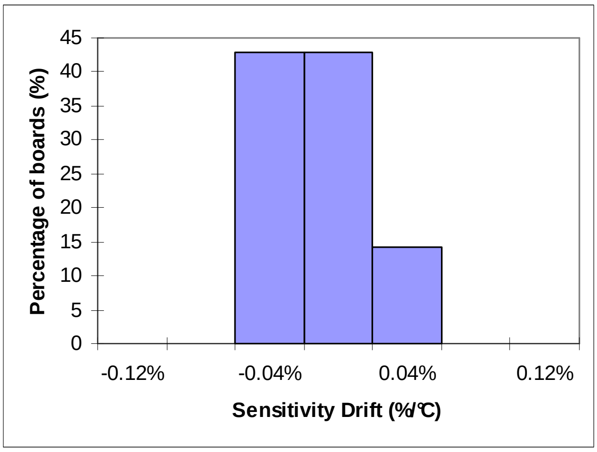

Figure 13. Z-axis sensitivity drift vs. temperature.

4 Software

The software required to operate the ISM400 board interfaced with the Imote2 is open-source and can be found at http://shm.cs.uiuc.edu/software.html. This software includes drivers for the QF4A512, the temperature and humidity sensor and the light sensor as well as a wide range of application software for acquiring data locally and remotely.

4.1 Driver

After installing the ISMHP Toolsuite the driver for the ISM400 (formerly SHM-A) sensor board can be found in the shm/sensorboards/SHM_A directory. Included in this directory are the main driver for the QF4A512 (ADC) as well as drivers for the SHT11 (temperature and humidity) and the TAOS 2561 (light) components. Table 7 describes the contents of each file.

Table 7. ISM400 driver files.

Component	File	Description
QF4A512 - Accelerometer and external input ADC	AccelSensorM.nc	Module and configuration file for QF4A512 operation.
	AccelSensorC.nc	
	AccelSensor.h	Defines constants associated with QF4A512 operation.
	filters.h	Defines configuration files and filter delays to be loaded for QF4A512 operation.
TAOS 2561 – Light Sensor	LightSensorM.nc	Module and configuration file for light sensor operation.
	LightSensorC.nc	
	LightSensor.h	Defines constants and numerical relationships for light sensor
SHT11 – Temperature and Humidity Sensor	TempHumSensorM.nc	Module and configuration file for temperature and humidity sensor operation.
	TempHumSensorC.nc	
	TempHumSensor.h	Defines constants and numerical relationships for temperature and humidity sensor.
	hardware.h	Defines SHT11 I2C parameters.
ISM400 – whole board operation	SensorboardM.nc	Module and configuration file for ISM400 board management including channel setup, memory allocation for sensed data and temperature correction.
	SensorboardC.nc	
	sensorboard.h	Defines constants for ISM400 board including temperature correction factors.
	TempCalibrationM.nc	Module and configuration file for a utility to estimate temperature correction factors. Operates with BluSH command.
	TempCalibrationC.nc	

4.2 Channel configuration file

The channel configuration file specifies the number of active channels as well as the sampling rate, analog gain, and digital filter characteristics for each channel. There are four default configuration files included in the ISM400 sensor board driver in the ISHMP Toolsuite. Table 8 gives the parameters for each of these files.

Table 8. Default QF4A512 configuration parameters.

Sampling Rate (Hz)	Cut-off Frequency (Hz)	Gain	Active Channels	Latency (points)	File Name
25	10	1	1,2,3	76	filter3ch_fs25Hz_fc10Hz.h
50	20	1	1,2,3	89	filter3ch_fs50Hz_fc20Hz.h
100	40	1	1,2,3	78	filter3ch_fs100Hz_fc40Hz.h
280	70	1	1,2,3	94	filter3ch_fs280Hz_fc70Hz.h

Please refer to “ISM400 Sensor Board: Advanced User’s Guide” for instructions on creating new configuration files.

4.3 Application software

The application software in the Illinois SHM Toolsuite allows the acquisition of data from the ISM400 sensor board. Please see the associated documentation for further instructions on the use of the application software.

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