Strain Gauge/Instrument Amplifier Shield (2 Channels)

Version 1.0

Augustus 2014

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1. Shield Overview

The Strain Gauge/Instrument Amplifier shield (SGS from here on further) are intended for precise amplification of measurements specifically for bridge amplifiers, medical instrumentation and industrial process control. Instrumentation signals of small values, in the order of mV (millivolts) or less, need to be amplified to generate information of meaning to be processed. Prototyping boards like Arduino have a 10 bit ADC which means that the resolution of input/outputs are 4.9mV for a 5V (will be different for 3.3V or other referencing voltages) supply. Therefore changes less than 4.9mV cannot be easily recognised by the process board without the necessary amplification and possible noise filtering.

The AD8426 was selected to be used as the amplifier for the shield. The gain produced by the AD8426 amplifier ranges from 1 to 1000, AD8426 Datasheet Analog Devices Rev.0, depending on the RGAIN resistor value. Another valuable feature is the voltage reference adjustment on board to adjust the output voltage reference in order to be used with a single power supply ADC, which the Arduino makes use of.

For filtering, a second order Bessel low pass filter for 1k Hz was designed to help smooth out unwanted interference. The filter frequency can easily be changed by replacing the resistors and capacitors for a low pass filter. It is also possible to alter the filter to become a high-pass filter.

2. Shield
2.1 Shield Schematics

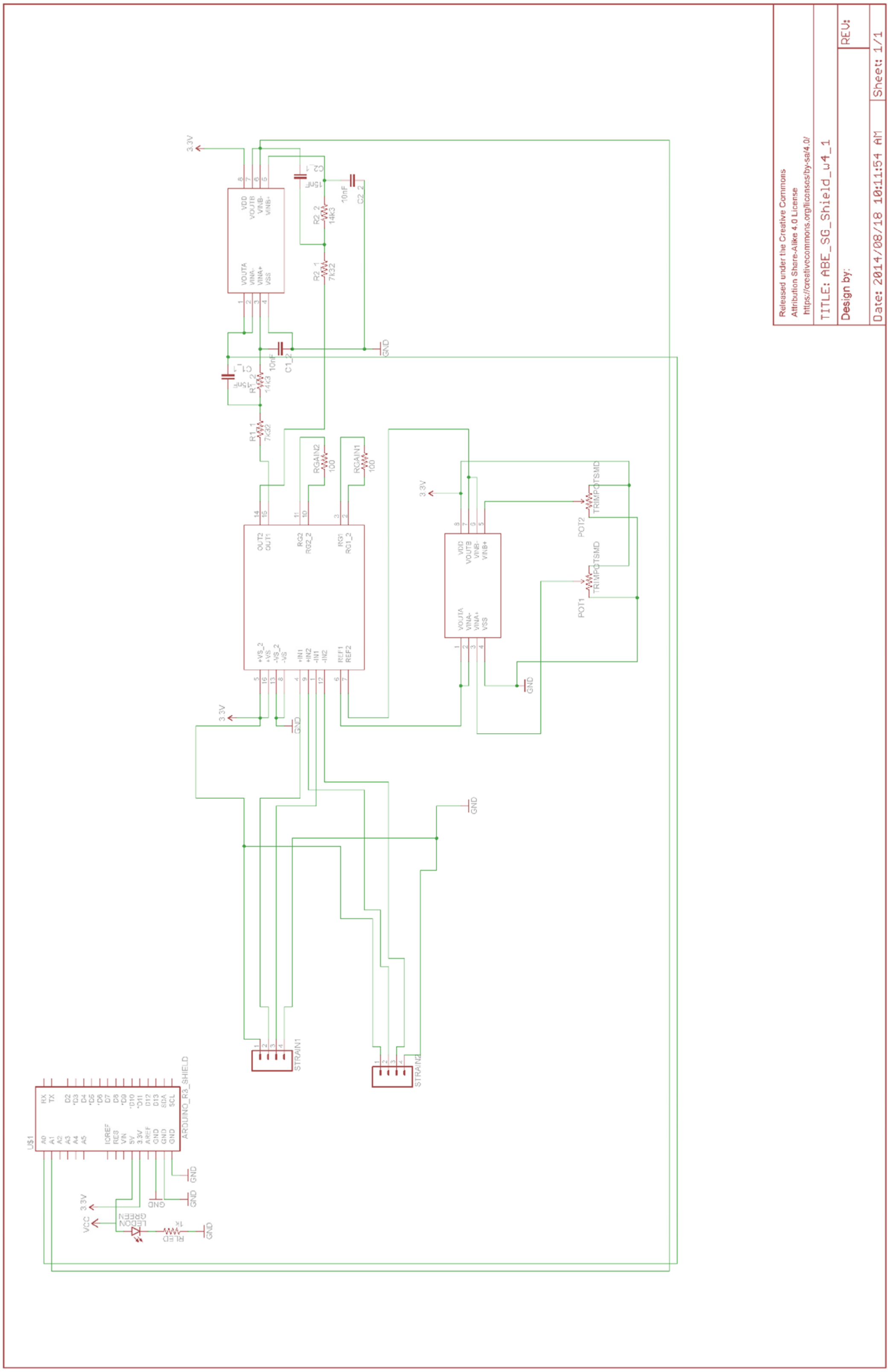

Figure 1: SGS Schematic v1.0

2.2 Shield Layout

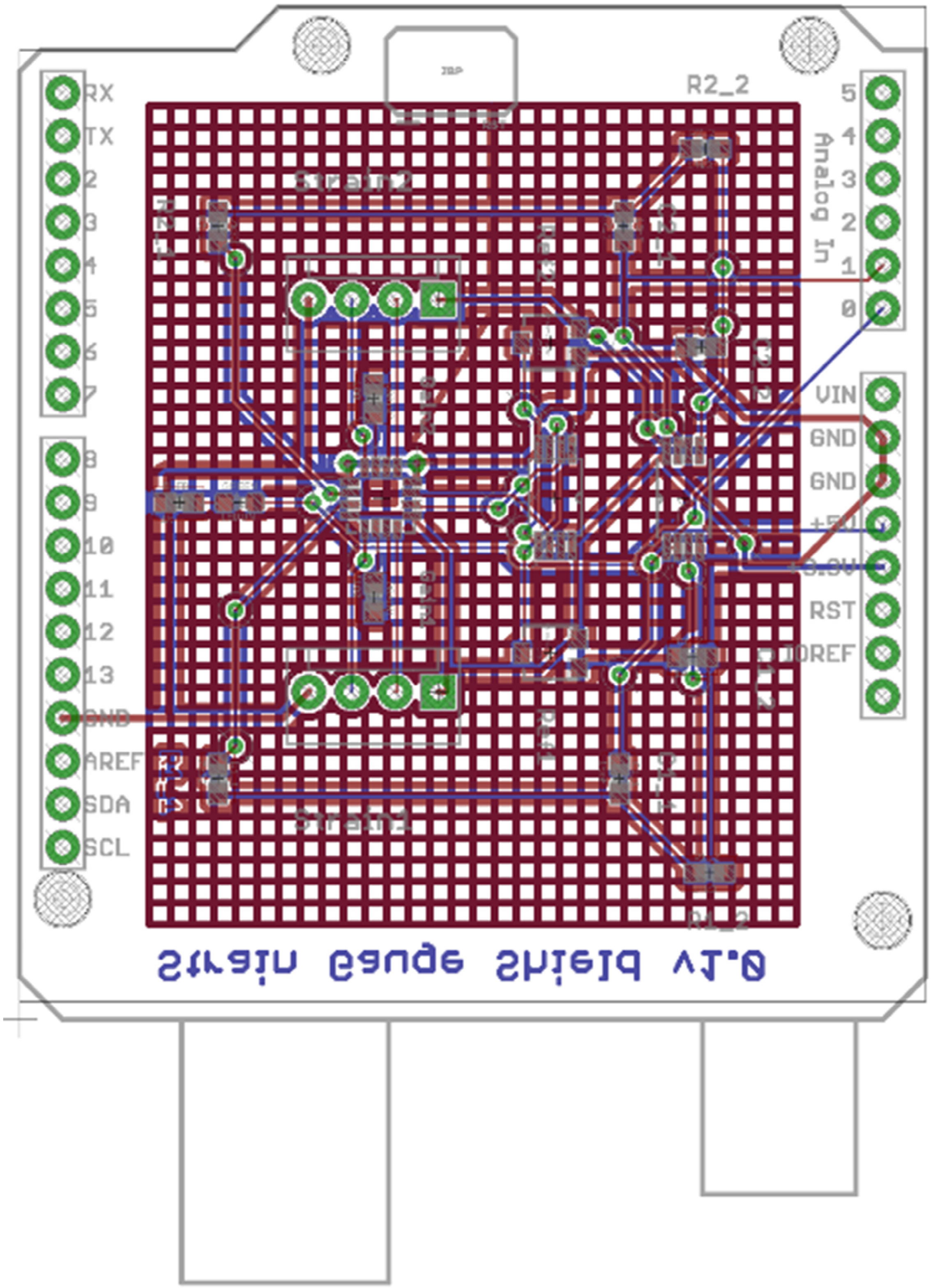

Figure 2: SGS Shield Board layout v1.0 with ground grid

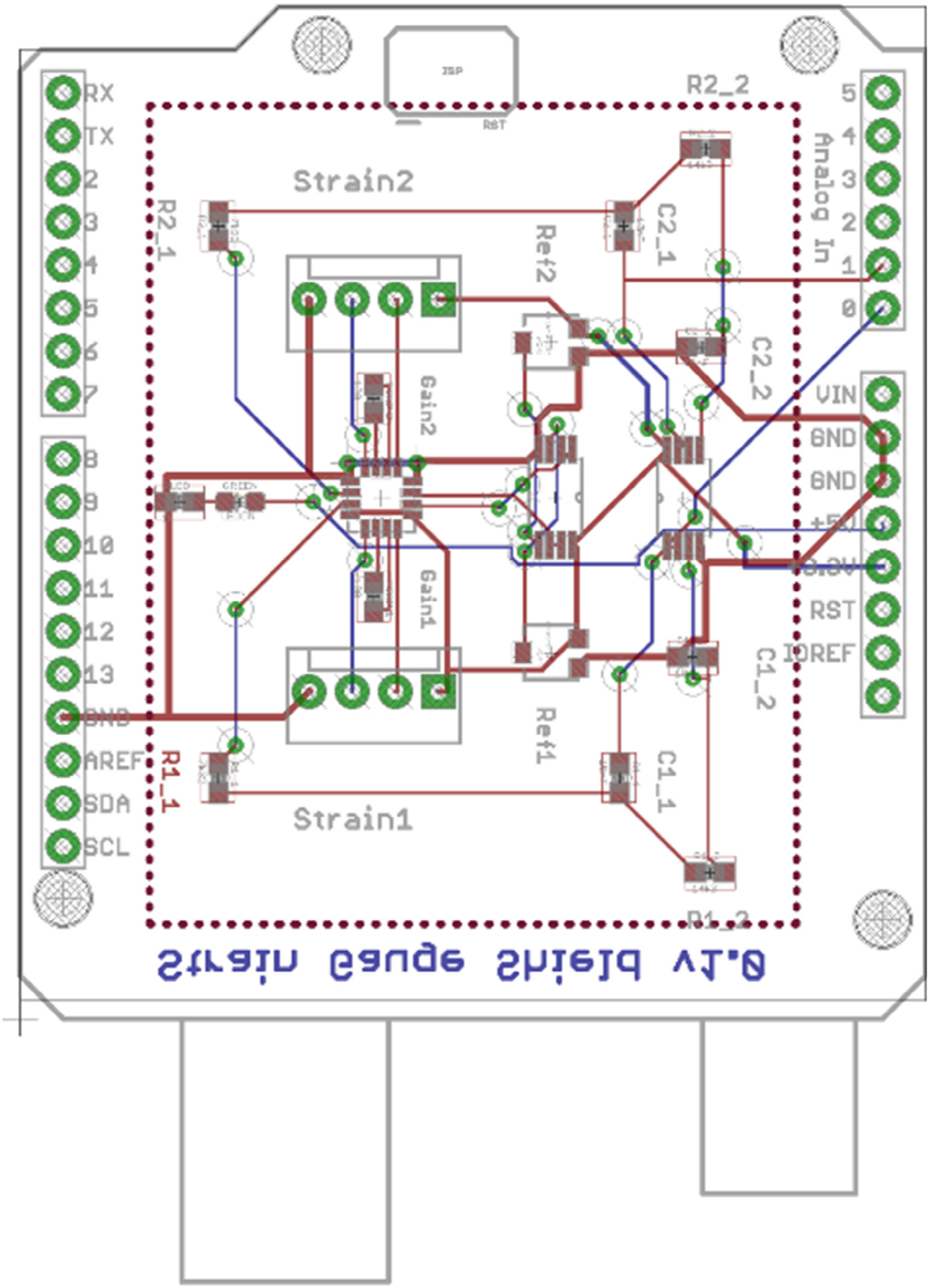

Figure 3: SGS Shield Board layout v1.0 without ground grid.

3. Strain Gauges

Strain gauges are essentially sensors which produce a very small change in resistance for sensing strain. In basic terms a strain gauge is an instrumentation sensor within the correct setup dynamics of a circuit. The following paragraph's goal is to explain how strain gauges work. Strain gauges can be substituted with output characteristics of different sensors per specific application if there is a need.

Strain measurements are the actual strain experienced by a material when a force is applied to it whether it is a linear, axial, compression or expansion force. A good educational reference is http://en.wikipedia.org/wiki/Stress%E2%80%93strain_curve about the science behind strain in materials.

3.1 Strain Gauge Characteristics

Figure 4: Strain Gauge shows how a normal strain gauge looks like.

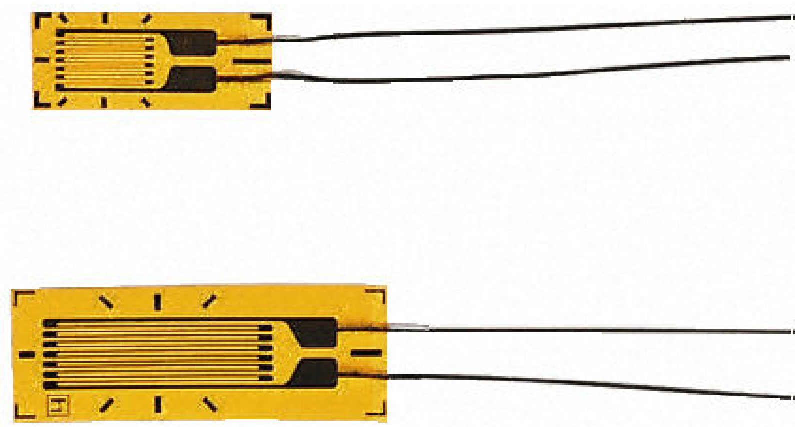

Figure 4: Strain Gauge

References of good explanations on how strain gauges operate and the basic science behind them can be found on the following websites:

- http://www.ni.com/white-paper/3092/en/
- http://en.wikipedia.org/wiki/Strain_gauge
- http://en.wikipedia.org/wiki/Load_cell
- http://www.sensorland.com/HowPage002.html

If you prefer a more interactive explanation:

- https://www.youtube.com/watch?v=D3J41HE_RMA
- https://www.youtube.com/watch?v=cP5rs3YIcbo

3.2 Wheatstone bridges

The Wheatstone bridge is the principal layout for certain sensors in general to use the electrical properties of the circuit to extract meaningful information. The SGS without the Wheatstone bridge will only be a differential amplifier with a high sensitivity for weak signals.

There are different setups of Wheatstone bridges depending on the sensitivity and magnitude of the signal produced by the sensing element/s, in this case the strain gauge. It could however be any sensing element that replace the strain gauge/s. The Wheatstone bridge can also adjust for certain initial offset imbalances or for outside factors that influence the sensing element like temperature as show in the reference links in section 3.1.

The following references explains the setup of the Wheatstone bridge:

- http://www.hbm.com.pl/pdf/w1569.pdf
- http://www.transducertechniques.com/wheatstone-bridge.aspx

4. Circuit Building blocks

The high-level block diagram of the shield presented as in Figure 5: High-level block diagram.

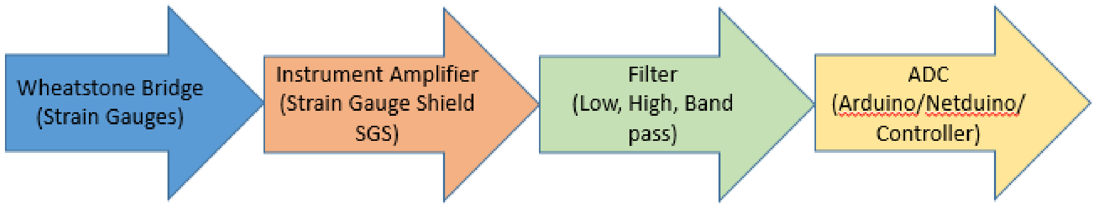

Figure 5: High-level block diagram

The following sub-paragraphs will explain more about the different building blocks.

4.1 Strain Gauge Inputs via Wheatstone bridges

See chapter 3 for more detail.

4.2 Instrumentation Amplifier

The instrumentation amplifier used, AD8426, is a differential amplifier. The datasheet will show all the electronic characteristics of this amplifier.

There are two changes per channel that can be adjusted for the specific use of the SGS, which are:

- The Gain per channel.
    - The gain (amplification) per channel through the amplifier is dependent on the resistor value RGAIN1/2 marked as Gain1/Gain2 on the board layout Figure 2: SGS Shield Board layout v1.0. The gain factor needs to be picked based on the specific application and sensitivity of the total Wheatstone bridge with the strain gauges incorporated.

      Figure 6. Extract form the AD8426 datasheet shows the values that RGAIN1/2 should be made to get the required gain per application. The standard RGAIN1/2 value selected, 100 Ohms for the SGS, is in the general selection range for applications with Wheatstone bridge Strain gauges. Figure 7: RGAIN positions on SGS shows the actual position of where the RGAIN1/2 resistors were placed if a different gain might be required that is different than the setup gain of 495 with a 100 ohm resistor.

1% Standard Table Value of R_G	Calculated Gain
49.9 kΩ	1.990
12.4 kΩ	4.984
5.49 kΩ	9.998
2.61 kΩ	19.93
1.00 kΩ	50.40
499 Ω	100.0
249 Ω	199.4
100 Ω	495.0
49.9 Ω	991.0

The AD8426 defaults to G = 1 when no gain resistor is used. The tolerance and gain drift of the R_G resistor should be added to the AD8426 specifications to determine the total gain accuracy of the system. When the gain resistor is not used, gain error and gain drift are minimal.

Figure 6. Extract form the AD8426 datasheet

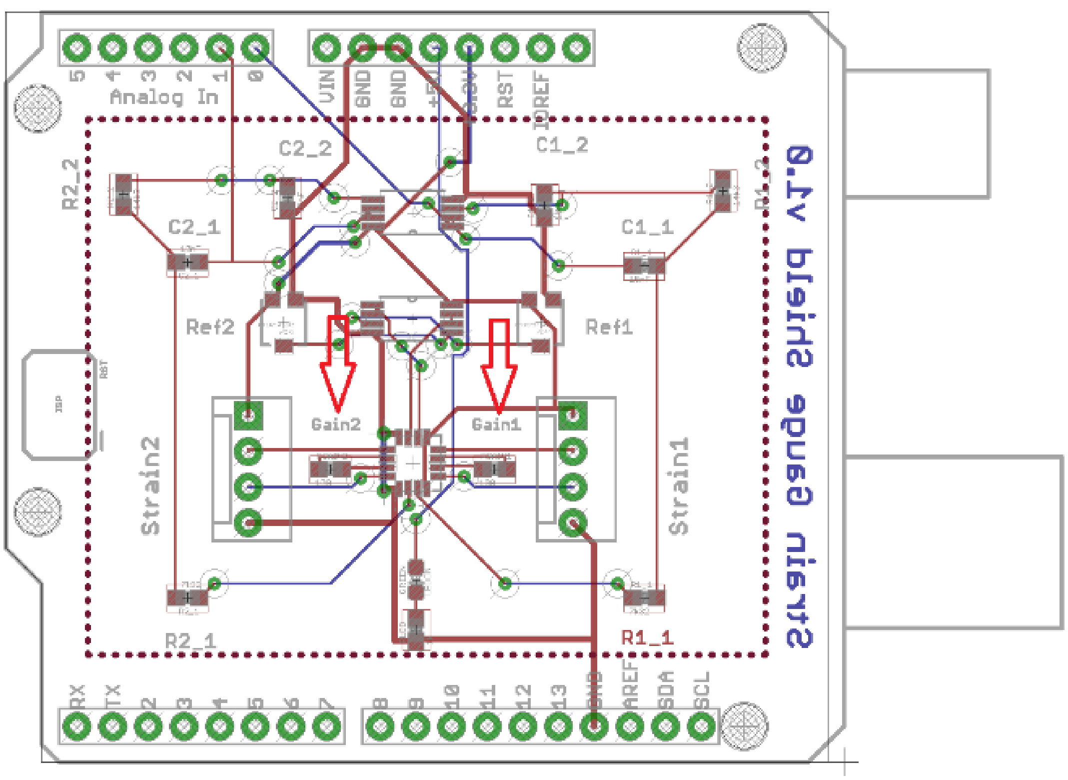

Figure 7: RGAIN positions on SGS

- The Reference voltage per channel.
  - The reference voltage is used to offset the output signal to a mid-supply voltage in order to be used with a single power supply ADC which is part on the Duino boards in use. Each Strain channel has its own reference voltage to be set with the specific

channel potentiometer as shown in Figure 8: Reference potentiometers positions on SGS.

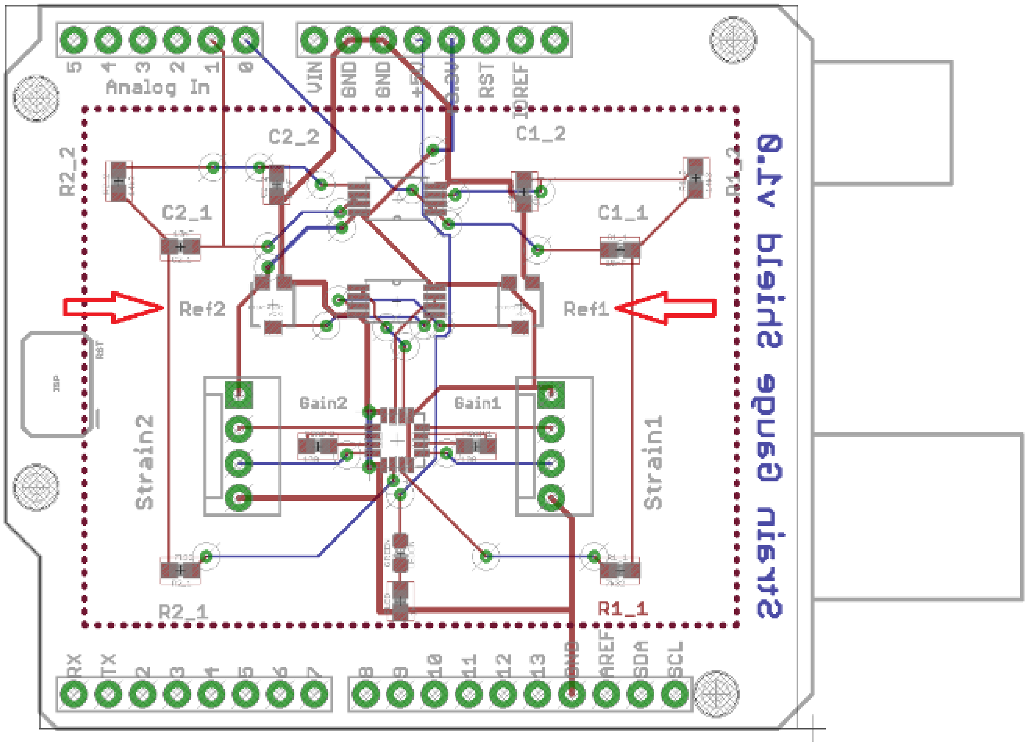

Figure 8: Reference potentiometers positions on SGS.

4.3 Filter

The SGS has been fitted with a low-pass 2nd order Bessel filter at 1000 Hz for both channels after the instrument amplifier. The filter can easily be adjusted by replacing the resistor values (R1_1, R1_2, R2_1 and R2_2) and capacitor values (C1_1, C1_2, C2_1 and C2_2) for the specific frequency that might be required. Component names R1_1, R1_2, C1_1 and C1_2 related to channel one. Component names R2_1, R2_2, C2_1 and C2_2 related to channel 2)

For ease of reference to adjust the filter one can use the Freeware program FilterLab (http://filterlab.software.informer.com/2.0/) to calculate the required values of the 2nd order Bessel filter to cater for the necessary frequencies if the setup 1000 Hz is not sufficient for the user.

It is also possible to change the low-pass filter to a high-pass filter if need be, because the resistors and capacitors can change places (resistors and capacitors are 0603 specified packaging) for easy placement on the PCB.