



SCL SENSOR EVALUATION BOARD SSEB V1.0

For
Pressure Sensor
Temperature Sensor
& 24-Bit Sigma Delta ADC (SC1218)
User Operational Manual



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1. Introduction

SSEB V1.0 is aimed to help students to learn:

- Analog front-end & Sensor Signal Conditioning.
- Calibration & Temperature Compensation algorithm.
- Evaluates their own developed or commercial available sensors
- Develop & Implement their own algorithms.

SSEB V1.0 is aimed to evaluate following components:

- SCL Temperature Sensor (PRT)
- SCL Pressure Sensor (1.5 Bar)
- SCL Readout ASIC SC1218
- Commercially available Piezo resistive Pressure Sensors
- Commercially available PRTs.

To operate EV Board, connect the board to any USB port of a PC/Laptop through USB cable, provided with the kit. EV Board can be used in two ways:

- i. Evaluation Mode
- ii. Development Mode

Evaluation Mode

- In Evaluation Mode, a C# based windows GUI will read & display calibrated pressure & temperature data from SCL sensors. C# based GUI software can be downloaded from SCL website.
- SSEB V1.0 Board provides corrected Pressure & Temperature readings in different scientific units. Each SSEB V1.0 comes with unique ID. This unique ID is for the sensors mounted to it and their corresponding calibration coefficients.
- SCL Pressure & Temperature sensors can be evaluated by exposing/applying pressure & temperature. For evaluation in lab environment, EV Board is calibrated from 0°C to 50 °C & upto 1500 mBar-abs.

Development Mode

- In Development Mode, user can modify, develop & implement their own algorithms. For development, Arduino based firmware can be download from SCL website.
- EV Board serves as a 24-bit data acquisition system. User can modify firmware & even evaluate their own developed/commercial sensors by using Arduino IDE serial monitor. Complete detail is provided in software section of user manual.



- Sensors & readout ASIC (SC1218) are soldered for contact reliability. User may de-solder Pressure & Temperature sensors from the board to replace their own developed / commercial available sensors to evaluate by using 24 bit sigma delta ADC, SC1218.
- After replacing SCL Sensors, user needs to calibrate/compensate their Pressure & Temperature Sensors and re program readout ASIC (SC1218) for their sensor values. Re-programming can be done in Development Mode.
- SSEB V1.0 comes with pre programmed calibration coefficient for SCL sensors. Calibration coefficients are printed inside EV Box box. User may any time restore factory settings by placing SCL sensors & entering default calibration coefficients into SSEB V1.0 in Development Mode.
- For operation in development mode, SSEB V1.0 is developed compatible with Arduino UNO R3 boards. Arduino boards are very popular among students, low in cost & readily available in local market. Arduino programming IDE is free to download & provides user friendly programming platform.

Student can download Reference User Manual from SCL website. Manual contains details of SSEB V1.0 Hardware & Software for ready reference.

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

For Development Mode, 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 V1.0) Kit Details	
1	SSEB V1.0 Box contains assembled Board with following parts designed & developed by SCL	
	1a	Pressure Sensor (S1)
	1b	Temperature Sensor (S2)
	1c	Sensor Signal Conditioner (U1)
	1d	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_for_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_Csharp_V1.0.exe"	
3	User Operational Manual	
4	Sensor & IC Datasheets	
5	Un-boxing demo Video	
6	Firmware for Arduino IDE "Firmware_for_Aurduino_IDE.ino"	
7	Software Arduino IDE (Arduino IDE 2.2.1 or latest)	

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3. Operational Procedure:

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

Evaluation Mode:

- i. Download the C# based GUI software: "**GUI_Software_Csharp_V1.0.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_for_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.

Development Mode:

- i. Download & Install latest version of "**Arduino IDE (Arduino IDE 2.2.1)**", from <https://www.arduino.cc/en/software>.
- ii. Firmware code "**Firmware_for_Aurduino_IDE.ino**" is available at SCL website.
- iii. Before downloading the firmware into EV Board, replace the sample calibration coefficients for pressure sensor (A₁ to A₆) and temperature sensor (B₁ to B₃) with coefficients, provided with EV Board Kit Box, for SCL sensors or replace with your own coefficients for other sensors.
- iv. Connect EV Board using USB cable to PC/Laptop.
- v. Download & run the edited firmware into EV Board through (**Arduino IDE 2.2.1**). Open the Serial Monitor output window. The output corresponding to input pressure and input temperature will be displayed in mBar and °C.
- vi. For development with sensor other than SCL sensor, you may remove the SCL sensor and connect your sensors. Signal names & connection details for Pressure & temperature sensor is provided in hardware description.

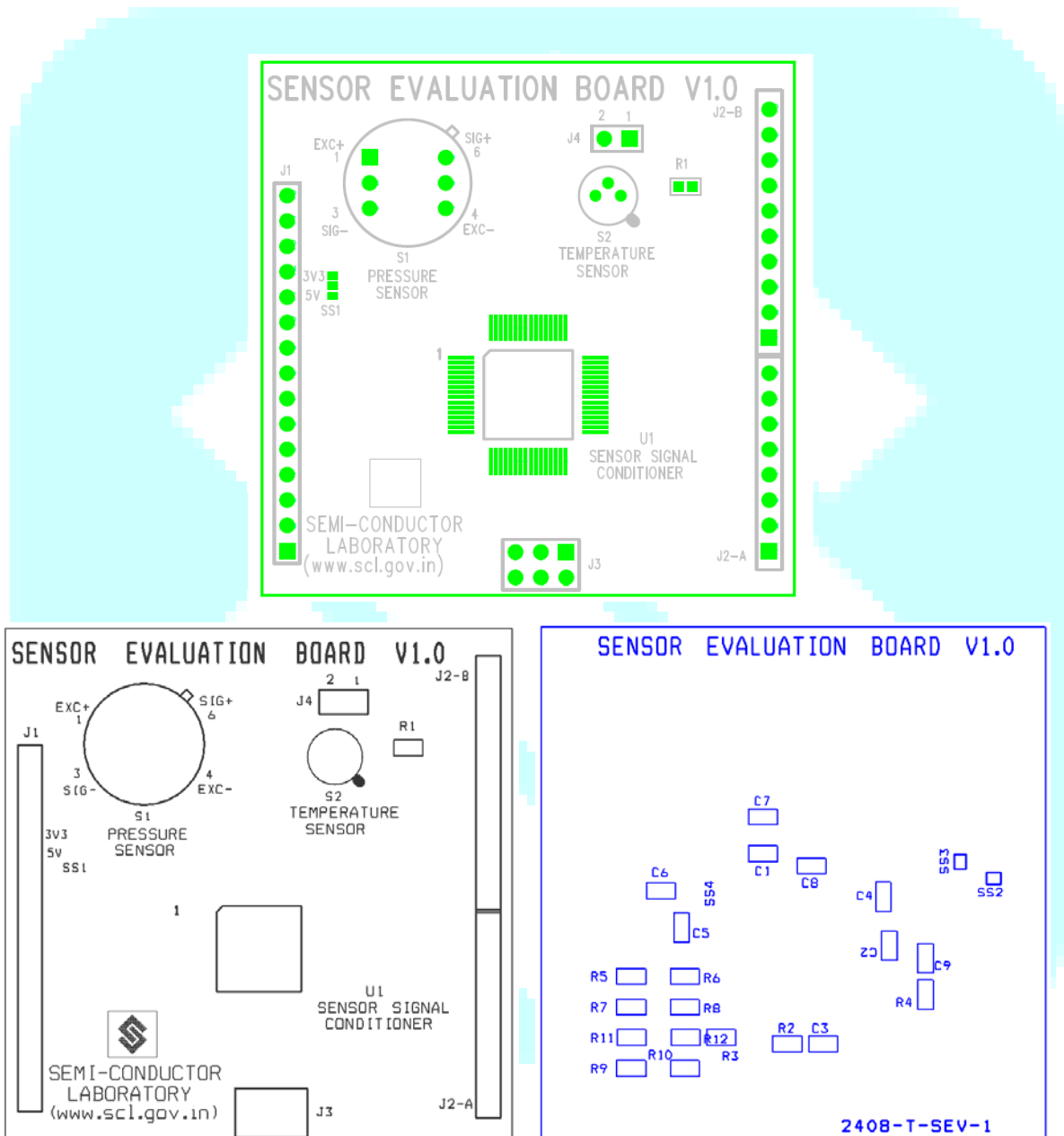
Required Equipments:

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

4. Hardware Description

SSEB V1.0 provides corrected Pressure (mBar) & Temperature (°C) readings. Sensor calibration coefficients and ASIC (SC128) configuration registers are programmed for SCL sensors mounted on the board.

Kit includes an assembled SSEB V1.0 and a USB cable. Major components mounted are pressure sensor, temperature sensor and readout IC SC1218. SSEB V1.0 is pin compatible with Arduino Uno R3 board for interface & display at PC through USB cable.





Component List

Reference	Quantity	Description
S1	1	Pressure Sensor (TO-8)
S2	1	Temperature sensor (TO-46)
U1	1	Readout IC, SC1218-0 (CQFP-64)
Jumpers/Connectors & Solder Select		
J1	1	CON15; Power Connector
J2-A	1	CON8; Arduino Digital 8-Pin Connector (DRDY signal)
J2-B	1	CON10; Arduino Digital 10-Pin Connector (SPI signals)
J3	1	CON3X2;
J4	1	CON2; Unused, alternate sensor site
SS4	1	Solder Short
SS1, SS2, SS3	3	Solder Short
Other Passive Components		
C ₁ , C ₃ , C ₄ , C ₅ , C ₆ , C ₉	6	0.1μF ceramic X7R capacitors
C ₂	1	1μF ceramic X7R capacitors
C ₇ , C ₈	2	1KpF ceramic X7R capacitors
C ₉	1	0.1μF ceramic X7R capacitors
R ₁ , R ₂	2	4.75KΩ Resistor
R ₃ , R ₄ , R ₅ , R ₇ , R ₉ , R ₁₁	6	1KΩ Resistor
R ₆ , R ₈ , R ₁₀ , R ₁₂	4	2KΩ Resistor

Pressure Sensor (S1)

Pressure sensor (S1), packaged in 6-pin TO-8 package is mounted on top side. SCL pressure sensor is piezo resistive wheat stone bridge with four (04) active elements. Bridge resistance of sensor is ~2KΩ. Pressure sensor is excited with reference voltage 1.22V by using REFOUT signal of SC1218. Sensor output signal (INP2 & INN2) corresponds to measured pressure is connected to channel-2 of SC1218.

Temperature Sensor (S2)

Temperature sensor (S2), packaged in 3-pin TO-46 package is also mounted on top side. SCL temperature sensor is Pt based thin film PRT. Sensor nominal resistance at 25°C is 1 KΩ. Temperature sensor is excited with reference voltage 1.22V by using REFOUT signal of SC1218. A series current limiting resistor R1 (4.75KΩ) is connected to limit the current through PRT (~ 0.2mA). Sensor output signals (INP1) corresponding to measured temperature is connected to channel-1 of SC1218.

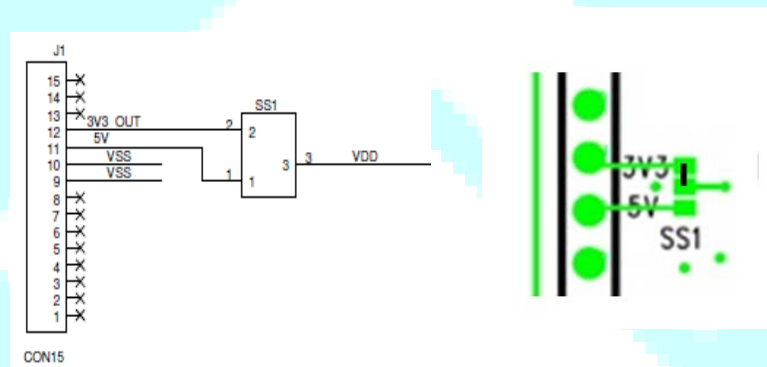
SC1218 (U1)

SC1218 (U1) is SCL developed sensor readout IC with 24-bit sigma delta ADC. SC1218 is packaged in CQFP-64 package and mounted on top side of evaluation board.

Analog outputs of both pressure & temperature sensors are fed to two different channels of SC1218. SC1218 provides gain & produce 24-bit digital data on SPI bus. An SPI master (Ardiuno Uno in this case) will read the pressure and temperature data on SPI bus and the same will be displayed on serial monitor of Ardiuno IDE on PC/Laptop.

Power Connector (J1)

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



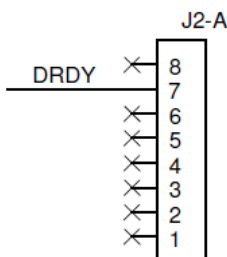
Pin	Signal	Description
1	NC	-
2	NC	-
3	NC	-
4	NC	-
5	NC	-
6	NC	-
7	NC	-
8	NC	-

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.

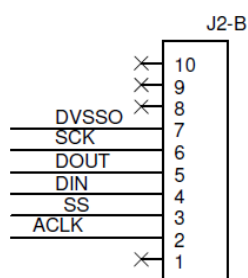


Pin	Signal	Description
1	NC	-
2	NC	-
3	NC	-
4	NC	-

Pin	Signal	Description
5	NC	-
6	NC	-
7	DRDY	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 RDATAAC 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

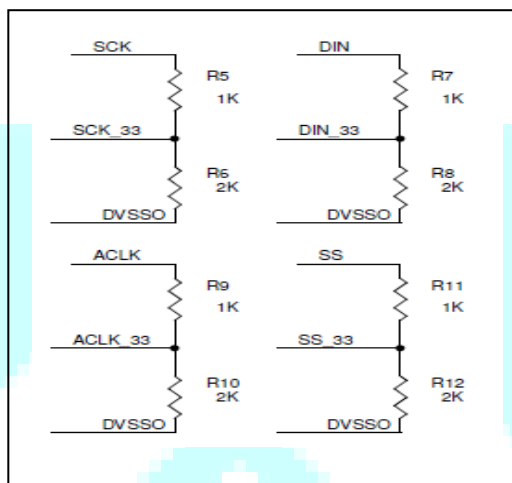


Pin	Signal	Description
1	NC	-
2	ACLK	ADC Clock Input
3	SS	Serial Interface Enable, active low
4	DIN	Serial Data In
5	DOUT	Serial Data Out

Pin	Signal	Description
6	SCK	Serial Clock
7	DVSSO	GND
8	NC	-
9	NC	-
10	NC	-

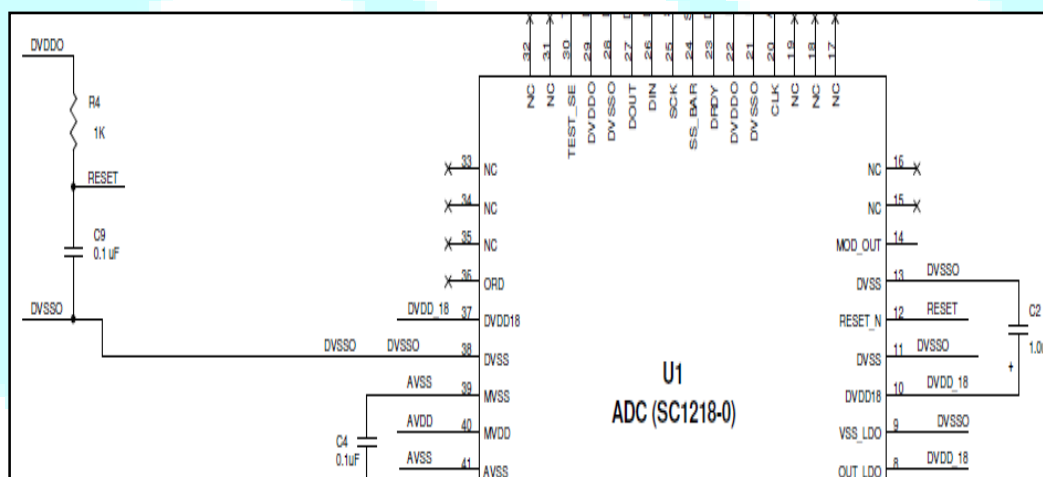
Level Translators:

Arduino Uno works for 5V supply and generates SPI signals of 5V level, whereas SC1218 is operated with a supply of 3.3V and it generates 3.3V signals. 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 SC1218. Details are shared in datasheet of SC1218.





5. Software Description

Evaluation board can be operated in two modes:

- i. Evaluation Mode
- ii. Development Mode

Operation Mode	Firmware for SSEB V1.0	Software for PC/laptop
Evaluation	"Firmware_for_Csharp_GUI.ino"	"GUI_Software_Csharp_V1.0.exe"
Development	"Firmware_for_Arduino_IDE.ino"	"Arduino IDE (Arduino IDE 2.2.1)"

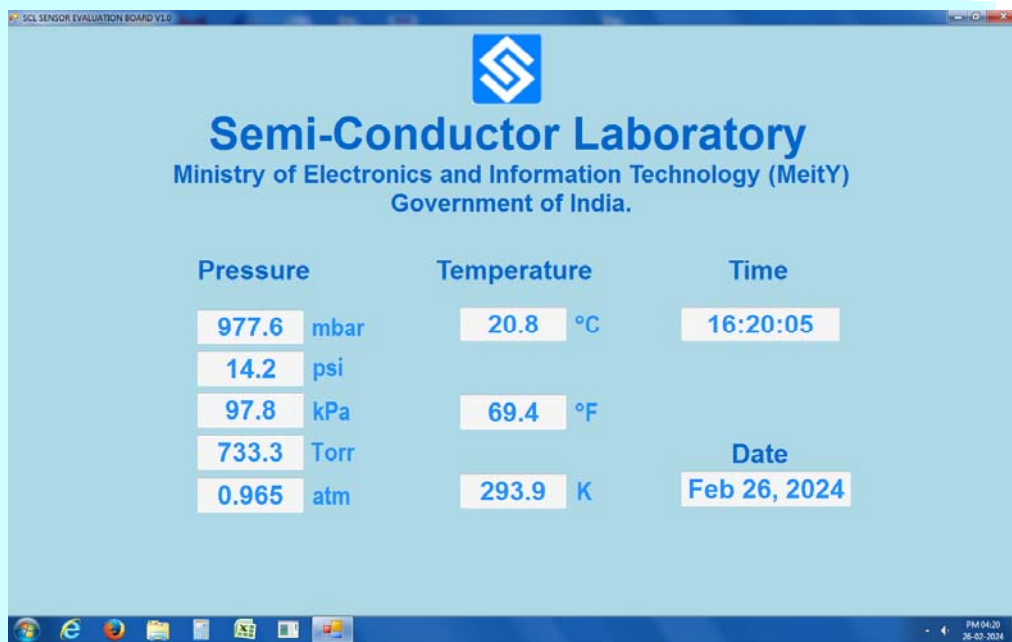
Operational Mode: Evaluation Mode
<p><u>Firmware to download into SSEB V1.0 Board</u> "Firmware_for_Csharp_GUI.ino" (Default Firmware code)</p> <p>Already downloaded in EV Board. The firmware is available at SCL website.</p> <p><u>Restore Factory Settings:</u></p> <ul style="list-style-type: none"> • To restore factory settings, the firmware can be downloaded into EV Board. • For downloading the firmware, replace sample calibration coefficients mentioned in firmware code with the coefficients provided with the Kit. • Once the sample coefficients are replaced with corresponding calibration coefficients with SCL sensors, download firmware into EV Board through "Arduino IDE (Arduino IDE 2.2.1)" software.
<p><u>Software to download & install on PC/laptop</u> "GUI_Software_Csharp_V1.0.exe" (Default Software)</p> <ul style="list-style-type: none"> • This C# based windows GUI will read the EV Board through USB port & display calibrated pressure & temperature in different scientific units. (Default Settings) • The C# based GUI will only work either with default firmware code or by restoring factory settings.
Operational Mode: Development Mode
<p><u>Firmware to download into SSEB V1.0 Board</u> "Firmware_for_Arduino_IDE.ino"</p> <ul style="list-style-type: none"> • For operating in Development Mode, "Firmware_for_Arduino_IDE.ino" is available at SCL website. • For development with SCL sensors, follow the steps of Restore factory Settings by using this firmware. • For using own developed/ commercial sensors, follow the steps of Restore factory Settings by replacing calibration coefficients, in the firmware code, corresponding with sensors.
<p><u>Software to download & install on PC/laptop</u> "Arduino IDE (Arduino IDE 2.2.1)"</p> <ul style="list-style-type: none"> • This Software IDE can be downloaded from "https://www.arduino.cc/en/software" • The IDE will print calibrated readout values of pressure & temperature sensors. • This IDE will be used for downloading firmware (for C# based GUI or for Arduino IDE)



5.1 C# based GUI

C# based windows GUI software is available for displaying calibrated pressure & temperature values in various scientific units. User can download the "GUI_Software_Csharp_V1.0.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. Evaluation Board is pre programmed with sensor calibration coefficients as provided along with EV Board Box. The GUI is shown below.



Note: User can restore factory settings of SSEB V1.0 by re-programming firmware code for C# GUI. This firmware "Firmware_for_Csharp_GUI.ino" can be downloaded from SCL website and can be programmed/uploaded using Arduino IDE.

The firmware code uses sample calibration coefficient. Before re programming the firmware code for C# GUI, please be ensure to replace sample calibration coefficients with coefficients provided with your kit.



5.2 Arduino Based Code

For users to operate in development mode, firmware code is developed for Arduino IDE. User can download the arduino firmware code "Firmware_for_Aurduino_IDE.ino" from SCL website.

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.

Once firmware is downloaded into EV Board, calibrated Pressure (in mbar) and temperature (in °C) readings can be noted from Arduino IDE serial monitor. Readings in serial monitor is shown below.

```
COM20
Pressure Counts: -2759 Temperature Counts: 22611
Pressure, mBar : 986.91 Temperature, degree C : 21.62

Pressure Counts: -2759 Temperature Counts: 22611
Pressure, mBar : 986.91 Temperature, degree C : 21.62

Pressure Counts: -2756 Temperature Counts: 22611
Pressure, mBar : 987.07 Temperature, degree C : 21.62

Pressure Counts: -2757 Temperature Counts: 22611
Pressure, mBar : 987.02 Temperature, degree C : 21.62

Pressure Counts: -2758 Temperature Counts: 22611
Pressure, mBar : 986.96 Temperature, degree C : 21.62

Pressure Counts: -2760 Temperature Counts: 22612
Pressure, mBar : 986.87 Temperature, degree C : 21.63

Pressure Counts: -2754 Temperature Counts: 22612
Pressure, mBar : 987.20 Temperature, degree C : 21.63

Pressure Counts: -2761 Temperature Counts: 22612
Pressure, mBar : 986.82 Temperature, degree C : 21.63

Pressure Counts: -2762 Temperature Counts: 22612
Pressure, mBar : 986.76 Temperature, degree C : 21.63

Pressure Counts: -2764 Temperature Counts: 22612
Pressure, mBar : 986.66 Temperature, degree C : 21.63

Pressure Counts: -2759 Temperature Counts: 22612
Pressure, mBar : 986.93 Temperature, degree C : 21.63

Pressure Counts: -2756 Temperature Counts: 22611
Pressure, mBar : 987.07 Temperature, degree C : 21.62

Pressure Counts: -2757 Temperature Counts: 22611
Pressure, mBar : 987.02 Temperature, degree C : 21.62

Pressure Counts: -2758 Temperature Counts: 22611
Pressure, mBar : 986.96 Temperature, degree C : 21.62

Pressure Counts: -2760 Temperature Counts: 22612
Pressure, mBar : 986.87 Temperature, degree C : 21.63
```

Firmware code is well commented where ever is required. User can learn calibration and compensation algorithms implemented for sensor evaluation board.

User can also develop their own algorithms for SCL sensors, their own developed or commercial sensors.



```

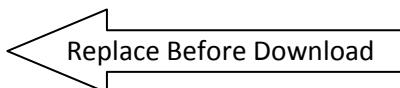
/*****
/****          Pressure Sensor Sample calibration coefficients          ****
/*****/
    
```

```

/***** Replace Below Sample coefficients with Coefficients provided with the kit *****/
    
```

```

float A_1 = 0.0000000011080;
float A_2 = 0.00004703;
float A_3 = 0.7096;
float A_4 = 0.00000377;
float A_5 = 0.8155;
float A_6 = -280.4266;
    
```



```

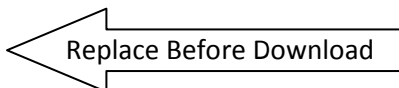
/*****
/****          Temperature Sensor calibration coefficients          ****
/*****/
    
```

```

/***** Replace Below Sample coefficients with Coefficients provided with the kit *****/
    
```

```

float B_1 = 0.0000002045;
float B_2 = 0.00939;
float B_3 = -288.1458;
    
```



```

/*****
/*          Readout ASIC (SC1218) Control Registers          */
/*****/
//ADC control registers Pressure sensor
    
```

Replace sample calibration coefficients in firmware with coefficients provided in EV Board KIT as shown below.

Unique Board ID: PR116-2144S02

Handling Instructions

Handle the box gently. Rough handling can dislodge the evaluation board and can damage sensors.

Protect evaluation board from water & dust.

It is recommended to carry Evaluation Board in the box provided to prevent any damage.

CMOS based Integrated Circuits are ESD sensitive. It is recommended to use ESD precautions while handling the evaluation board.



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SCL Sensor

Calibration Coefficients

Pressure Sensor	
A1	0.0000000011080
A2	0.00004703
A3	0.7096
A4	0.00000377
A5	0.8155
A6	-280.4266
Temperature Sensor	
B1	0.0000002045
B2	0.00939
B3	-288.1458

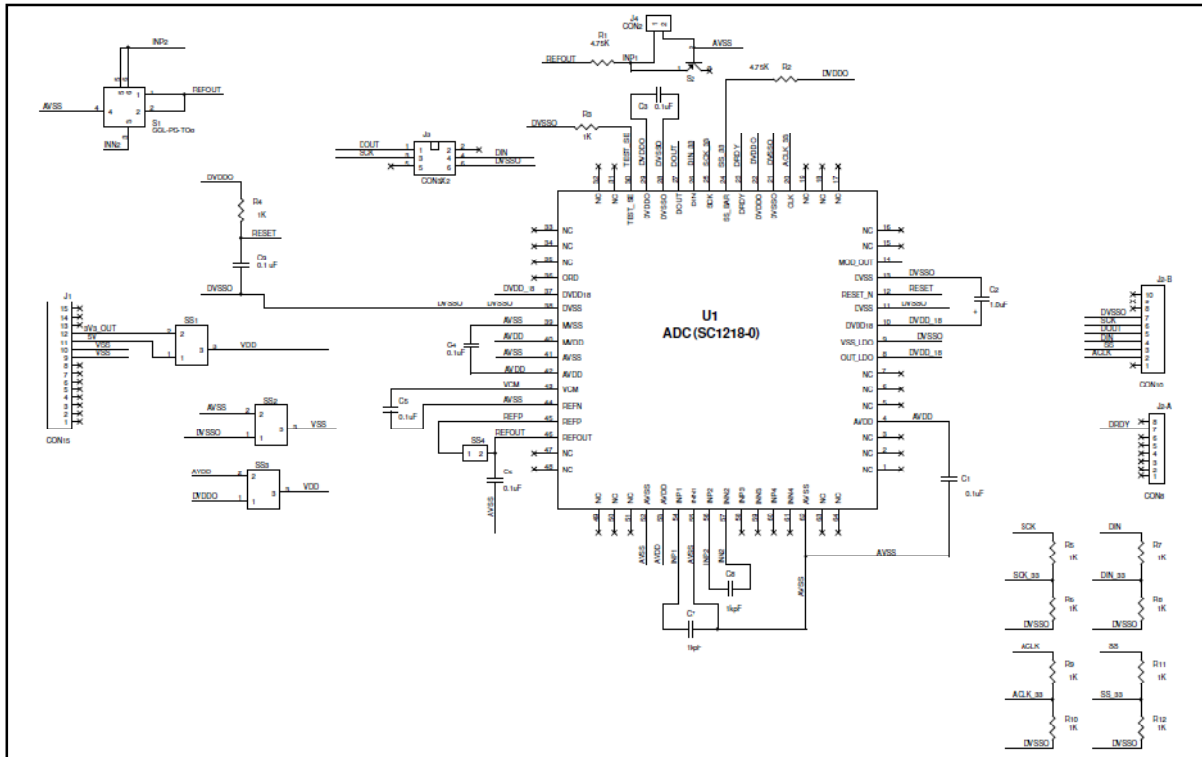
Software Download Links:

https://www.scl.gov.in/sys_dev

<https://www.arduino.cc/en/software>

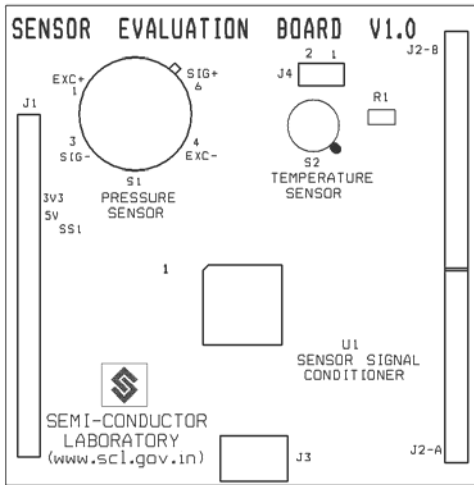


6. Evaluation Board Schematic

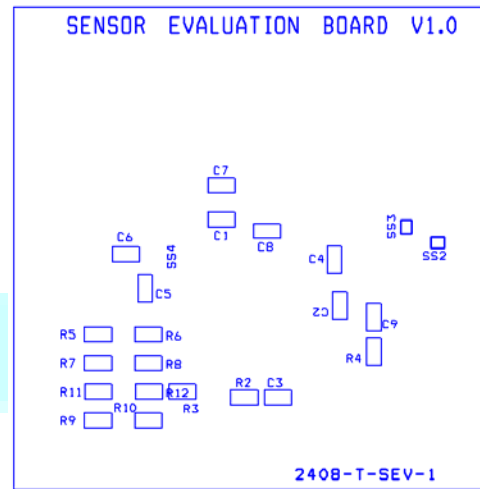


EV Board Schematic Diagram

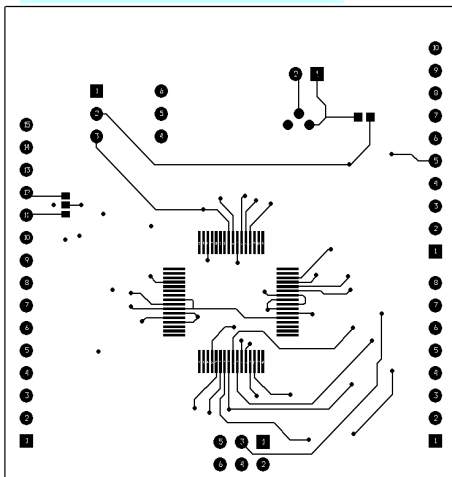
7. Evaluation Board Layout



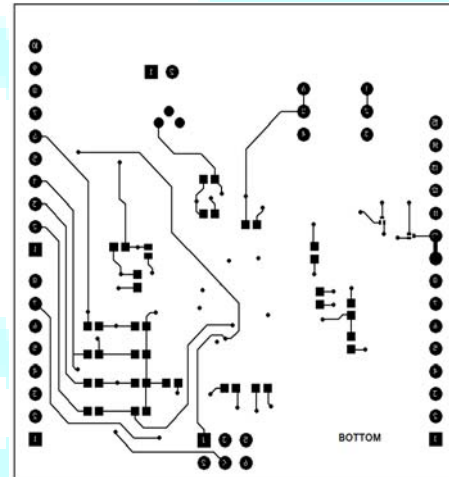
Silk Screen Top



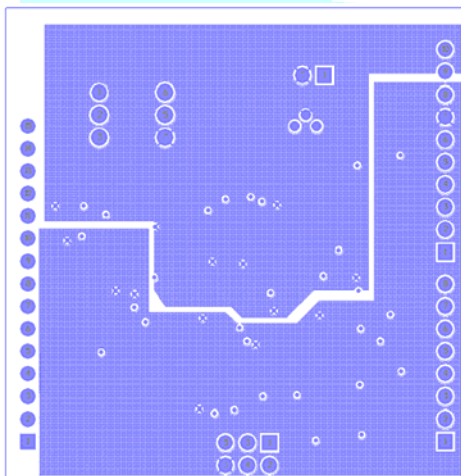
Silk Screen Bottom



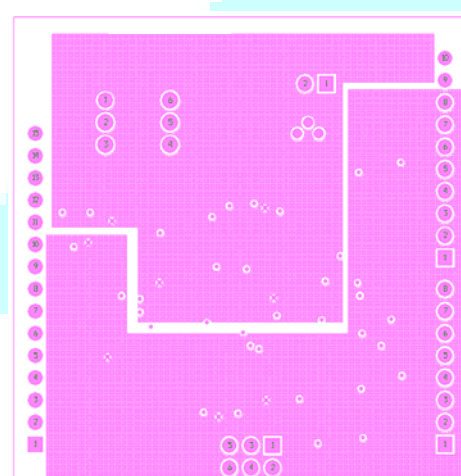
Top Layer



Bottom Layer



Inner 1 (VSS)



Inner 2 (VDD)



8. Pressure Sensor Calibration & Compensation

SCL pressure sensor is in the form of a close Wheatstone bridge. Sensor bridge is excited by on-chip (REFOUT of SC1218) generated 1.22V. REFOUT is also used for ADC reference. Differential output of pressure sensor is then amplified by PGA of 128. Amplified sensor output is then digitized by sigma delta ADC.

Table below shows the settings of SC1218 for pressure sensor:

Serial No.	Configuration Register	Value
1	PGA	128
2	OSR	2048
3	CR1	0xE1
4	CR2	0x00

After configuration programming of SC1218, raw data of pressure sensor was captured for input pressures (upto to 1500mBar) & for temperature range of 10°C to 40°C and the output data was read from SC1218 through SPI.

Temperature compensation and calibration coefficients are computed for each sensor using following equation:

$$P \text{ (Corrected)} = A_1 * P * T^2 + A_2 * P * T + A_3 * P + A_4 * T^2 + A_5 * T + A_6$$

$$P \text{ (mbar)} = m * P \text{ (Corrected)} + c$$

Where:

P (Corrected) = Temperature Compensated & Calibrated Pressure Data in counts (16 bit signed integer)

P (mbar) = Temperature Compensated & Calibrated Pressure Data in mbar

P = Raw Pressure digital data counts (16 bit signed integer)

T = Raw Temperature digital data counts (16 bit signed integer)

A₁, A₂, A₃, A₄, A₅, A₆ = Coefficients

m = 0.0250, c = 750

These coefficients (A1 to A6) will be entered in the firmware source code to get final corrected pressure value in mBar on serial monitor of Arduino IDE (Arduino IDE 2.2.1).

Coefficients corresponding to each sensor are provided with the sensor evaluation kit.



9. Temperature Sensor Calibration

Sensor output was captures for temperature range of 10°C to 40°C and the output data was read from SC1218 through SPI.

Table below shows the settings of SC1218 for temperature sensor:

Serial No.	Configuration Register	Value
1	PGA	4
2	OSR	2048
3	CR1	0x40
4	CR2	0x00

The sensor is calibrated (range) and the calibration coefficients are computed for each sensor using following equation:

$$T(\text{calibrated}) = (B_1T^2 + B_2T + B_3)$$

T(calibrated) = Calibrated temperature data in °C

T = Raw Temperature digital data counts (16 bit signed integer)

B₁, B₂, B₃ = *Coefficients*

These coefficients (B1 to B3) will be entered in the firmware source code to get final corrected temperature value in °C on serial monitor of Arduino IDE (Arduino IDE 2.2.1).