SCL SENSOR
EVALUATION BOARD
SSEB V2.0

For
MEMS Based Accelerometer
& Accelerometer Signal Conditioner (SC1259)

INCLINOMETER/ TILT SENSOR

User Operational Manual

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CONTENTS

1. Introduction

SSEB V2.0 is aimed to help students to leans:

- Signal Conditioning for Capacitive Sensors.
- Sensor Calibration algorithm.
- Calculation of Inclination/Tilt angles
- Develop & Implement their own algorithms.

SSEB V2.0 is aimed to evaluate following components/ application:

- SCL Capacitive Accelerometer Sensor (1.2 g)
- SCL Accelerometer Signal Conditioner Readout ASIC IC SC1259
- SSEB V2.0 is aimed to develop applications for inclination/ tilt measurement

Evaluation Mode

To operate EV Board, connect the board to any USB port of a PC/Laptop through USB cable, provided with the kit.

- A C# based windows GUI will read & display calibrated values of accelerometers corresponding to X & Y axis. C# based GUI software can be downloaded from SCL website. Following parameters are displays:
- Tilt (degrees)
- Acceleration (g)
- Capacitance (pF)

Student can download Reference User Manual from SCL website. Manual contains details of SSEB V2.0 Hardware & Software for ready reference.

For Evaluation, C# based GUI software can be downloaded from SCL website.

For Development, Arduino based firmware can be downloaded from SCL website. Arduino programming IDE can be downloaded from Arduino website.

Un-boxing demo video can also be seen from SCL website.

2. Kit Details & Downloads

S. No.	SCL Sensor Evaluation Board (SSEB V2.0) Kit Details	
1	SSEB V2.0 Box contains assembled Board with following parts designed & developed by SCL	
	1a	Accelerometer MCM (U1) for X axis
	1b	Accelerometer MCM (U4) for Y axis
	1c	Mounting Connectors compatible with Arduino UNO board J1 & J2 (J2-A & J2-B)
2	Arduino UNO R3 Board	
3	USB interface data Cable	

S. No.	Available downloads	Links
1	Firmware for C# based GUI **"Firmware_SSEB-V2.0_Csharp_ GUI.ino"**	**https://www.scl.gov.in/sys_dev.html** SCL Home Page ➢ SCL Facilities ➢ System Development 
2	C# Based GUI software **"GUI_Software_SSEBV-2.0_Csharp_ V2.0.exe"**	
3	User Operational Manual	
4	Sensor & IC Datasheets	
5	Un-boxing demo Video	
6	Firmware for Arduino IDE **"Firmware_SSEB-V2.0_Aurduino_ IDE.ino"**	
7	Software Arduino IDE (Arduino IDE 2.2.1 or latest)	**https://www.arduino.cc/en/software**

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3. Operational Procedure:

Operation of EV Board requires firmware code (already downloaded into EV board hardware) & software code (GUI/IDE) to get desired values on PC/Laptop. Procedure is as follows:

i. Download the C# based GUI software: **"GUI_Software_SSEB-V2.0_Csharp_V2.0.exe"** from SCL website. Connect EV Board using USB cable to PC/Laptop. Run the **exe** file in windows OS. It will display calibrated pressure and temperature readings in different scientific units.

ii. Default Firmware code **"Firmware_SSEB-V2.0_Csharp_GUI.ino** is already downloaded in EV Board. Also available at SCL website to download. Use this firmware for restoring factory default settings by using coefficients mentioned in EV Board KIT.

Required Equipments:

1. PC/Laptop
2. Pressure Source
3. Sensor temperature source

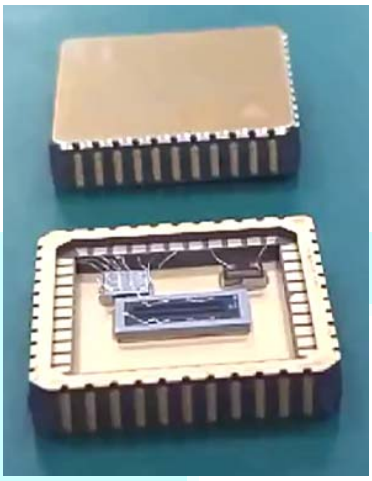
4. Hardware Description

Kit includes an assembled SSEB V2.0 and a USB cable. Major components mounted are accelerometer multi chip modules (MCMs, U1 & U2) which contains MEMS sensor, SC1259 and temperature sensor within same package (CLCC-44). SSEB V2.0 is pin compatible with Arduino Uno R3 board for interface & display at PC through USB cable.

Component List

Reference	Quantity	Description
U1	1	Accelerometer MCM for X-Axis (Top)
U2	1	LT1761, Linear Voltage Regulator (Not Mounted)
U3	1	PIC18F13K22, Microcontroller (Not Mounted)
U4	1	Accelerometer MCM for Y-Axis (Bottom)
Jumpers/Connectors & Solder Select		
J1	1	CON15-BERG: Power Connector
J2	1	CON4-BERG: I2C Signal (used when U3 mounted)
J2-A	1	CON8-BERG: Arduino Digital 8-Pin Connector (Data Ready Signal, DRDY-X, DRDY-Y)
J2-B	1	CON10; Arduino Digital 10-Pin Connector (SPI signals)
J3	1	CON5-BERG: Used for Programming U3
SS1	1	Solder Short between DVSS & AVSS
SS2	1	Solder Short between DVDD & AVDD
SS3	1	Selecting DVDD 5.0V or 3.3V
SS4	1	Solder Short, used when U2 used
SS5	1	Solder Short, used to by pass U2
Other Passive Components		
C1, C2, C3, C5, C6, C9, C10, C11, C12, C14, C15, C16	12	0.1µF ceramic X7R capacitors
C4, C7	2	1.0 µF ceramic X7R capacitors
C8, C13	2	0.01 uF ceramic X7R capacitors
R1, R7, R6, R18	4	4.75KΩ Resistor
R2, R3	2	10KΩ Resistor
R8, R10, R12, R14, R16	5	1KΩ Resistor
R89, R11, R13, R15, R17	5	2KΩ Resistor
R4, R5	2	Used when U2 mounted for 3.3V

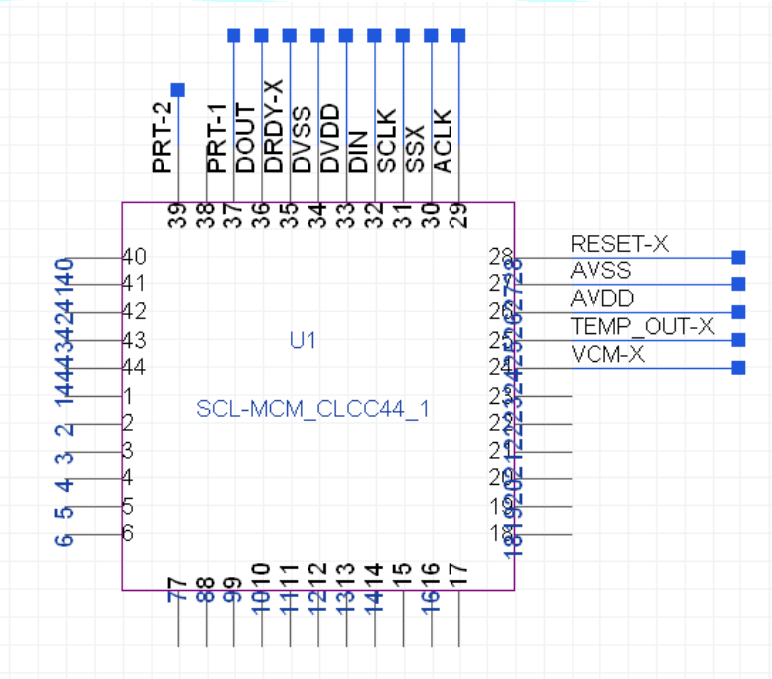
Accelerometer Multichip Modules (U1 & U4)



Accelerometer Multichip Module (MCM, CLCC-44) contains following components:

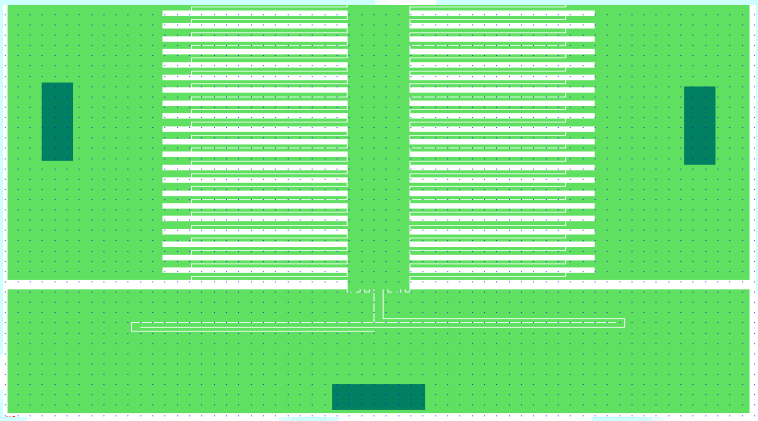
- MEMS Based Accelerometer (1.2g)
- Accelerometer Signal Conditioner IC, SC1259
- Temperature Sensor (PRT)

Accelerometer Multichip module (MCM) pin details are as below:



MEMS Based Accelerometer (1.2g)

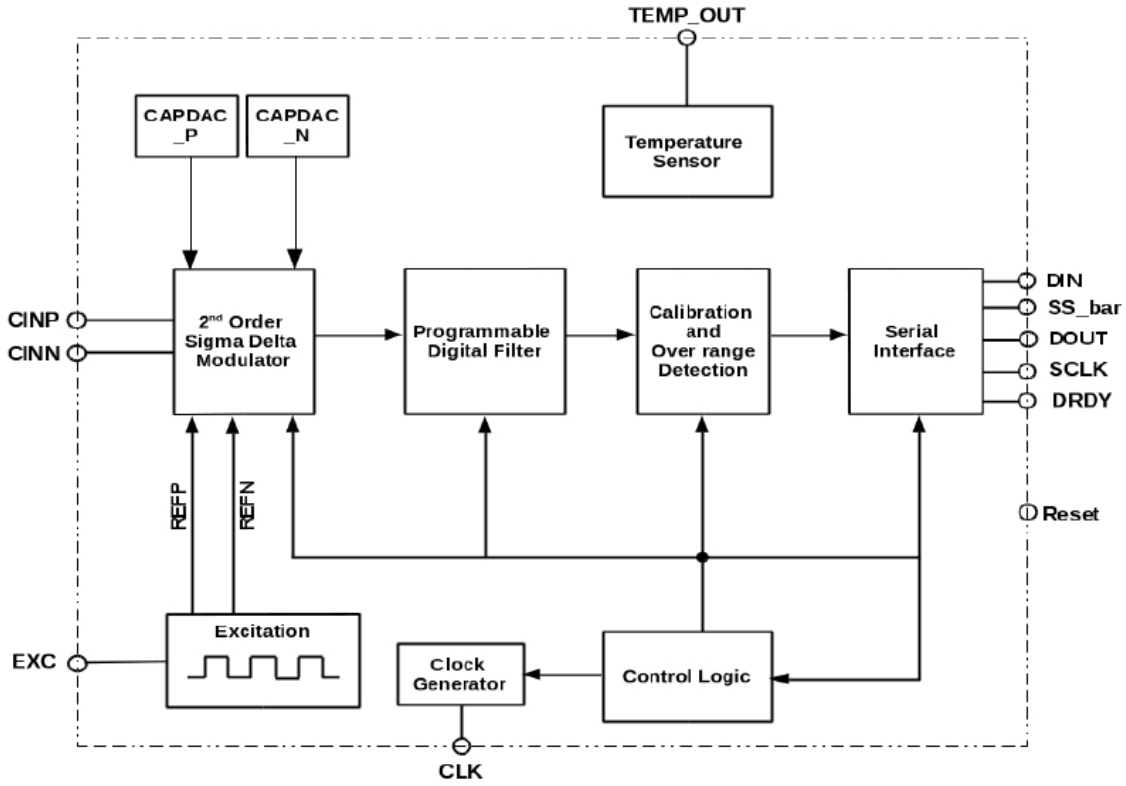
SCL developed MEMS based accelerometer measures acceleration/ inclination angle by changing it's capacitance. Multiple arrays of capacitors are used to increase sensitivity. Sensor forms a comb shaped capacitive structure with one electrode fixed and another electrode attached with movable proof mass. When an external force is applied the proof mass deflects causing change in sensor capacitance.



Accelerometer Signal Conditioner IC, SC1259

Accelerometer Signal Conditioner (ASC) is a Sigma Delta Modulator based high resolution Capacitance-to-Digital Converter. It senses the change in the differential capacitance connected at the input and produces a 24 Bit digital code proportional to this change. This device is developed for sensing the capacitance change of MEMS based Accelerometer and can be used in other similar applications as well. The capacitance to be sensed can be directly connected at the input of this device.

ASC incorporates a Second Order Sigma Delta (ΣΔ) Modulator. The ΣΔ Modulator converts the difference in the input differential capacitors into a digital 1 bit pulse train whose average duty cycle represents the digitized signal information. The pulse train is then processed by a digital sinc3 filter to produce a digital output. A block level diagram of the ASIC is shown below.

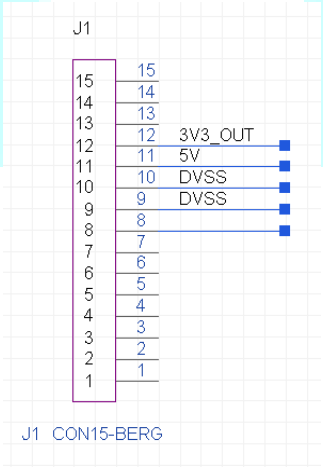


Temperature Sensor (PRT)

An un-committed Pt based temperature sensor is also assembled within CLCC-44 package. This sensor can be used to accurately measure the temperature of MEMS based accelerometer. SCL temperature sensor is Pt based thin film PRT. Sensor nominal resistance at 25°C is 1 KΩ.

Power Connector (J1)

SC1218 operates at 3.3V. Evaluation board supply voltage VDD is shorted with 3.3V output from Arduino Board as shown below:



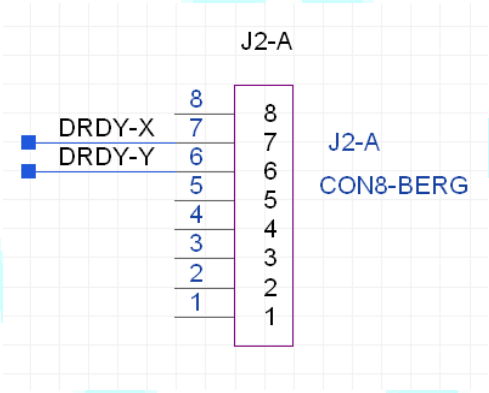
Pin	Signal	Description
1	NC	-
2	NC	-
3	NC	-
4	NC	-
5	NC	-
6	NC	-
7	NC	-
8	NC	-

Pin	Signal	Description
9	VSS	GND
10	VSS	GND
11	5V	Power Supply
12	3.3V	Power Supply
13	NC	-
14	NC	-
15	NC	-

Signal Connector (J2)

J2-A connector

Figure below shows the schematic part corresponding to J2-A connector.

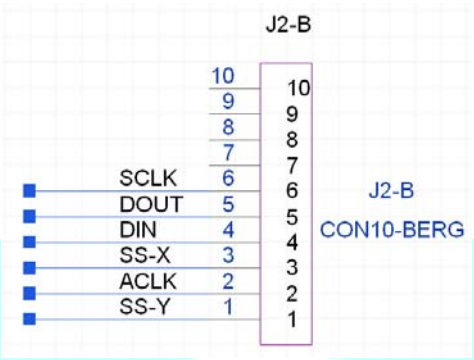


Pin	Signal	Description
1	NC	-
2	NC	-
3	NC	-
4	NC	-

Pin	Signal	Description
5	NC	-
6	DRDY-Y	Data Ready Signal, (active low)
7	DRDY-X	Data Ready Signal, (active low)
8	NC	-

(DRDY) Data Ready is active Low Signal. The DRDY pin is used as a status signal to indicate when new digital code is ready to be read from the ADC. DRDY goes low when new data is available. It becomes high when a read operation from the data register is executed using RDATA or RDATAC command. The DRDY pin goes high at the middle of read of 2nd MSB byte. In case, when no read operation is performed, DRDY will remain low. After switching channel (for reading pressure or temperature) wait for three DRDY active low cycles before reading the data of the switched channel.

J2-B connector

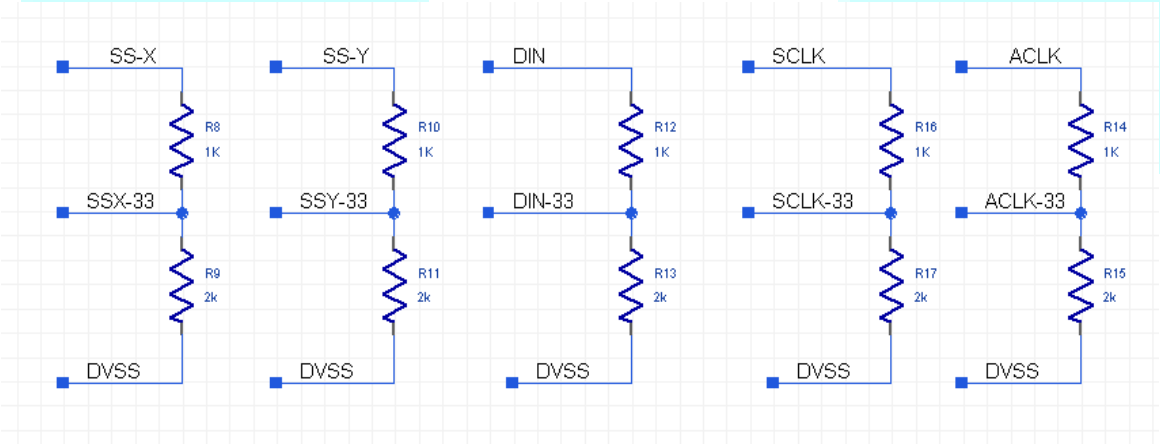


Pin	Signal	Description
1	SS-Y	Slave Select-Y, active Low
2	ACLK	ADC Clock Input
3	SS-X	Slave Select-X, active Low
4	DIN	Serial Data In
5	DOUT	Serial Data Out

Pin	Signal	Description
6	SCLK	SPI Serial Clock
7	NC	-
8	NC	-
9	NC	-
10	NC	-

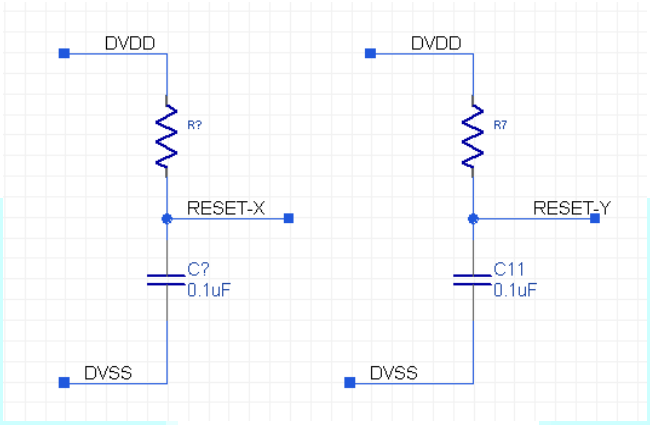
Level Translators:

Arduino Uno works for 5V supply and generates SPI signals of 5V level, whereas SC1259 is operated with a supply of 3.3V. Therefore level translators (5V to 3.3V) are incorporated in the evaluation board. Figure below shows the potential divider circuit part of schematic which is used as level translator.



Power On Reset

A power on reset RC circuit is implemented for SC1259. Details are shared in datasheet of SC1259.



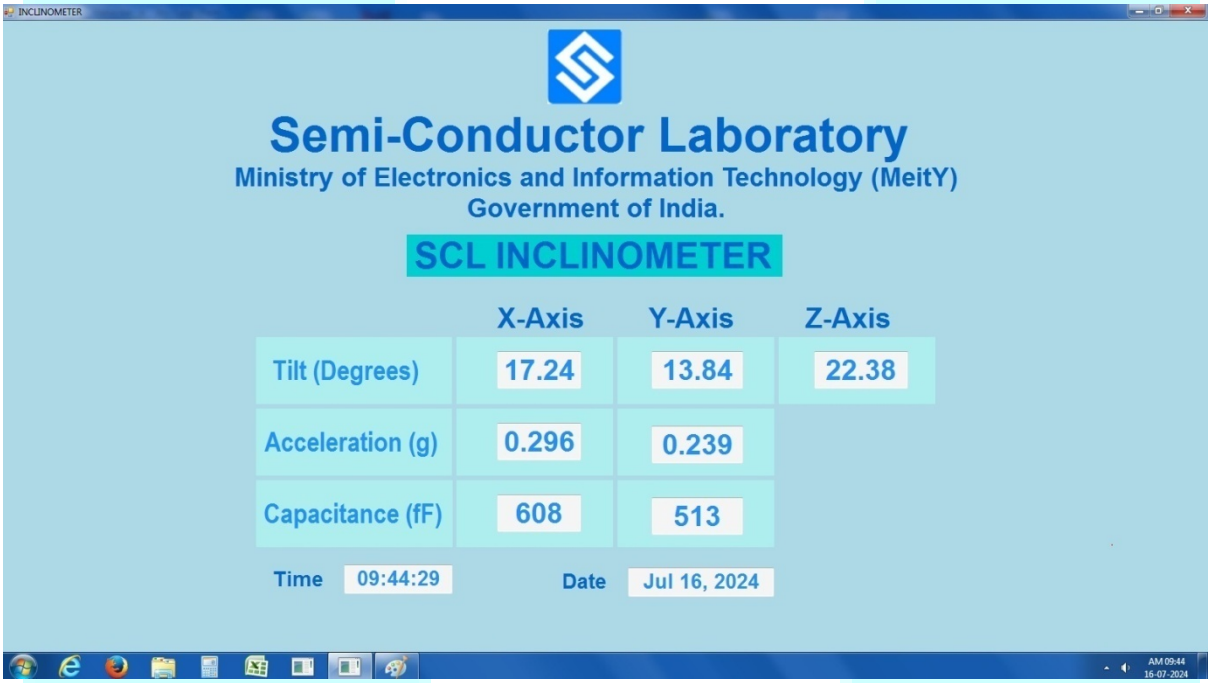
5. Software Description

Firmware for SSEB V2.0	Software for PC/laptop
"Firmware_SSEB-V2.0_Csharp_GUI.ino"	"GUI_Software_SSEBV-2.0_Csharp_V2.0.exe"

5.1 Software Code

C# based windows GUI software is available for displaying calibrated tilt angles. User can download the **"GUI_Software_SSEBV-2.0_Csharp_V2.0.exe"** file from SCL website.

User has to plug in the evaluation board to PC/laptop via USB cable provided with EV Board and run the **.exe** file.

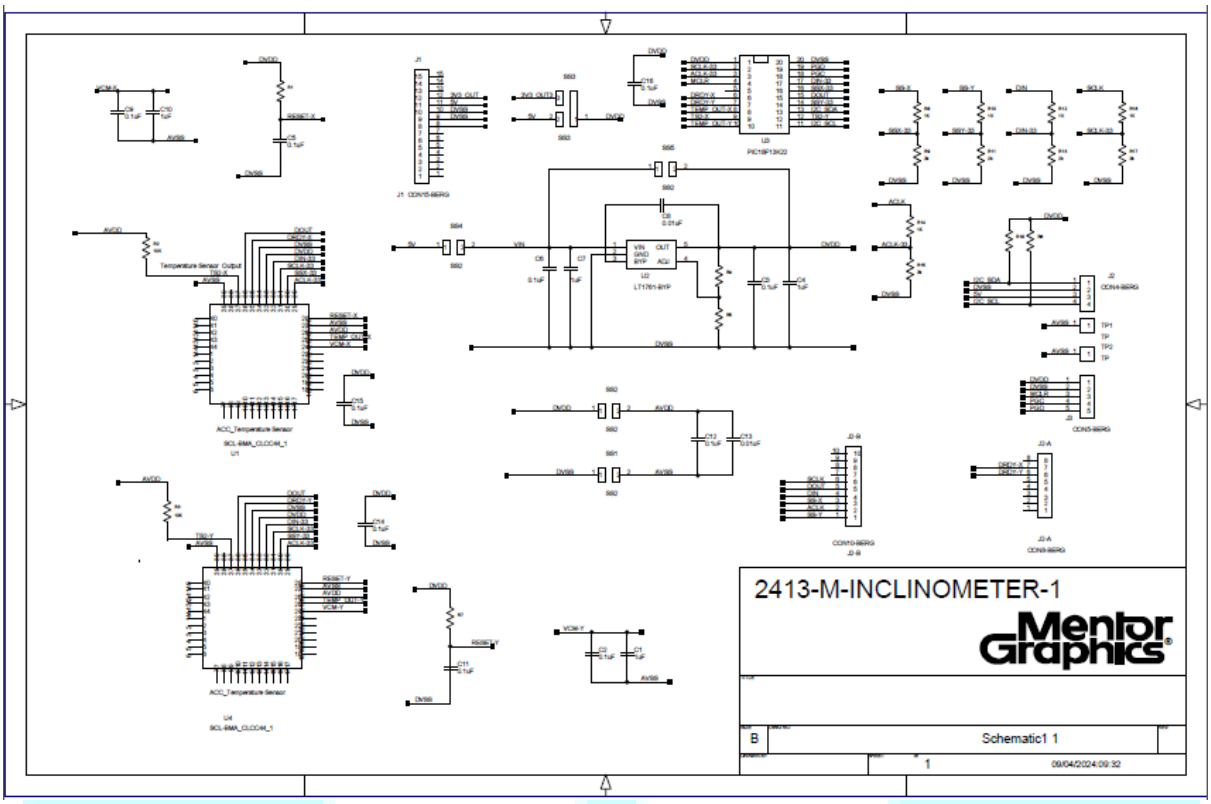


5.2 Firmware Code

Evaluation Board is pre programmed with firmware which contains sensor calibration coefficients. Firmware is developed to provide calibrated measured values to C# based GUI. The firmware **"Firmware_SSEB-V2.0_Csharp_GUI.ino"**can also be downloaded from SCL website. Generic firmware will contains sample calibration coefficients. User can edit and modify firmware for any applications.

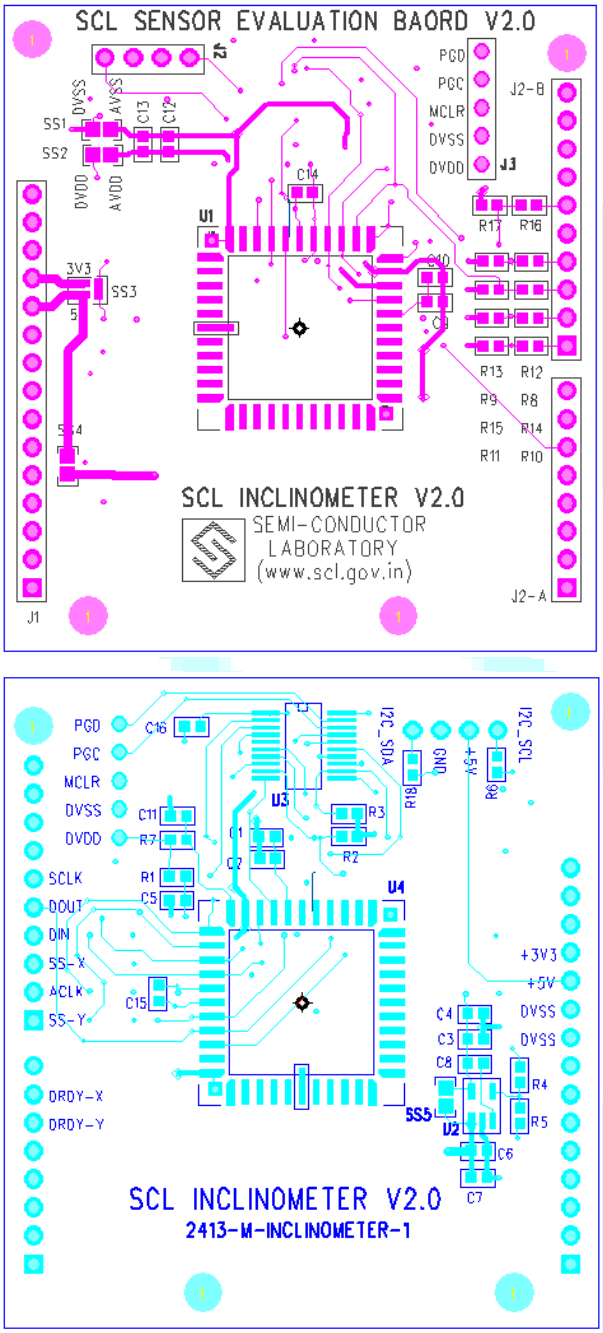
The firmware code uses sample calibration coefficient. Before re programming the firmware code for Arduino IDE, please ensure to replace sample calibration coefficients with coefficients provided with your kit.

6. Evaluation Board Schematic



EV Board Schematic Diagram

7. Evaluation Board Layout



8. Inclinometer Calibration

SCL 1.2g accelerometer is a capacitive based MEMS sensor. Differential Capacitance change due to acceleration/tilt input is digitized by 24-bit sigma delta ADC.

Table below shows the configuration register settings of SC1259:

Serial No.	Configuration Register	Value (X-axis)	Value (Y-axis)
1	CR1	0x00	0x00
2	CR2	0x07	0x07
3	DECIM_reg	0xFF	0xFF
4	CAPDAC_P	0x28	0x28
5	CAPDAC_N	0x28	0x28

After programming of configuration registers of SC1259, raw data of tilt sensor captured at different angles (-45°, 0°, +45°) and the output data was read from SC1259 through SPI bus. These angles have direct relation with acceleration (in g) as sine function. A linear relation fit done between acceleration (in g) and the 16-bit signed digital data.

$$Acceleration\ ,in\ g = m * Raw\ Data + C$$

$$tilt\ angle, in\ degrees = \sin^{-1}(Acceleration, in\ g) * 180/\pi$$

Inclination along X-Y plane/Z-axis is calculated using following equation:

$$\gamma = \cos^{-1}\left(\sqrt{1 - \left(\cos(\frac{\pi}{2} - \alpha) * \cos(\frac{\pi}{2} - \alpha) + \cos(\frac{\pi}{2} - \beta) * \cos(\frac{\pi}{2} - \beta)\right)}\right)$$

$$\alpha = \sin^{-1}(A_x), \beta = \sin^{-1}(A_y)$$

Where, Ax & Ay are measured acceleration in X & Y directions.

α & β are tilt angles towards X & Y directions in radians

γ is inclination angle of X-Y plane in radians

Linear fit coefficients (m & c) will be entered in the firmware source code to get inclination angles, in degrees, on serial monitor of Arduino IDE (Arduino IDE 2.2.1).