ISIM Lab 2 – Strain Gauge

Jamie Cho

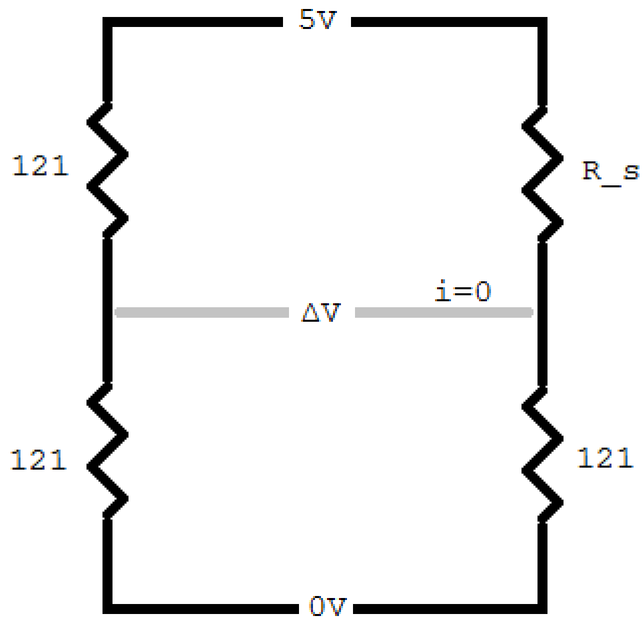

Figure 1. The diagram of the Strain Gauge circuit, which will be referred to extensively in this document. For simplicity of representation, potentiometers and the strain gauge setup were removed; more specific diagram is already detailed in the lab handout. R_s is R_{strain}.

1)

The equation derived from the above circuit is:

$$\Delta V_{amp} = \left(1 + \frac{100000}{R_{gain}}\right) * \left(\left(5 - \frac{5}{121 + 121} * 121\right) - \left(5 - \frac{5 * R_{strain}}{121 + R_{strain}}\right)\right)$$

Notice that for the parallel resistors, R_{strain} ought to be calculated beforehand.

Equivalently, solving this for $R_{strain,}$:

$$R_{strain} = -\frac{121 * (R_{gain} * (2 * V + 5) + 500000)}{R_{gain} * (2 * V - 5) - 500000}$$

The following MATLAB script is the implementation of the first equation. It also reveals the derivation of the first formula step-by-step:

```
function V = V_amp(R_strain, R_gain)
% Independent Variables

Gain = 1 + 100000/R_gain;
I_left = 5/(121 + 121);
I_right = 5/(121+ R_strain);
```

```
V_left = 5 - I_left*121;
V_right = 5 - I_right * R_strain;
V_raw = V_left - V_right;
V = V_raw * Gain;

end
```

Running the following command line:

```
R_eq = @(R1,R2) 1/(1/R1 + 1/R2);

R_strain = R_eq(121,100*1000);

R_gain = 4990;

disp (V_amp(R_strain,R_gain));
```

displays -0.0318, which is consistent with measured value (-36 mV = -0.36V ≈ -.0318 V)

The following chart depicts the data obtained from repeated iterations:

Resistance(Ω)	Theoretical (V)	Experimental (V)	Discrepancy (%)
100 K	-0.0318	-.036	-13.2%
499 K	-0.0064	-.008	-25%
1 M	-0.0032	-.004	-25%

To account for the (relatively big) discrepancy, it is important to note that – as indicated above – I used a 4.99KΩ resistor for the amplifier, which undermined the resolution of the measure; 200Ω resistor consistently failed to perform as anticipated on my circuit, outputting in the range of 2.36V regardless of change in R_{strain}. Baffled by the results, I consulted my peers, one of whom – Eric Miller – attributed this phenomenon to the limitation in the Analog Discovery's capacity of measurement. The input voltage was simply too big to display a meaningful value. At his advice, I changed the resistor from 200Ω resistor to 4.99KΩ resistor, after which the experimental data was coherent with the theoretical data.

That is, though the discrepancy may seem large, it is significantly similar to the theoretical value, especially considering that even a delicate change – in this experiment – brings about great ramifications. After the extensive verification, the results may now be applied in the following section.

2)

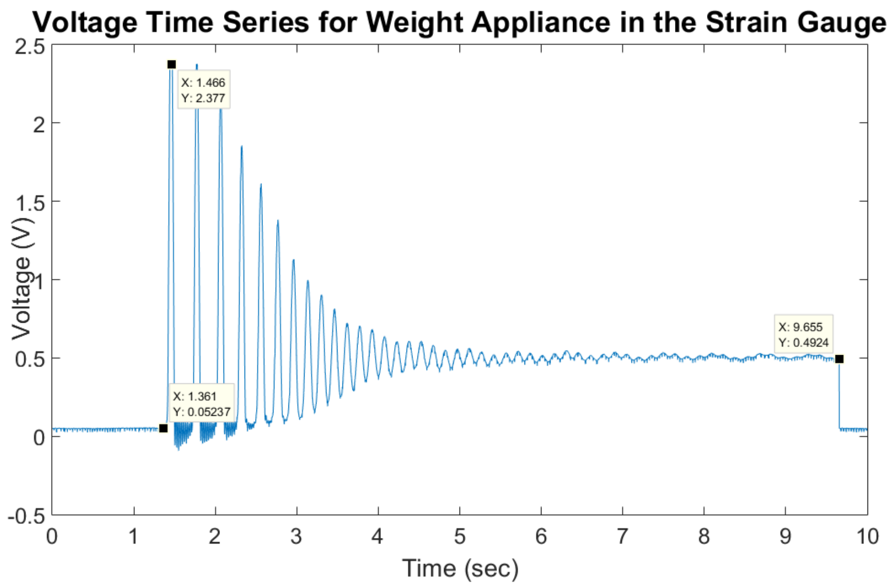

Figure 2. Amplified Voltage Time Series; it is unclear from the figure, but the initial jump was from 0.05237 to 2.377 Volts, later settling at 0.4924 Volts.

In order to measure the minute change in the strain gauge, the 4.99KΩ resistor was supplanted with 200Ω resistor. For this scenario, the difference in resistance incurred by the strain gauge was sufficiently small for the Analog Discovery to accommodate. However, the trend as visible from the plot implies that the first peak measure still may have been inaccurate (i.e. capped out) due to the limitations of the instrument. Fortunately, the experiment was not concerned with the immediate strain caused by the impact; the difference in voltage due to the appliance of weight can be calculated by the juxtaposing the equilibrium value taken from the time at which the weight settled (.4924 V) to the initial value (0.05237 V): this yields the value of 0.44 volts.

To figure out the change in resistance incurred by the strain gauge, the second equation was applied as follows:

```
>> S = @(G,V) -121*(G*(2*V+5)+500000) / (G * (2*V-5) - 500000);
disp(S(200,.44));
  121.0850
```

Here, S is R_{strain}, G is R_{gain}, and V is the measured voltage difference.
Subtracting the theoretical data of 121Ω from the value, we now obtain .0850Ω as the additional resistance supplied by the strain gauge.

3)

The smallest voltage resolution obtainable from this circuit is – at least, by the Analog Discovery – 2 mV, or 0.002 V. Retaining the R_{gain} of 100Ω, the smallest resistance change can be found by applying the same equation:

```
>> S = @(G,V) -121*(G*(2*V+5)+500000) / (G * (2*V-5) - 500000);
disp(S(200,.002));
   121.0004
```

It is thus seen that the smallest detectible resistance change is .0004Ω.

4)