USER MANUAL

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XTRINSIC-SENSE Board

Evaluation Board for Freescale Xtrinsic Sensors

For use with Freescale FRDM-KL25z and Raspbery Pi Host Platforms

Exclusively from

element14

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Kit Overview

The XTRINSIC-SENSE board demonstrates the capabilities of Freescale's Xtrinsic sensors. The Xtrinsic Sensor board includes interfacing and support for the following host platforms:

- Freescale FRDM-KL25Z
- Raspberry Pi (Model B)

The software drivers and code enable engineers to easily evaluate and demonstrate the performance of the sensors in a variety of applications including:

- eCompass
- Mobile Phones/Tablet Computers
- Remote Control/Wireless Mouse
- Game Consoles
- Navigation Devices
- Medical Devices

Kit Contents:

- Xtrinsic Sense Board
- Quick Start Guide

Xtrinsic Sense Board

The sensor board comes equipped with three of Freescale's new-generation XTRINSIC MEMS sensors. The **MPL3115** (U1) is designed for accurate measurement of temperature and pressure, the **MAG3110** (U2) for detection of magnetic fields, and the **MMA8491** (U3) for measurement of physical positions.

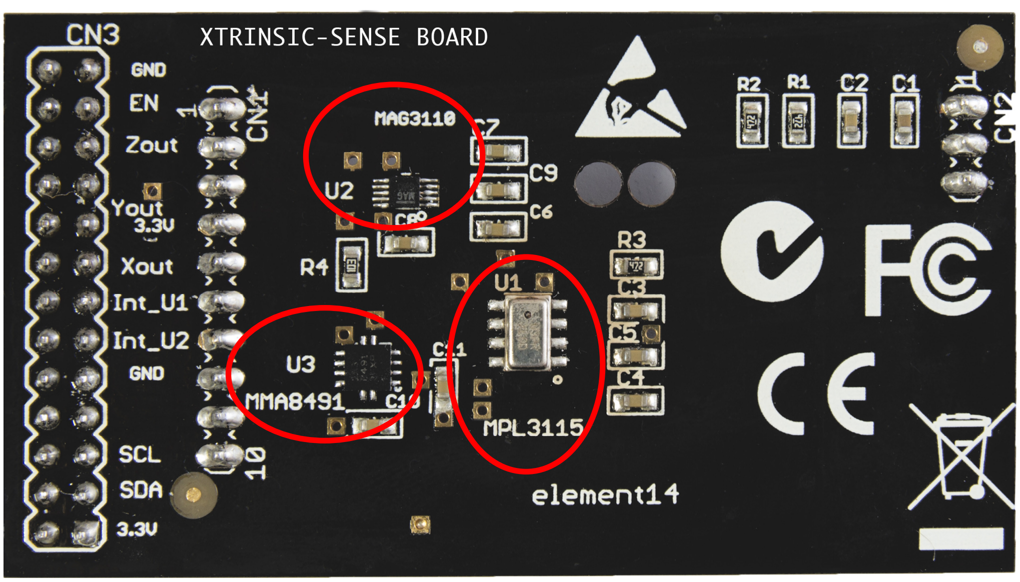


Figure 1 - Sensor Board

MPL3115

The MPL3115 is a high-precision sensor used to provide accurate pressure and altitude data. It features an adjustable sampling rate, ultra-low power consumption and intelligent functions, suitable for applications such as mobile, medical and security devices. MPL3115 is able to provide digitized output, two separated wake-up interrupts, minimum/maximum threshold mechanism, and autonomous data acquisition. The self data processing ability of the MPL3115 reduces the need for communication with MCUs, which reduces overall system power consumption.

MAG3110

The MAG3110 is a small, low-power, digital 3-axis magnetometer featuring a wide measurement range. It can measure magnetic fields (the overlapped fields consisting of the geomagnetic field and the fields created by components on PCB) on each of the 3 axes in the position where it is placed. The MAG3110 features an I2C serial interface, and is capable of measuring magnetic fields of up to 10 Gauss with an output data rate up to 80Hz. The output data rate can vary depending on the sampling intervals and may be adjusted from 12ms to several seconds.

MMA8491Q

The MMA8491Q is a low voltage, 3-axis low-g accelerometer housed in a 3 mm by 3 mm QFN package. The device can accommodate two accelerometer configurations, acting as either an easy to implement 45° Tilt Sensor or a digital (I2C) output accelerometer. In the 45° Tilt Sensor mode, it offers extremely easy board implementation by using a single line of output per axis. In the digital output mode, 14-bit ±8g raw data can be read from the device with high 1 mg/LSB sensitivity. The extreme low power capabilities of the MMA8491Q reduce the low data rate current consumption to less than 400 nA per Hz.

Pin Definition of Connectors

This section will briefly introduce the connectors used on sensor board and the pins of these connectors in terms of definition, function and application.

Board Top View

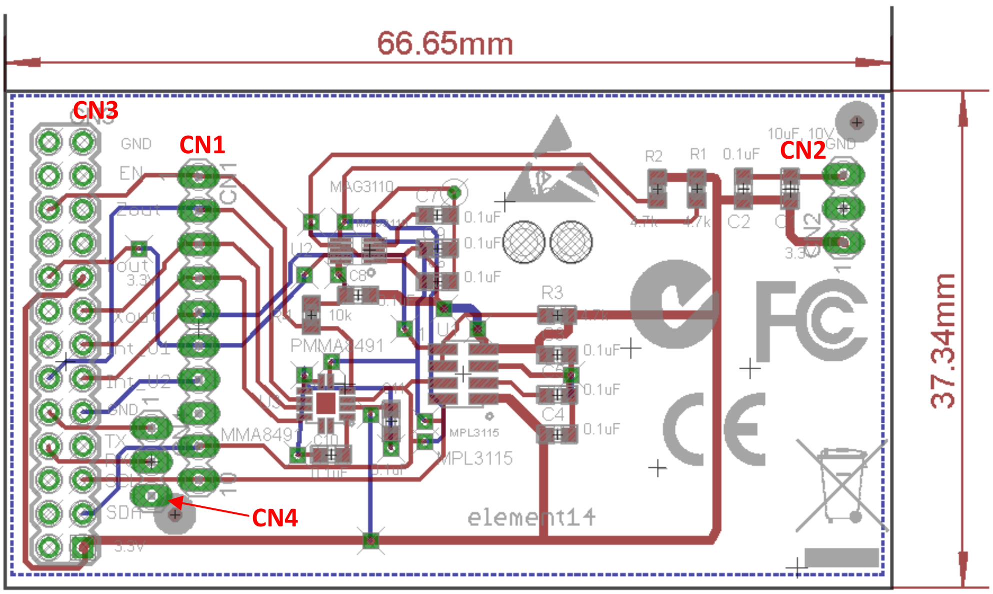


Figure 2 - Sensor Board Top View

Pin Definition

CN1 – Used for interface with FRDM-KL25z host platform

Pin No.	Pin Name	Description
1	EN	MMA8491 Enable Pin
2	ZOUT	MMA8491 Push-Pull Z-Axis Tilt Detection Output
3	YOUT	MMA8491 Push-Pull Y-Axis Tilt Detection Output
4	XOUT	MMA8491 Push-Pull X-Axis Tilt Detection Output
5	INT_MPL3115	MPL3115 Interrupt
6	INT_MAG3110	MAG3110 Interrupt
7	GND	Ground
8	NC	No Connection
9	SDA_SENSOR	I2C Slave Data Line
10	SCL_SENSOR	I2C Slave Clock Line

Table 1 - CN1 FRDM-KL25z Data Interface Connector

CN2:FRDM-KL25z Power Supply Connector

Pin No.	Pin Name	Description
1	VDD	+3.3V DC Power Supply
2	NC	No Connection
3	GND	Ground

Table 2 - CN2 FRDM-KL25z Power Supply Connector

CN3 – Raspberry Pi Interface

Pin No.	Pin Name	Description
1	VDD	+3.3V DC Power Supply
2	NC	No Connection
3	SDA_SENSOR	I2C Slave Data Line
4	NC	No Connection
5	SCL_SENSOR	I2C Slave Clock Line
6	GND	Ground
7	NC	No Connection
8	TX	RPi UART TXD0
9	GND	Ground
10	RX	RPi UART RXD0
11	INT_MPL3115	MPL3115 Interrupt
12	ZOUT	MMA8491 Push-Pull Z-Axis Tilt Detection Output
13	XOUT	MMA8491 Push-Pull X-Axis Tilt Detection Output
14	GND	Ground
15	YOUT	MMA8491 Push-Pull Y-Axis Tilt Detection Output
16	NC	No Connection
17	VDD	+3.3V DC Power Supply

18	INT_MAG3110	MAG3110 Interrupt
19	NC	No Connection
20	GND	Ground
21	NC	No Connection
22	EN	MMA8491 Enable Pin
23	NC	No Connection
24	NC	No Connection
25	GND	Ground
26	NC	No Connection

Table 3 - CN3 RPi Interface Connector

CN4: RPi UART Interface

Pin No.	Pin Name	Description
1	RX	RPi UART RXD0
2	TX	RPi UART TXD0
3	GND	Ground

Table 4 - CN4 RPi UART Interface Connector

Freescale Freedom FRDM-KL25Z

The FRDM-KL25Z features a KL25Z128VLK - a KL2 family device boasting a max operating frequency of 48MHz, 128KB of flash, a full-speed USB controller, and loads of analog and digital peripherals. The FRDM-KL25Z has an easy access to MCU I/O via Arduino ™ R3 compatible I/O connectors.

The board also features a programmable OpenSDA debug interface with multiple applications available including:

- Mass storage device flash programming interface
- P&E Debug interface provides run-control debugging and compatibility with IDE tools
- CMSIS-DAP interface: new ARM standard for embedded debug interface

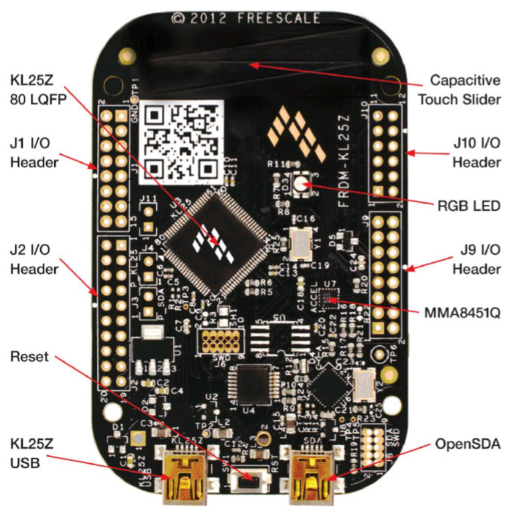


Figure 3 - FRDM-KL25Z board

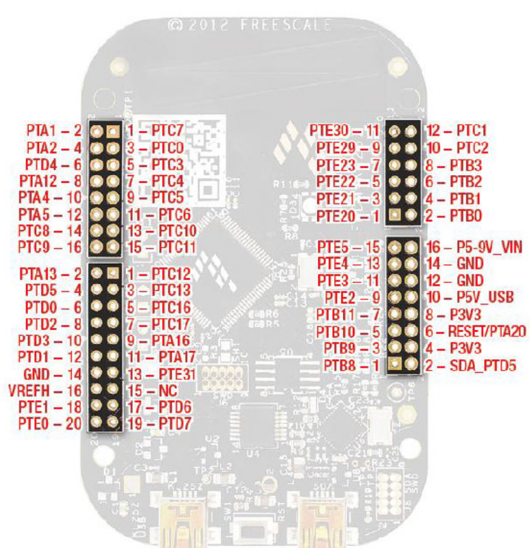
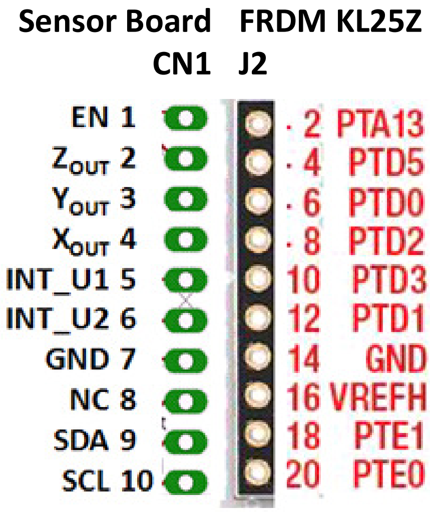


Figure 4 - Pinouts of I/O headers on FRDM-KL25Z

XTRINSIC-Sense board and FRDM-KL25Z

Pin mapping



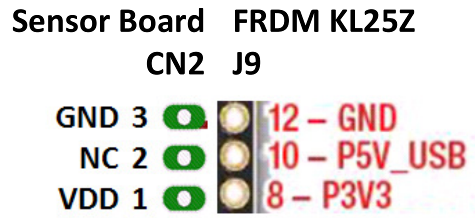


Figure 5 - XTRINSIC-SENSE Board w/ FRDM-KL25Z

Raspberry Pi

The Raspberry Pi features a BCM2835 SoC which includes an ARM1176JZF-S 700MHz processor, VideoCore IV GPU, and 512 MB of RAM (Model B). It also includes two USB ports and a 10/100 Ethernet controller. The Raspberry Pi has an easy access 26-pin GPIO I/O header (2x13, 0.1" center). Four additional GPIO available on P5. The board also features primary and secondary I^2C channels.

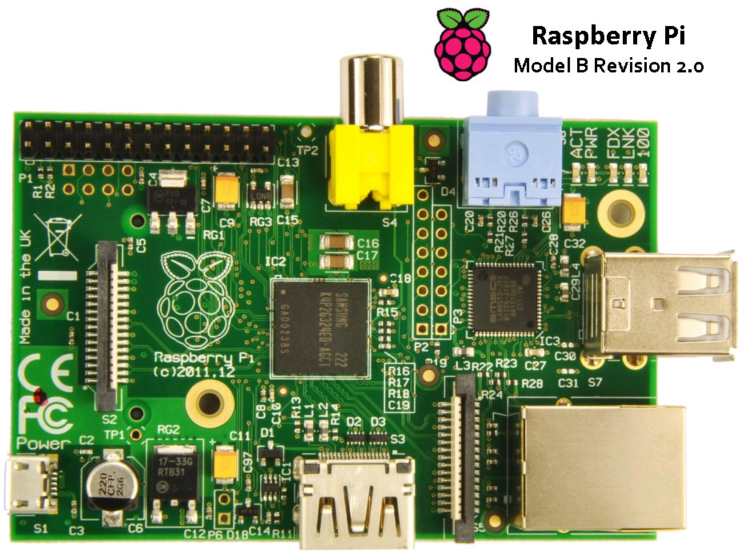


Figure 6 - Raspberry Pi board

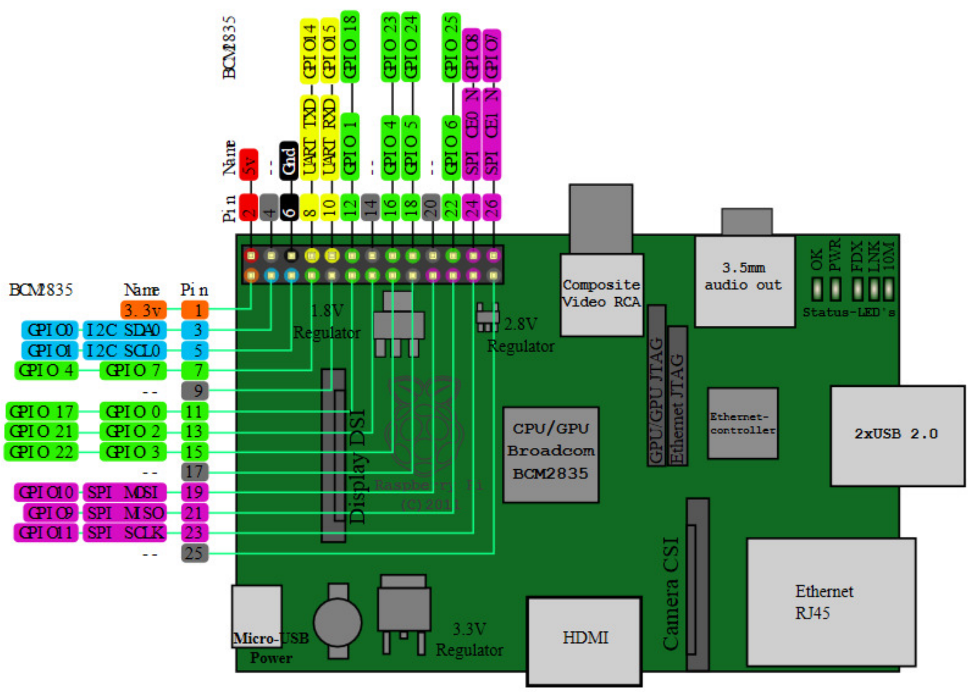


Figure 7 - Pinouts of I/O headers on Raspberry Pi

XTRINSIC-Sense board and Raspberry Pi

Pin mapping

Sensor Board	CN3	Raspberry Pi P1
+3V3	1	1 – +3V3
SDA_SENSOR	3	3 – SDA1
SCL_SENSOR	5	5 – SCL1
nc	7	7 – GPIO_GCLK
GND	9	9 – GND
INT_MPL3115	11	11 – GPIO_GEN0
XOUT	13	13 – GPIO_GEN2
YOUT	15	15 – GPIO_GEN3
+3V3	17	17 – +3V3
nc	19	19 – SPI_MOSI
nc	21	21 – SPI_MISO
nc	23	23 – SPI_SCLK
GND	25	25 – GND

Sensor Board	CN3	Raspberry Pi P1
nc	2	2 – +5V0
nc	4	4 – +5V0
GND	6	6 – GND
TX	8	8 – TXD0
RX	10	10 – RXD0
ZOUT	12	12 – GPIO_GEN1
GND	14	14 – GND
nc	16	16 – GPIO_GEN4
INT_MAG3110	18	18 – GPIO_GEN5
GND	20	20 – GND
EN	22	22 – GPIO_GEN6
nc	24	24 – SPI_CE0_N
nc	26	26 – SPI_CE1_N

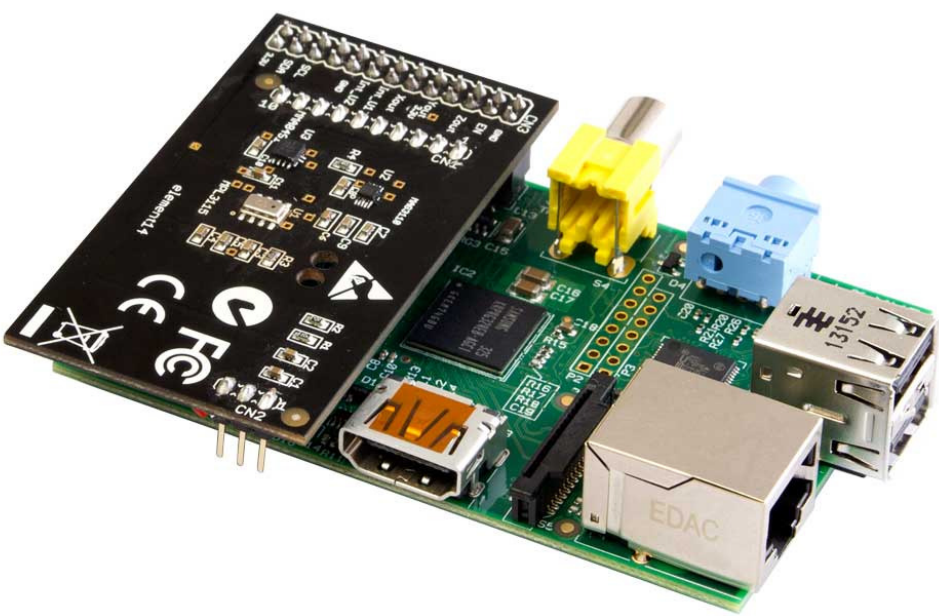


Figure 8 - XTRINSIC-SENSE Board w/ Raspberry Pi

Drivers for Xtrinsic Sense Board

Driver for MPL3115A2

Driver Interfaces

The MPL3115A2 features three kinds of modes, 8 different sample rates, 16 different acquisition time steps (1 second to 9 hours), and compensated direct reading of pressure (20 bit in Pascal) or altitude (20 bit in meters). The driver provides the following interfaces for implementing these features.

Table 5 - MPL3115A2 Interface list

1	Modes of Operation	void MPL3115A2_Active (void)
2		Uint8_t MPL3115A2_Standby (void)
3		Uint8_t MPL3115A2_Init_Alt (void)
4		Uint8_t MPL3115A2_Init_Bar (void)
5	Over sample	void MPL3115A2_SetOSR (uint8_t)
6		void MPL3115A2_SetStepTime (uint8_t)
7	Read raw data	uint32_t MPL3115A2_Read_Alt (void)
8		uint32_t MPL3115A2_Read_Bar (void)
9		uint32_t MPL3115A2_Read_Temp (void)

Operation Modes

MPL3115A2 has three operation modes: Standby, Active Altitude, and Active Barometer. These modes can be implemented using the following interfaces.

Table 6 - MPL3115A2_Active

Name	MPL3115A2_Active
Prototype	void MPL3115A2_Active (void)
Param	Void
Return Value	Void
Description	Put MPL3115A2 into Active Mode

Table 7 - MPL3115A2_Standby

Name	MPL3115A2_Standby
Prototype	Uint8_t MPL3115A2_Standby (void)
Param	Void
Return Value	The value of CTRL_REG1 before modification
Description	Put MPL3115A2 into Standby Mode

Table 8 - MPL3115A2_Init_Alt

Name	MPL3115A2_Init_Alt
Prototype	Uint8_t MPL3115A2_Init_Alt (void)
Param	Void
Return Value	0 – fail, 1 – success
Description	Initialize MPL3115A2 for Alt mode

Table 9 - MPL3115A2_Init_Bar

Name	MPL3115A2_Init_Bar
Prototype	Uint8_t MPL3115A2_Init_Bar (void)
Param	Void
Return Value	0 – fail, 1 – success
Description	Initialize MPL3115A2 for Bar mode

Over Sampling

Output Sample Rate can be set as shown in Table 10 - System Output Data Rate Selection. Table 10 and 11 contain the functions used for configuring over-sampling parameters.

Table 10 - System Output Data Rate Selection

OSR	Oversample Ratio	Minimum Time Between Data Samples
0	1	2.5 ms
1	2	5 ms
2	4	10 ms
3	8	20 ms
4	16	40 ms
5	32	80 ms
6	64	160 ms
7	128	320 ms

Table 11 - MPL3115A2_SetOSR

Name	MPL3115A2_SetOSR
Prototype	void MPL3115A2_SetOSR (uint8_t osr)
Param	OSR Ratio
Return Value	Void
Description	Change the OSR Ratio

Table 12 - MPL3115A2_SetStepTime

Name	MPL3115A2_SetStepTime
Prototype	void MPL3115A2_SetStepTime (uint8_t step)
Param	Sample Step = 2^step;
Return Value	Void
Description	Change sample step

Data Acquisition

Pressure (20 bit in Pascals), Altitude (20 bit in meters), and Temperature (12 bit in degrees Celsius) can be read by functions contained in the following tables, and be calculated using the formulas in section 0

Table 13 - MPL3115A2_Read_Alt

Name	MPL3115A2_Read_Alt
Prototype	uint32_t MPL3115A2_Read_Alt (void)
Param	Void
Return Value	The raw data for Altitude:
Description	Read Altitude data from MPL3115A2

Table 14 - MPL3115A2_Read_Bar

Name	MPL3115A2_Read_Bar
Prototype	uint32_t MPL3115A2_Read_Bar (void)
Param	Void
Return Value	The raw data for Barometer
Description	Read Barometer data from MPL3115A2

Table 15 - MPL3115A2_Read_Temp

Name	MPL3115A2_Read_Temp
Prototype	uint32_t MPL3115A2_Read_Temp (void)
Param	Void
Return Value	The raw data for temperature
Description	Read Temperature data from MPL3115A2

Raw Data Structure and Calculations

Alt Raw Data

Table 16 - Alt raw data structure

<table>
<tr><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td>24</td><td>23</td><td></td><td></td><td></td><td></td><td></td><td></td><td>16</td><td>15</td><td></td><td></td><td></td><td></td><td></td><td></td><td>8</td><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="8">Invalid</td><td colspan="8">ALT_MSB</td><td colspan="8">ALT_CSB</td><td colspan="8">ALT_LSB</td></tr>
</table>

Integer part: ALT_MSB x 2^8 + ALT_CSB
Decimal part: (ALT_LSB / 2^4) x 0.0625

Bar raw data

Table 17 - Bar raw data structure

31	24	23	16	15	8	7	0
Invalid		BAR_MSB		BAR_CSB		BAR_LSB	

Integer part: (BAR_MSB x 2^{16} + BAR_CSB x 2^{8} + BAR_LSB) / 2^{6}

Decimal part: BAR_LSB.BIT5 x0.5 + BAR_LSB.BIT4 x 0. 25

Temperature raw data

Table 18 - Temperature raw data structure

31	24	23	16	15	8	7	0
Invalid		Invalid		T_MSB		T_LSB	

Integer part: T_MSB

Decimal part: (T_LSB / 2^{4}) x 0.0625

Drivers for MAG3110

Driver Interfaces

MAG3110 is a digital 3-axis magnetometer from which the data can be read using interfaces contained in Table 19 to Table 24

Table 19 - MAG3110 Interface list

1	Initialize	Uint8_t MAG3110_Init(void)
2		void MAG3110_DeInit(void)
3	Read raw data	uint32_t MAG3110_ReadRawData_x(void)
6		uint32_t MAG3110_ReadRawData_y(void)
7		uint32_t MAG3110_ReadRawData_z(void)

Table 20 - MAG3110_Init

Name	MAG3110_Init
Prototype	Uint8_t MAG3110_Init(void)
Param	Void
Return Value	0 – fail, 1 – success
Description	Initialize MAG3110

Table 21 - MAG3110_DeInit

Name	MAG3110_DeInit
Prototype	void MAG3110_DeInit(void)
Param	Void
Return Value	Void
Description	Deinitialize MAG3110

Table 22 - MAG3110_ReadRawData_x

Name	MAG3110_ReadRawData_x
Prototype	uint32_t MAG3110_ReadRawData_x(void)
Param	Void
Return Value	Raw data for x-axis
Description	Read x-axis data from MAG3110

Table 23 - MAG3110_ReadRawData_y

Name	MAG3110_ReadRawData_y
Prototype	uint32_t MAG3110_ReadRawData_y(void)
Param	Void
Return Value	Raw data for y-axis
Description	Read y-axis data from MAG3110

Table 24 - MAG3110_ReadRawData_z

Name	MAG3110_ReadRawData_z
Prototype	uint32_t MAG3110_ReadRawData_z(void)
Param	Void
Return Value	Raw data for z-axis
Description	Read x-axis data from MAG3110

Raw Data Structure and calculations

X-Axis data

X-axis 16-bit output sample data of the magnetic field strength is expressed as signed 2's complement.

Table 25 - X-Axis data structure

<table>
<tr><td>31</td><td></td><td></td><td></td><td></td><td></td><td></td><td>24</td><td>23</td><td></td><td></td><td></td><td></td><td></td><td></td><td>16</td><td>15</td><td></td><td></td><td></td><td></td><td></td><td></td><td>8</td><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td>0</td></tr>
<tr><td colspan="8">Invalid</td><td colspan="8">Invalid</td><td colspan="8">X_MSB</td><td colspan="8">X_LSB</td></tr>
</table>

Scale factor
Data (in µT unit) = Data(Count) x 0.1

Y-Axis data

Y-axis 16-bit output sample data of the magnetic field strength is expressed as signed 2's complement.

Table 26 - Y-Axis data structure

31							24	23							16	15							8	7							0
Invalid								Invalid								Y_MSB								Y_LSB							

Z-Axis data

Z-axis 16-bit output sample data of the magnetic field strength is expressed as signed 2's complement.

Table 27 - Z-Axis data structure

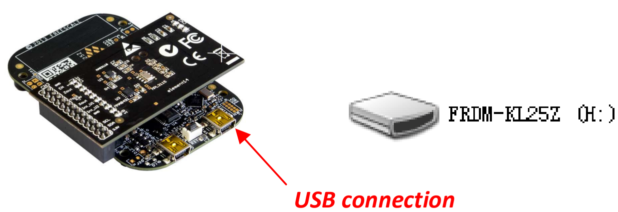
31							24	23							16	15							8	7							0
Invalid								Invalid								Z_MSB								Z_LSB							

Demonstration w/ FRDM-KL25Z

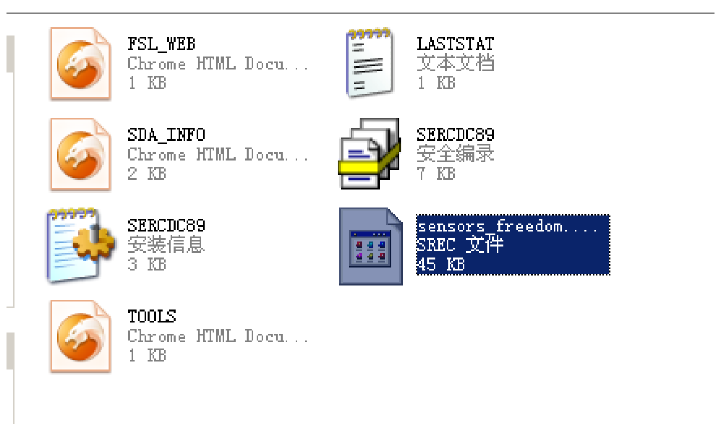
After the driver code is loaded onto the Freedom KL25Z, the sensor features can be demonstrated with a command line interface of HyperTerminal, or another UART tools.

Setup and Configuration

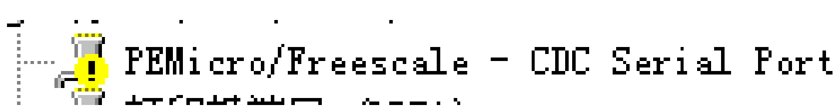
1. Plug in a USB cable from a USB host to the OpenSDA mini-B USB connector of the FRDM-KL25Z. The FRDM-KL25Z will be powered by this USB connection. FRDM-KL25Z comes with the mass-storage device (MSD) Flash Programmer OpenSDA Application preinstalled. It will appear as a removable storage drive with a volume label of FRDM-KL25Z. (Note: For more details on setup of the FRDM-KL25Z please refer to http://www.element14.com/community/docs/DOC-49219)

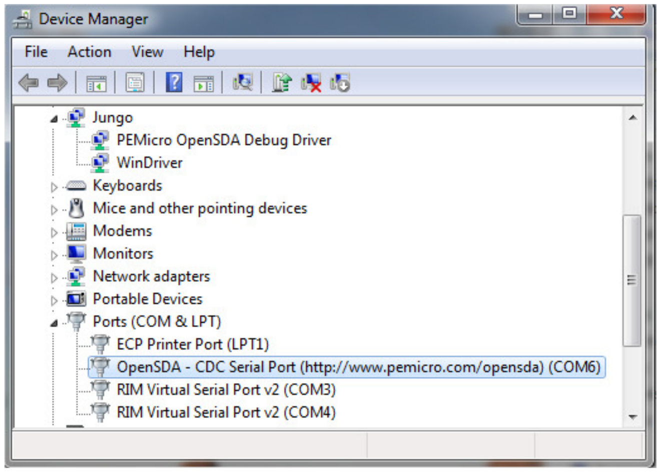


2. Open the FRDM-KL25Z drive, and drop the image "sensors_freedom.srec" into it, as seen below.



3. The MSD Flash Programmer also includes a USB virtual serial port which requires an .INF file for proper installation in Windows. The necessary .INF file is available as part of the P&E OpenSDA USB Drivers and on the FRDM-KL25Z removable drive.

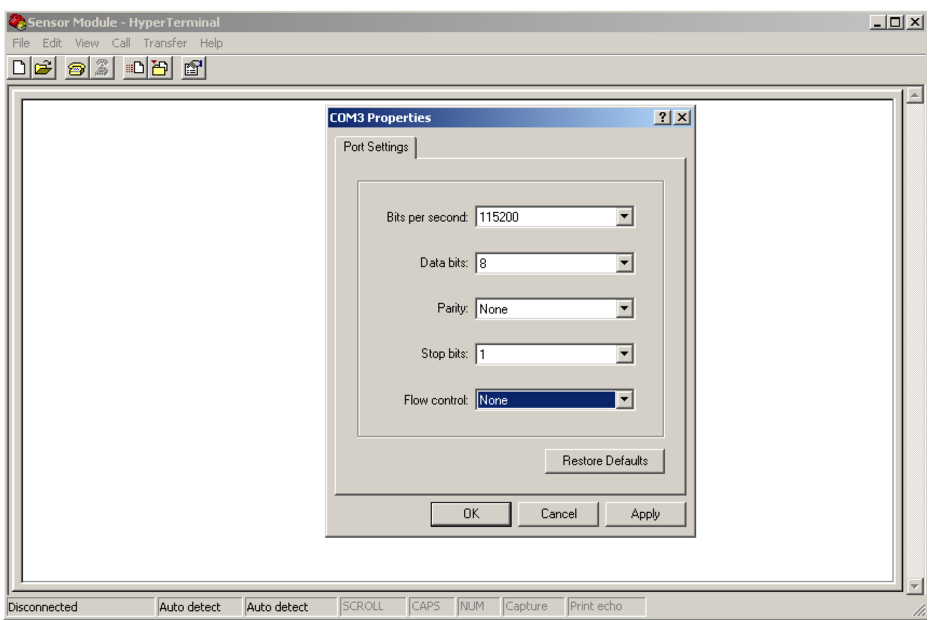




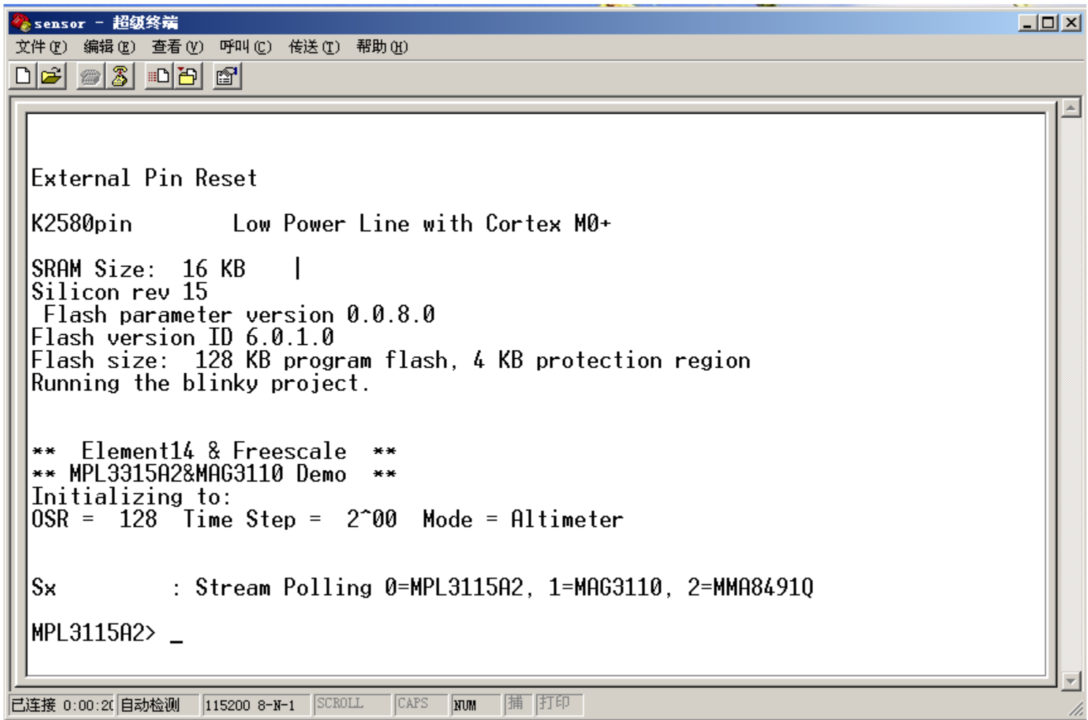
The serial port will be configured after the driver installation – eg. COM6 in the example.

4. Launch the terminal program (eg. Tera Term) with the properties as follows:

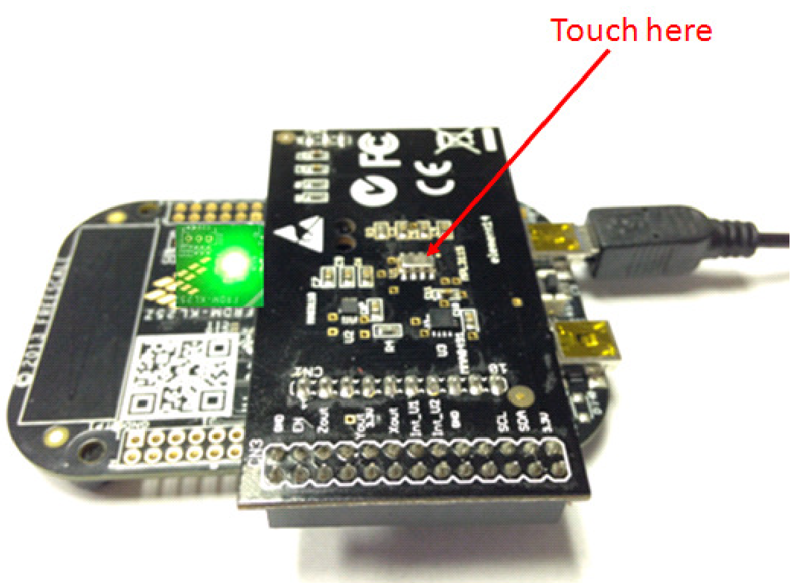
Baud rate	115200
Data bits	8-bit
Stop bits	1-bit
Parity	None
Flow control	None

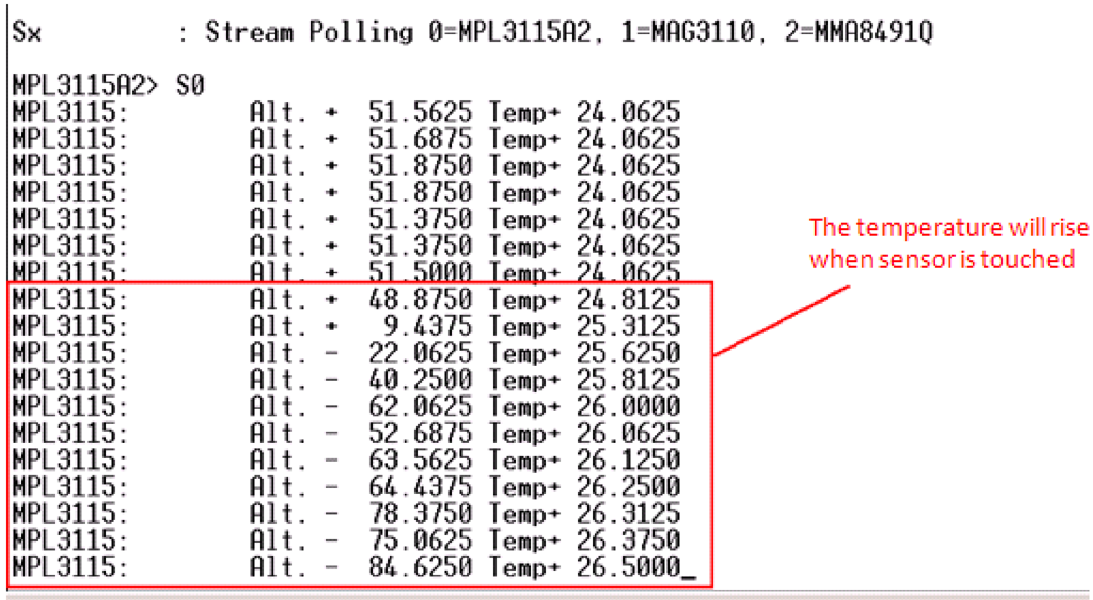


5. Reset the board by pressing the reset button (SW1), and you can see the information displayed below



6. Type 'S0' into the terminal through the PC keyboard, to try out the MPL3115A2 sensor. The terminal will begin to display temperature readings. Touch the sensor with your finger and notice that the temperature readings will start to rise. At the same time, the RGB LED will begin blinking red.



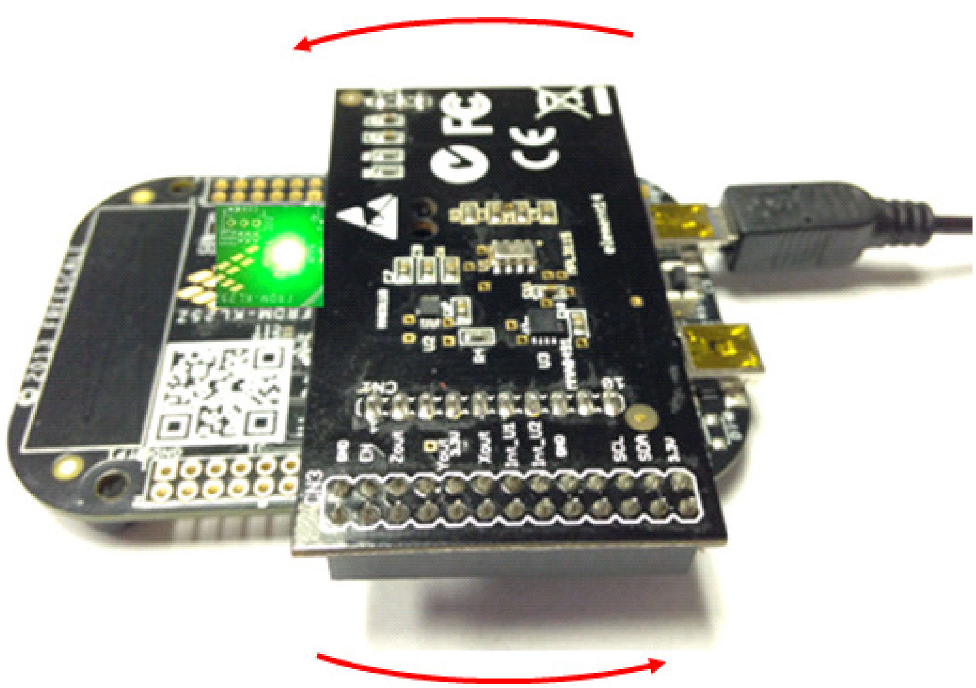


```
$x          : Stream Polling 0=MPL3115A2, 1=MAG3110, 2=MMA8491Q

MPL3115A2> S0
MPL3115:         Alt. +  51.5625 Temp+ 24.0625
MPL3115:         Alt. +  51.6875 Temp+ 24.0625
MPL3115:         Alt. +  51.8750 Temp+ 24.0625
MPL3115:         Alt. +  51.8750 Temp+ 24.0625
MPL3115:         Alt. +  51.3750 Temp+ 24.0625
MPL3115:         Alt. +  51.3750 Temp+ 24.0625
MPL3115:         Alt. +  51.5000 Temp+ 24.0625
MPL3115:         Alt. +  48.8750 Temp+ 24.8125
MPL3115:         Alt. +   9.4375 Temp+ 25.3125
MPL3115:         Alt. -  22.0625 Temp+ 25.6250
MPL3115:         Alt. -  40.2500 Temp+ 25.8125
MPL3115:         Alt. -  62.0625 Temp+ 26.0000
MPL3115:         Alt. -  52.6875 Temp+ 26.0625
MPL3115:         Alt. -  63.5625 Temp+ 26.1250
MPL3115:         Alt. -  64.4375 Temp+ 26.2500
MPL3115:         Alt. -  78.3750 Temp+ 26.3125
MPL3115:         Alt. -  75.0625 Temp+ 26.3750
MPL3115:         Alt. -  84.6250 Temp+ 26.5000_
```


Figure 9 - MPL3115 demo

7. Press the "Enter" key on the keyboard to quit the demo and go back to the menu. Type ‘S1’ to try out the MAG3110 sensor. Shake the board around, and you can see the 3-D magnetic field measurement change. At the same time, the RGB LED will begin blinking green.



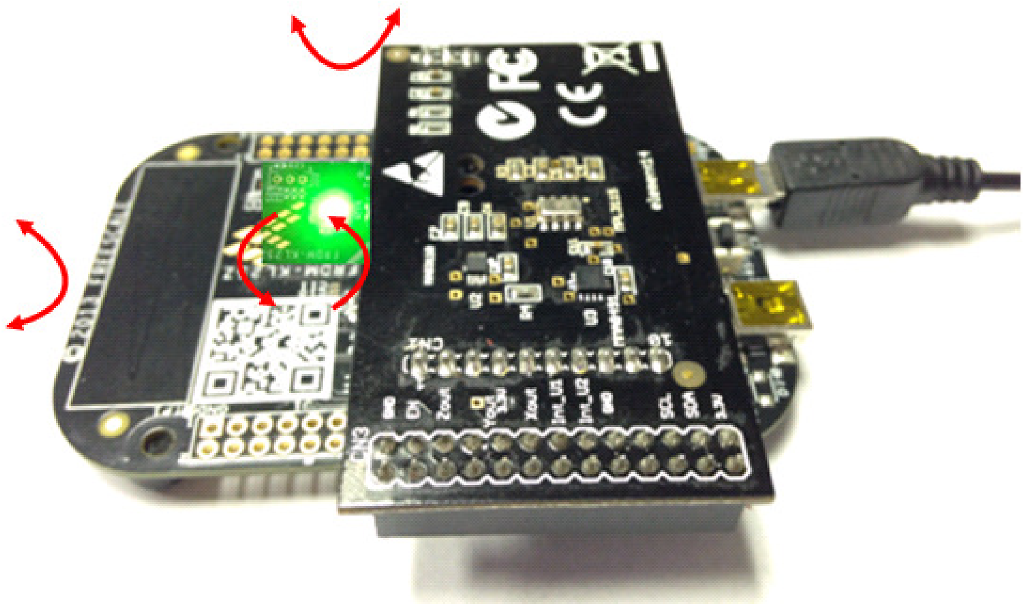
```
MAG3110:        X.-   8uT       Y.+  11uT       Z.-  30uT
MAG3110:        X.-   9uT       Y.+  10uT       Z.-  31uT
MAG3110:        X.-  11uT       Y.+   8uT       Z.-  32uT
MAG3110:        X.-  11uT       Y.+   5uT       Z.-  33uT
MAG3110:        X.-   9uT       Y.+   0uT       Z.-  32uT
MAG3110:        X.-   5uT       Y.-   1uT       Z.-  33uT
MAG3110:        X.-   3uT       Y.-   2uT       Z.-  32uT
MAG3110:        X.-   1uT       Y.-   1uT       Z.-  31uT
MAG3110:        X.+   0uT       Y.+   0uT       Z.-  30uT
MAG3110:        X.+   1uT       Y.+   2uT       Z.-  27uT
MAG3110:        X.+   1uT       Y.+   1uT       Z.-  31uT
MAG3110:        X.+   0uT       Y.+   0uT       Z.-  28uT
MAG3110:        X.-   3uT       Y.+   0uT       Z.-  30uT
MAG3110:        X.-   7uT       Y.+   1uT       Z.-  31uT
MAG3110:        X.-  10uT       Y.+   5uT       Z.-  30uT
MAG3110:        X.-  10uT       Y.+  10uT       Z.-  29uT
MAG3110:        X.-   7uT       Y.+  12uT       Z.-  29uT
MAG3110:        X.-   4uT       Y.+  12uT       Z.-  30uT
MAG3110:        X.-   2uT       Y.+  12uT       Z.-  28uT
MAG3110:        X.-   1uT       Y.+  12uT       Z.-  30uT
MAG3110:        X.-   2uT       Y.+  12uT       Z.-  27uT
MAG3110:        X.-   2uT       Y.+  13uT       Z.-  30uT
MAG3110:        X.-   2uT       Y.+  13uT       Z.-  29uT
MAG3110:        X.-   2uT       Y.+  13uT       Z.-  30uT_
```

Figure 10 - MAG3110 Demo

8. Press the "Enter" key on the keyboard to return the menu, and type ‘S2’ to try out the MMA8491Q sensor

```
Sx          : Stream Polling 0=MPL3115A2, 1=MAG3110, 2=MMA8491Q
MPL3115A2> S2
```

Turn the board from side to side and from front to back to see the corresponding x, y, and z coordinates change as the board is tilted. At the same time, the RGB LED will begin blinking blue.



```
MMA8491Q:        X.- 129mg        Y.- 652mg        Z.+ 618mg
MMA8491Q:        X.- 220mg        Y.- 909mg        Z.+ 479mg
MMA8491Q:        X.-  38mg        Y.-1136mg        Z.+ 458mg
MMA8491Q:        X.+  33mg        Y.- 696mg        Z.+ 593mg
MMA8491Q:        X.+  36mg        Y.- 306mg        Z.+1001mg
MMA8491Q:        X.+  73mg        Y.+ 297mg        Z.+ 930mg
MMA8491Q:        X.+ 101mg        Y.+ 881mg        Z.+ 486mg
MMA8491Q:        X.+  14mg        Y.+1320mg        Z.+ 121mg
MMA8491Q:        X.+ 120mg        Y.+1203mg        Z.+  67mg
MMA8491Q:        X.+  99mg        Y.+ 491mg        Z.+ 506mg
MMA8491Q:        X.-  78mg        Y.-  17mg        Z.+1171mg
MMA8491Q:        X.-  50mg        Y.-   1mg        Z.+ 909mg
MMA8491Q:        X.- 131mg        Y.-  89mg        Z.+ 976mg
MMA8491Q:        X.- 184mg        Y.-  29mg        Z.+1175mg
MMA8491Q:        X.-  87mg        Y.+  70mg        Z.+ 904mg
MMA8491Q:        X.-  95mg        Y.-  74mg        Z.+1026mg
MMA8491Q:        X.-  72mg        Y.+  33mg        Z.+1057mg
MMA8491Q:        X.-  84mg        Y.+   0mg        Z.+1036mg
MMA8491Q:        X.-  88mg        Y.+  33mg        Z.+1002mg
MMA8491Q:        X.-  76mg        Y.+  24mg        Z.+1015mg
MMA8491Q:        X.-  71mg        Y.+  49mg        Z.+1017mg
MMA8491Q:        X.-  88mg        Y.+  50mg        Z.+ 986mg
MMA8491Q:        X.- 118mg        Y.+  30mg        Z.+1023mg
MMA8491Q:        X.- 153mg        Y.+  64mg        Z.+ 987mg_
已连接 0:14:4  自动检测  115200 8-N-1  SCROLL  CAPS  NUM  捕  打印
```

Figure 11 - MMA8491Q Demo

Demonstration w/ Raspberry Pi

The demonstrations detailed below include set-up and programming of the Raspberry Pi specifically for use with the XTRINSIC-SENSE BOARD.

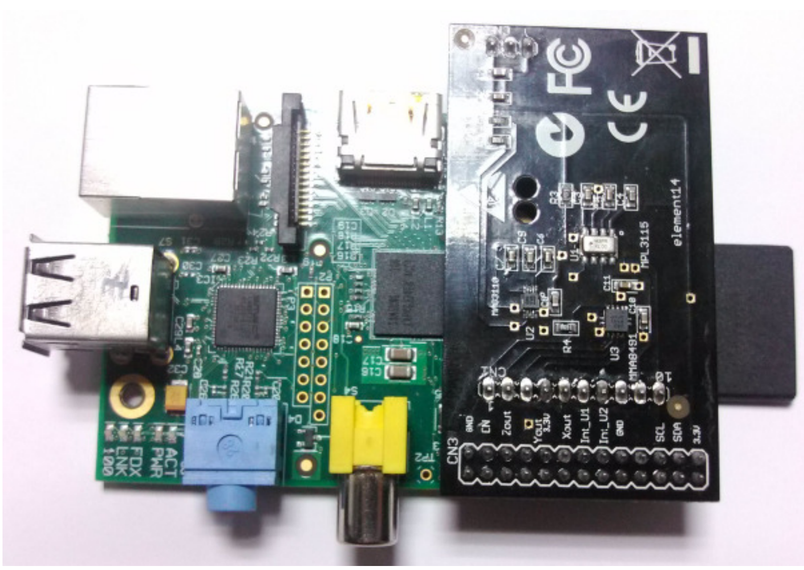
The demonstrations include terminal level demonstrations and web applications demonstrations. Note, the web application demonstrations require a network connection. These demonstrations are enabled though a supplied custom image file for Raspberry Pi to support connection to the XTRINSIC-SENSE BOARD.

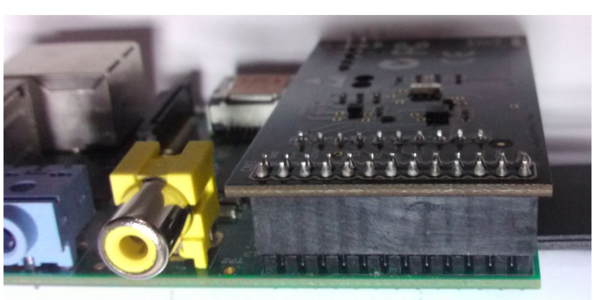
The final section includes details on how a user can modify the standard default Raspberry Pi image in order to use the I2C connection to run the same terminal and web application demonstrations.

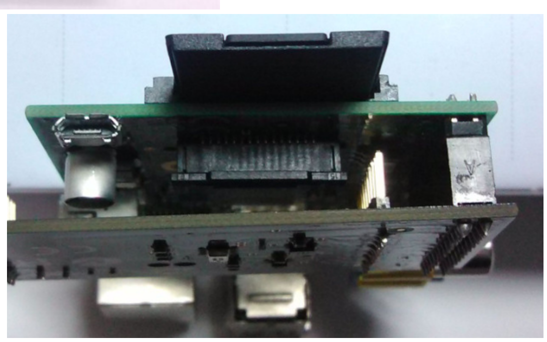
NOTE: The setup and terminal demonstration tests covered in steps 1 thru 7 (below) are also provided in the QuickStart Guide. A QuickStart Guide fold-out accompanies the XTRINSIC-SENSE BOARD kit and is also available on-line here:

Setup and Configuration

1. Connect the XTRINSIC-SENSE BOARD to the Raspberry PI board as shown below.



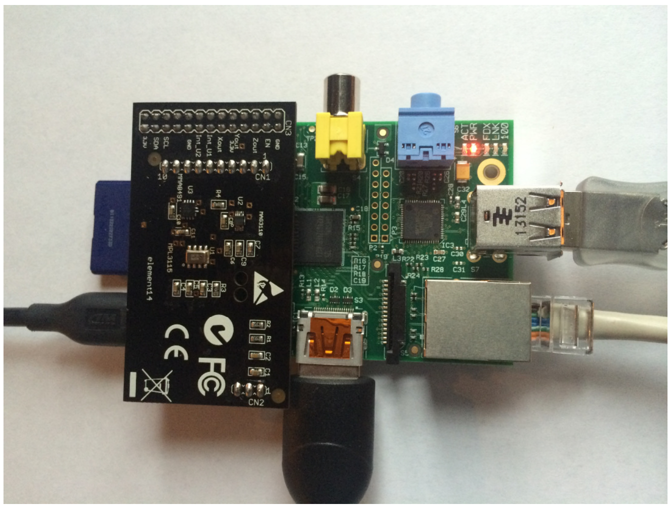




2. Download the custom operating system image offered and flash it to an SD card (4MB+). The custom Image for use with XTRINSIC-SENSE BOARD is available here:

   http://www.element14.com/mems_sense

3. Power on Raspberry Pi with a USB cable connection (as shown). Provide additional connections for needed peripherals.



4. Once in Raspberry Pi console mode enter in username (**pi**) and password (**raspberry**).

Sensor Terminal Tests

These following tests are run by executing python demo scripts *(described here)*:

- **mag3110.py**
  Test the Xtrinsic MAG3110 three-Axis, digital magnetometer, console will output the three-axis magnetometer value. *(The mag3110 can be calibrated by first running the mag3110_calibrate.py script. Calibration data will be stored in mag_calibration.data.)*

- **mpl3115a2.py**
  Test the Pressure/Altitude and Temperature, console will output the Temperature and Pressure/Altitude.

- **mma8491q.py**
  Test the Xtrinsic MMA8491Q 3-Axis multifunction digital accelerometer, console will output the 3-axis accelerometer data.

5. Test the MAG3110 sensor by entering the following at the Raspberry Pi's terminal prompt:

```
pi@raspberrypi:~$ cd ~/rpi_sensor_board/
```

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mag3110.py
```

The expected console output will look similar to the following:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mag3110.py
-572 645 0
MAG3110:        X. -17 uT       Y. 20 uT        Z. -56 uT
MAG3110:        X. -17 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 20 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 19 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 19 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 19 uT        Z. -57 uT
MAG3110:        X. -18 uT       Y. 18 uT        Z. -57 uT
```

Type “Ctrl+C” to exit test and get back to terminal prompt.

6. Test the MPLA3115A2 sensor by entering the following at the Raspberry Pi’s terminal prompt:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mpl3115a2.py
```

The expected console output will look similar to the following:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mpl3115a2.py
MPL3115:        Alt. -52.0      Temp: 21.192
MPL3115:        Alt. -52.0      Temp: 21.192
MPL3115:        Alt. -52.0      Temp: 21.192
MPL3115:        Alt. -52.0      Temp: 21.192
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.888    Temp: 21.176
MPL3115:        Alt. -51.2      Temp: 21.176
```

Type “Ctrl+C” to exit test and get back to terminal prompt.

7. Test the MMA8491Q sensor by entering the following at the Raspberry Pi’s terminal prompt:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mma8491q.py
```

The expected console output will look similar to the following:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mma8491q.py
MMA8491Q:       X. -310 mg      Y. -16 mg       Z. 996 mg
MMA8491Q:       X. -129 mg      Y. -22 mg       Z. 1051 mg
MMA8491Q:       X. -135 mg      Y. -2 mg        Z. 1052 mg
MMA8491Q:       X. -139 mg      Y. -15 mg       Z. 1070 mg
MMA8491Q:       X. -131 mg      Y. -3 mg        Z. 1041 mg
MMA8491Q:       X. -138 mg      Y. -10 mg       Z. 1046 mg
MMA8491Q:       X. -109 mg      Y. -15 mg       Z. 1029 mg
MMA8491Q:       X. -127 mg      Y. -11 mg       Z. 1031 mg
MMA8491Q:       X. -137 mg      Y. -13 mg       Z. 1035 mg
MMA8491Q:       X. -154 mg      Y. 2 mg         Z. 1063 mg
MMA8491Q:       X. -127 mg      Y. -9 mg        Z. 1056 mg
MMA8491Q:       X. -135 mg      Y. -19 mg       Z. 1053 mg
MMA8491Q:       X. -148 mg      Y. -12 mg       Z. 1039 mg
```

Type “Ctrl+C” to exit test and get back to terminal prompt.

Sensor Web Application Tests

These following web application tests require the Raspberry Pi to have network connection to the same network as an available PC’s local area network (LAN).

8. Once the Raspberry Pi is network connected obtain the IP inet address using the ifconfig command:

```
pi@raspberrypi:~$ ~/rpi_sensor_board $  ifconfig
```

The expected terminal display will similar to the following:

```
eth0      Link encap:Ethernet  HWaddr b8:27:eb:95:5c:56

          inet addr:192.168.2.138  Bcast:255.255.255.255  Mask:255.255.255.0

          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1

          RX packets:5644 errors:0 dropped:0 overruns:0 frame:0

          TX packets:3620 errors:0 dropped:0 overruns:0 carrier:0

          collisions:0 txqueuelen:1000
```

*NOTE: In this example case the Raspberry Pi’s IP address is: **192.168.2.138**. We will use this example IP address in the rest of the demo examples described below. For your testing use the IP address found for your specific case in place of this IP address.*

9. Upload the sensor data to the web application (invoked later on a network connected PC) by entering the following at the Raspberry PI's terminal command prompt:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python3 sensor_website.py
```

Console output:

```
pi@raspberrypi:~/rpi_sensor_board$ sudo python3 sensor_website.py
Input your choice for sensor
 1. mag3110
 2. mpl3115
 3. mma8491
 0. exit
Your choice:
```

Compass Application

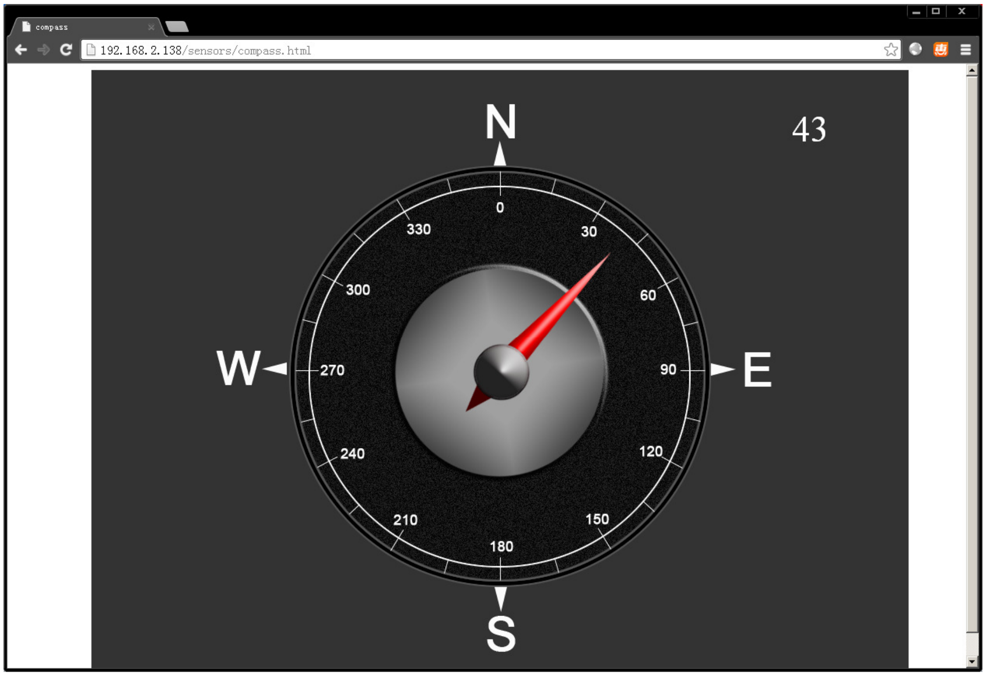
10. Choose 1 to test the MAG3110. Note the console output:

```
Your choice: 1
=================================================================
mag3110 sensor data will upload to compass.html
Use browser to open http://<rpi IP>/sensors/compass.html
Horizontally rotate your board, you can see the compass rotation
=================================================================
Your choice:
```

11. On a network connected PC, open a browser and enter in web address as instructed above. For this example that would be:

http://192.168.2.138/sensors/compass.html

12. The following should be displayed in the PC's browser:



Manually rotate the Raspberry Pi board to see corresponding movement on the compass display.

****

Tip *(optional)*

13. If the compass direction does not appear accurate, try calibrating using the following steps:

Enter in the following at the command prompt:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mag3110_calibrate.py
```

Console output:

```
pi@raspberrypi ~/rpi_sensor_board $ sudo python mag3110_calibrate.py
Calibrate your mag3110 sensor, Now horizontally rotate your board for 360 degrees
If you have done, press 0 to exit:
```

14. After exiting the calibration mode, try manually turning the Raspberry Pi board again and note the compass direction indicated in the PC browser's display. Check for better accuracy.

Temperature Application

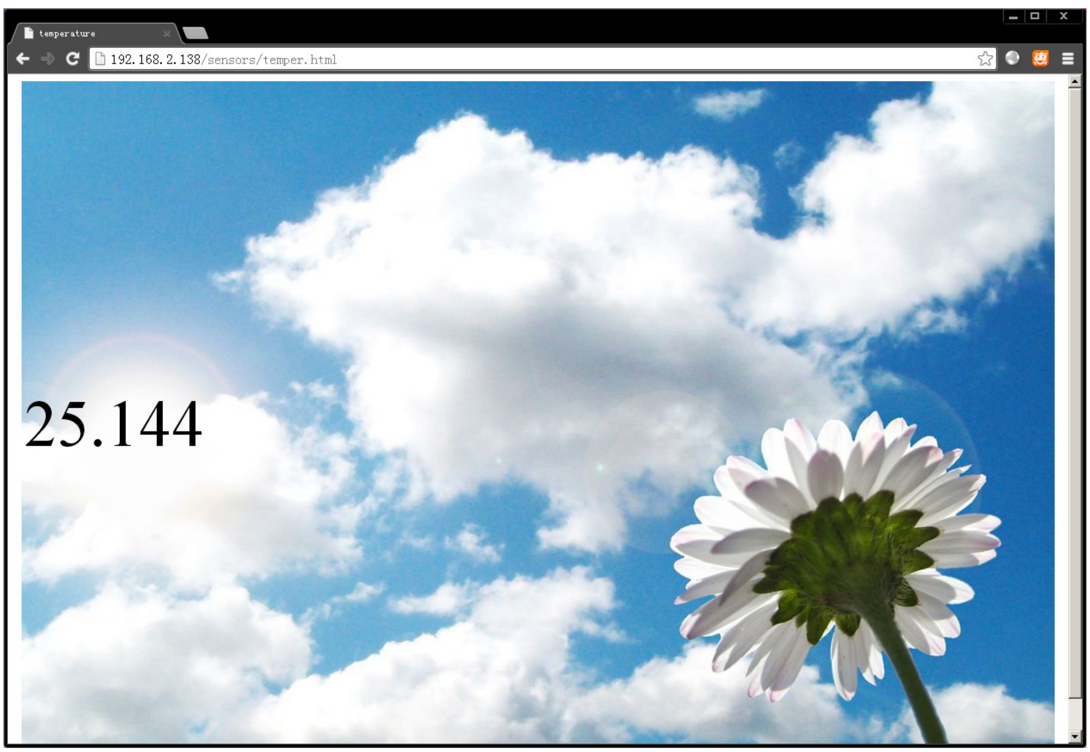
15. At the Raspberry Pi's console output choose **2** to test the MPL3115. The console output should display the following output:

```
Your choice: 2
=================================================================
mpl3115 sensor data will upload to temper.html
Use browser to open http://<rpi IP>/sensors/temper.html
Touch your sensor board, you can see temperature value
=================================================================
Your choice:
```

16. Re-direct the network connected PC's browser to the web address indicated above. For this example that would be:

    http://192.168.2.138/sensors/temper.html

17. The following should be displayed in the PC's browser. The temperature is displayed digitally in degrees C. For example, **25.144**° C. Touching or blowing on the MPL3115 (refer to Figure 1) should cause the temperature displayed to change.



Running Car Application

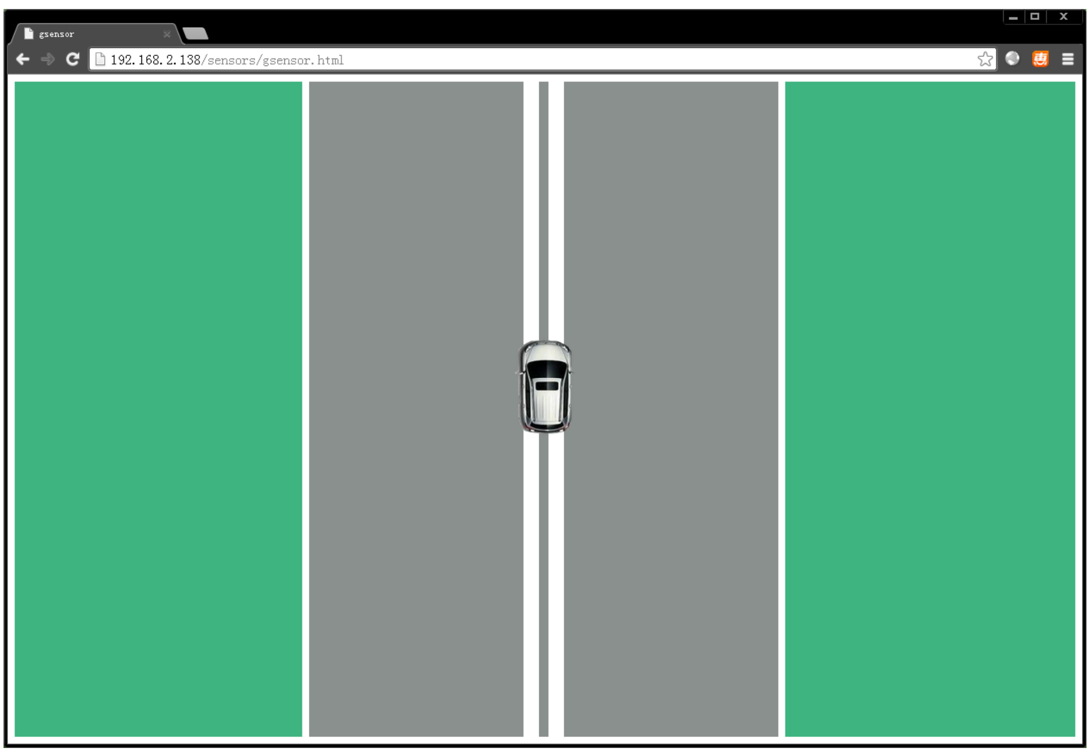
18. At the Raspberry Pi's console output choose **3** to test the MMA8491. The console output should display the following output:

```
Your choice: 3
=================================================================
mma8491 sensor will upload to gsensor.html
Use browser to open http://<rpi IP>/sensors/gsensor.html
The small car on the web will be controled by the board.
Vertical and horizontal rotation will move the car correspondingly
=================================================================
Your choice:
```

19. Re-direct the network connected PC's browser to the web address indicated above. For this example that would be:

    http://192.168.2.138/sensors/gsensorr.html

20. The following should be displayed in the PC's browser. Move and tilt the Raspberry Pi board to affect position of the car displayed on the screen.



21. Enter a choice of **0** or Ctrl-C to exit the testing.

This completes the terminal and web application demonstration tests for the XTRINSIC-SENSE BOARD with Raspberry Pi.

Make your own RPi image to support XTRINSIC-SENSE BOARD connection

The following sections provide instructions for editing and constructing a Raspberry Pi Flash image starting with an official RPi image file. The instructions include details on how to manually update an official RPi image to support the same terminal and web applications demonstrations detailed in steps 5 thru 21 above.

This section assumes user knowledge on accessing an official RPi image and programming it to Flash. This detail is NOT covered in this document.

Set-up

22. Follow step 1, 3 and 4 in the previous section to set-up, connect, and power the Raspberry Pi with XTRINSIC-SENSE BOARD.

Terminal tests

The XTRINSIC-SENSE BOARD communicates with the Raspberry Pi using the I2C interface. The I2C interface driver is included in later Raspbian distributions but is not enabled by default. You can always enable the I2C driver, or you can load it by hand when required. To always enable the I2C driver:

23. After logging into RPi, edit `/etc/modprobe.d/raspi-blacklist.conf` by typing:

```
$ sudo nano /etc/modprobe.d/raspi-blacklist.conf
```

24. Insert a hash(#) at the start of the line blacklist i2c-bcm2708, it should be read:

```
# blacklist i2c-bcm2708
```

Alternatively, to load the I2C driver by hand (will not be loaded on reboot):

Ctrl-X to save

25. Type in a terminal:

```
$ sudo modprobe i2c-bcm2708
```

26. Next, you need to install the sensor drivers. Download the driver and python test scripts from:

```
git clone http://git.oschina.net/embest/rpi_sensor_board.git
```

27. When the downloading finished, reboot your Raspberry Pi:

```
$ sudo reboot
```

28. Then you can test the sensor from terminal. Refer to steps 5 thru 7 above to run terminal demonstration tests.

Web application tests

29. Install the web server:
    - Install nginx web server, by typing:
      `sudo apt-get install nginx`
    - Start the nginx web server, typing:
      `sudo /etc/init.d/nginx start`

   The defualt server root is: /usr/share/nginx/www

30. Install the php package:
    - Install php, by typing:
      ```
      sudo apt-get update
      sudo apt-get install php5-fpm
      ```
    - Edit the config file of nginx
      `sudo nano /etc/nginx/sites-available/default`
    - Find the line start with *# listen 80*, delete the hash(#) , it should be read:
      `listen 80; ## listen for ipv4.`
    - Find the line start with *index*, add index.php, then it should be read:
      `index index.php index.html index.htm`
    - Find the definition of php, only delete the hashs(#) ahead of the following lines, it should be read:
      ```
      location ~ \.php$ {
      fastcgi_pass unix:/var/run/php5-fpm.sock;
      fastcgi_index index.php;
      include fastcgi_params;
      }
      ```

      Do not touch the other definitions.

31. Now, reload the config of **nginx** server:
    - `sudo /etc/init.d/nginx reload`

32. Test if the web server is up by browser. Should see something like the following screen:

33. Deploying the Web Application
    - Direct use symbolic links (created via ln-s) to complete the deployment, typing:

```
sudo ln -s
/home/pi/rpi_sensor_board/Rpi_Xtrinsic_Sensors/rpi_sensors_web/
/usr/share/nginx/www/sensors
```

    - Make proper access rights to the web app:

```
sudo chmod 0777 -R
/home/pi/rpi_sensor_board/Rpi_Xtrinsic_Sensors/rpi_sensors_web/
```

34. Test the Web applications in the same manners as described in steps 8 thru 21 above.

Hardware

This document includes the hardware design files for the XTRINSIC-SENSE BOARD on the following pages of this document.

Details on the supported host platforms can be found as noted below,

- For the Freescale FRDM-KL25Z board, please refer to:
  http://www.element14.com/community/docs/DOC-46626

- For the Raspberry Pi board please refer to:
  http://www.element14.com/community/docs/DOC-42993/l/raspberry-pi-single-board-computer

Schematic

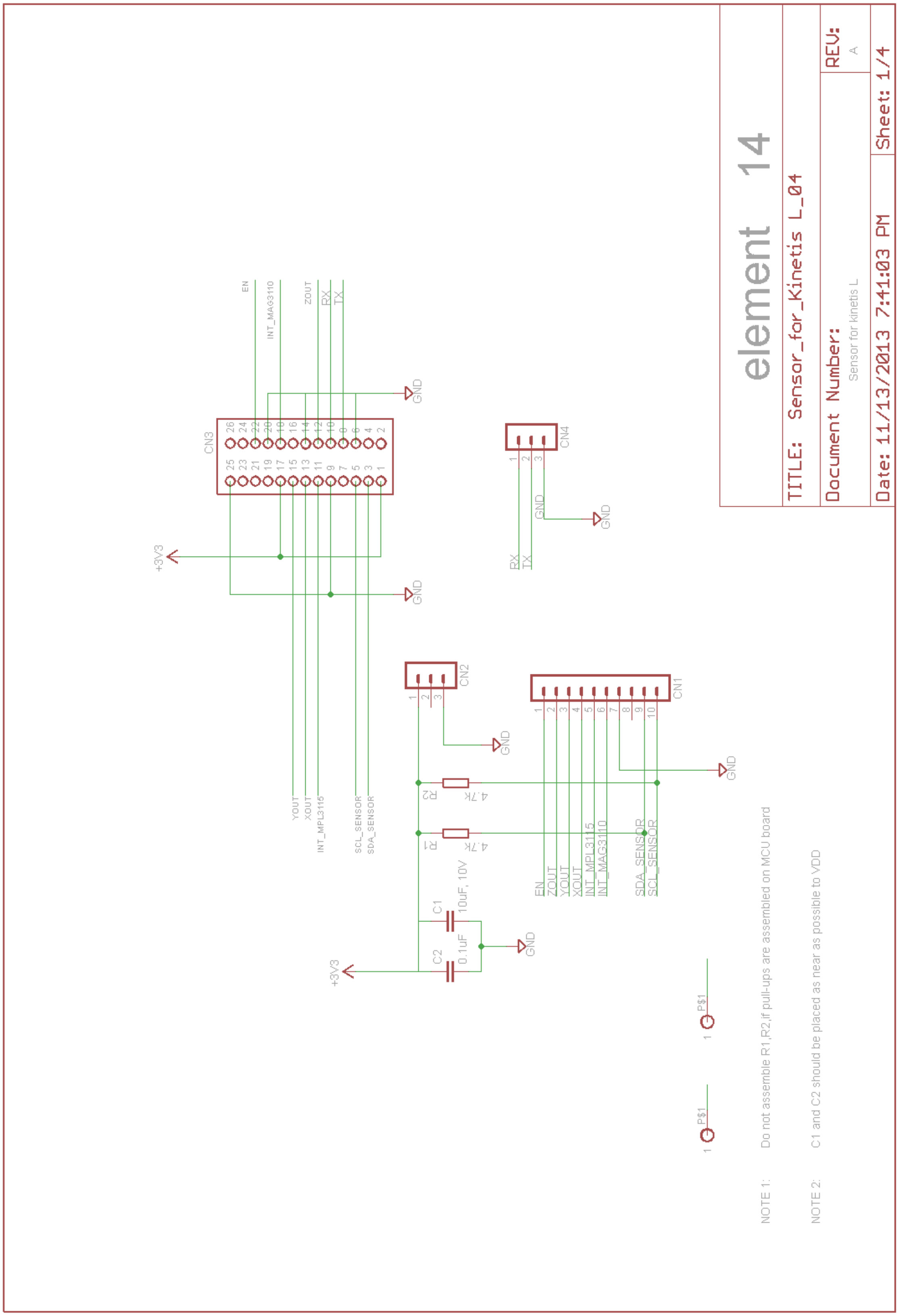


Figure 12 - Sensor Board Schematic - 1

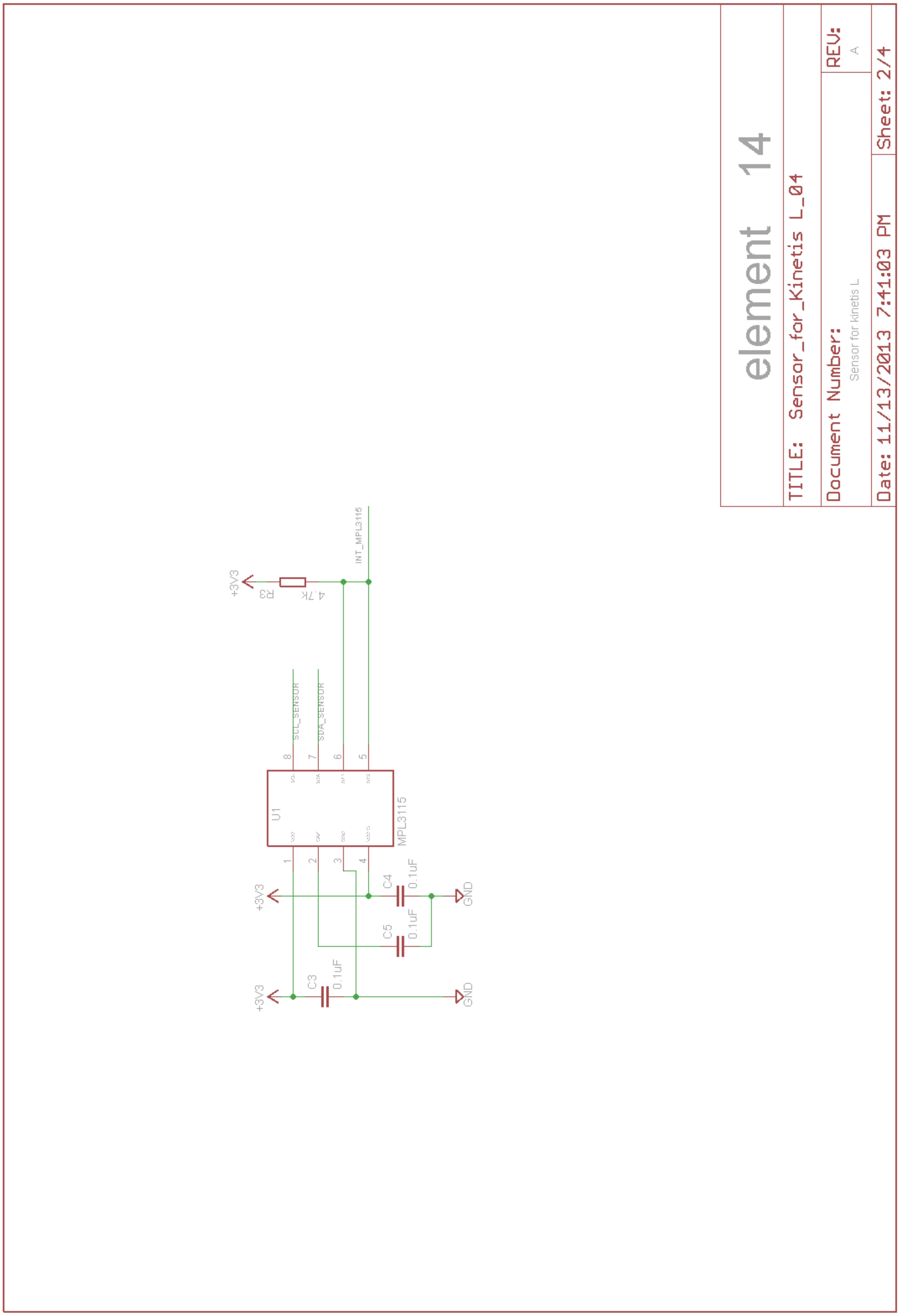


Figure 13 - Sensor Board Schematic - 2

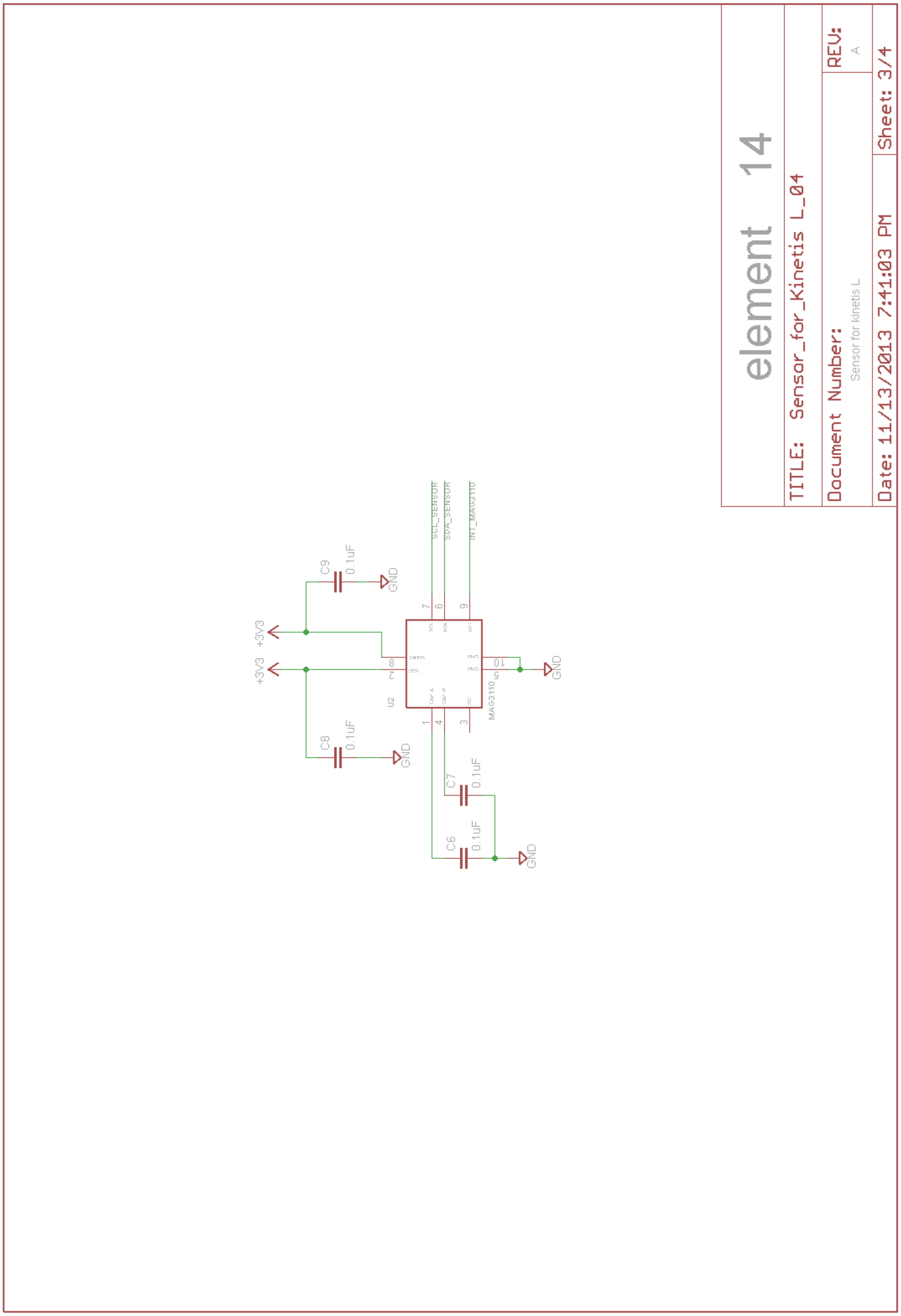


Figure 14 - Sensor Board Schematic - 3

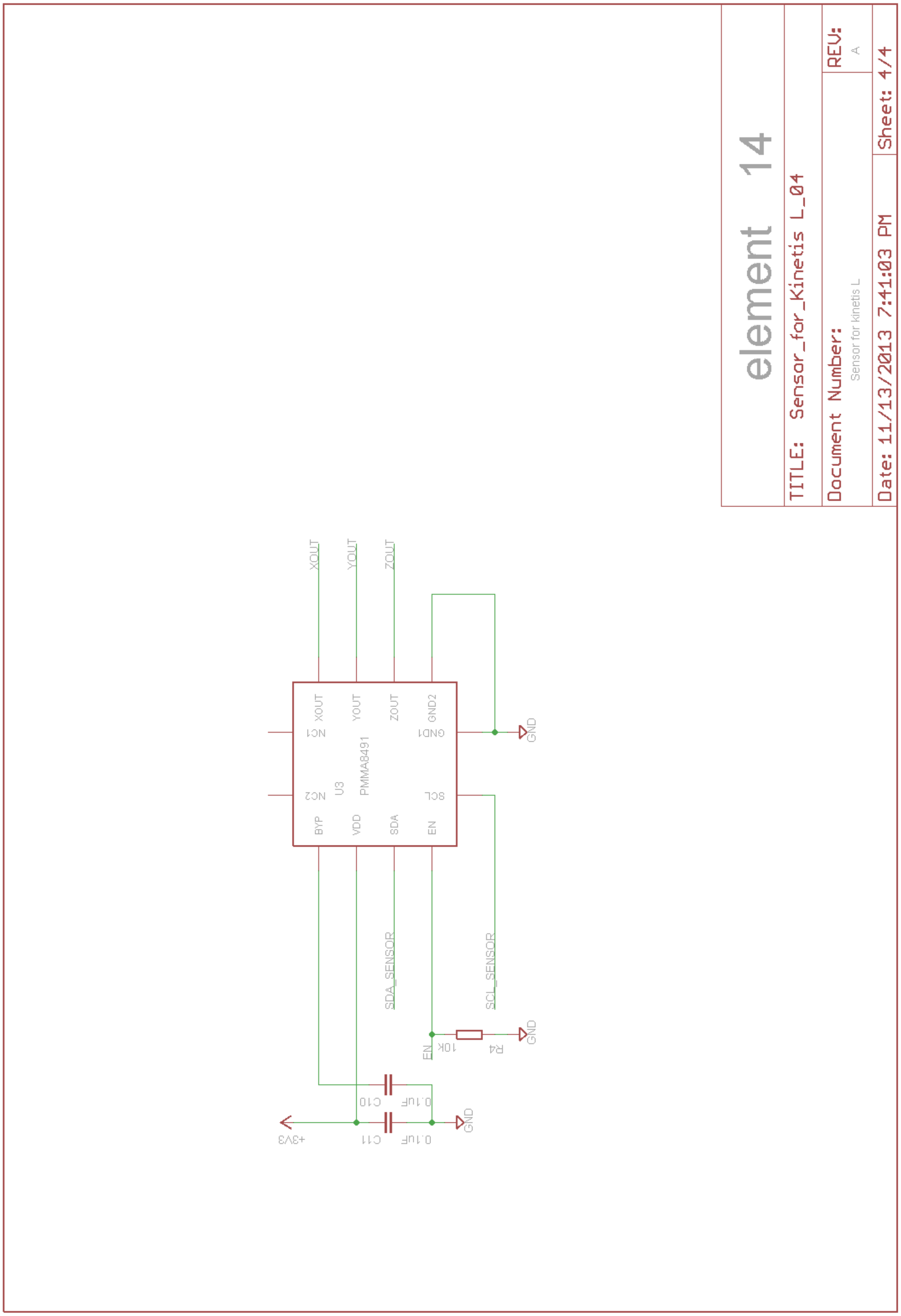


Figure 15 - Sensor Board Schematic - 4

PCB Layout

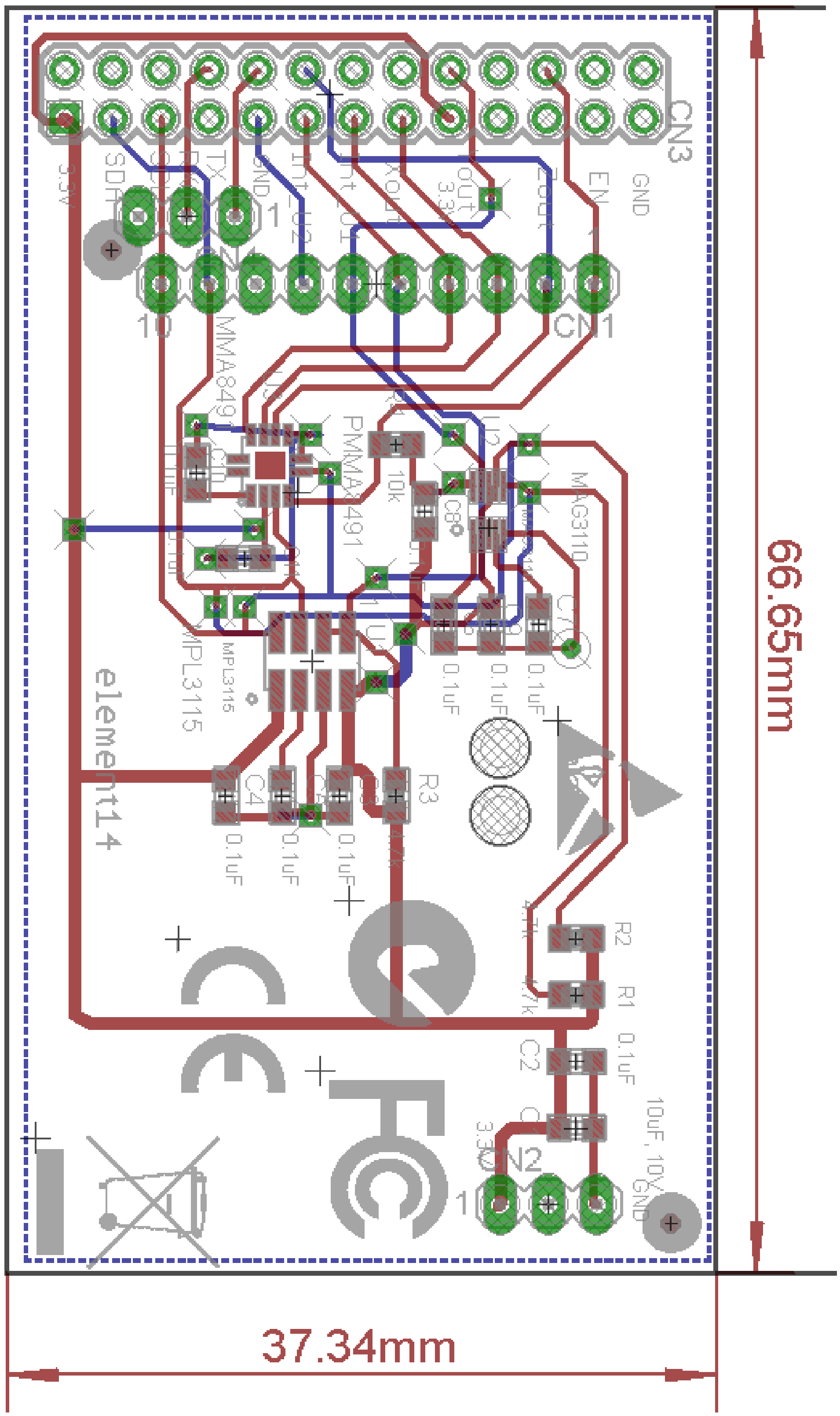


Figure 16 - Sensor Board PCB TOP View

Bill of Materials

Reference	Description	Manufacturer	Part No.	Farnell	Newark	Priority
U1	PRESSURE SENSOR, 20-110KPA					
		FREESCALE	MPL3115A2	2009084	61T7697	Preferred
U2	MAGNETOMETER, 3AXIS, I2C, 80HZ					
		FREESCALE	MAG3110FCR1	2080492	83T2982	Preferred
U3	ACCELEROMETER - SENSOR, QFN-16					
		FREESCALE	MMA8491Q	2291592	47W865	Preferred
C1	MLCC, 0603, 6.3V, 10UF					
		KEMET	C0603C106M9PACTU	1288201	86K0597	Preferred
		TAIYO YUDEN	JMK107BJ106MA-T	1463375	30K5476	Alternate
		AVX	QM036D106MAT	1867960	20T0206	Alternate
C2~ C11	MLCC, 0603, 16V, 0.1UF					
		AVX	CM105X7R104K16AT	1216538	01M7218	Preferred
		KEMET	C0603C104J4RACTU	1650834	64K2836	Alternate
		MULTICOMP	B0603R104KCT	9406140	37K9922	Alternate
R1, R2, R3	RESISTOR, 0603, 4.7K, 1%					
		MULTICOMP	MCHP03W8F4701T5E	1576293	01N6891	Preferred
		VISHAY	CRCW06034K70FKEA	1469807	52K8494	Alternate
		YAGEO	RC0603FR-074K7L	1117265	98K7410	Alternate
R4	RESISTOR, 0603, 10K, 1%					
		MULTICOMP	MCHP03W8F1002T5E	1576297	01N6844	Preferred
		VISHAY	CRCW060310K0FKEA	1469748	52K8063	Alternate
		YAGEO	RC0603FR-0710KL	1117235	68R0049	Alternate
CN1	HEADER, 2.54MM, VERTICAL THT, 10WAY					
		MOLEX	90120-0770	9733353	25M5816	Preferred
		SAMTEC	HTS-110-G-A	1929555	83T9016	Alternate
CN2, CN4	HEADER, 2.54MM, VERTICAL THT, 3WAY					
		TE	825433-3	3417657	99K0795	Preferred
		SAMTEC	HTS-103-G-A	1926586	83T8997	Alternate
CN3	HEADER, 2.54MM, 2x13					
			JT254-D180-850-213-001			

Table 28 - XTRINSIC-SENSE Board BOM list

ESD PRECAUTIONS AND PROPER HANDLING PROCEDURES

This section includes the precautions for mechanical handling and static precautions to be taken to avoid ESD damage:

- Avoid carpets in cool, dry areas. Leave development kits in their anti-static packaging until ready to be installed.
- Dissipate static electricity before handling any system components (development kits) by touching a grounded metal object, such as the system unit unpainted metal chassis.
- If possible, use antistatic devices, such as wrist straps and floor mats.
- Always hold a evaluation board by its edges. Avoid touching the contacts and components on the board.
- Take care when connecting or disconnecting cables. A damaged cable can cause a short in the electrical circuit.
- Prevent damage to the connectors by aligning connector pins before you connect the cable. Misaligned connector pins can cause damage to system components at power-on.
- When disconnecting a cable, always pull on the cable connector or strain-relief loop, not on the cable itself.