Strain Gauge

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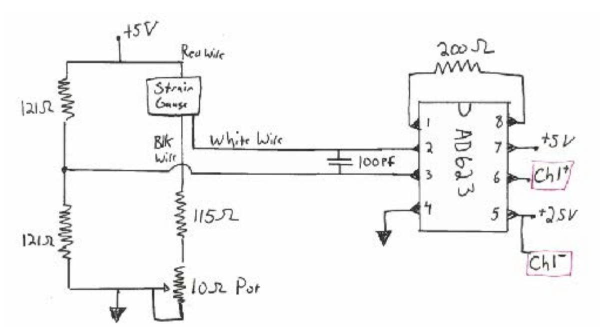
Abstract

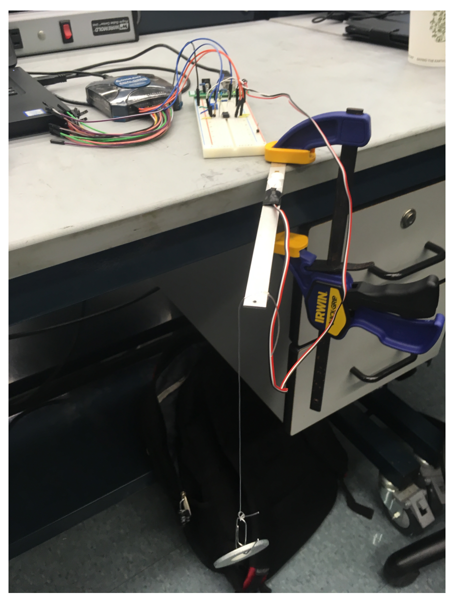
The purpose of the strain gauge lab is to utilize the concept of voltage divider, take advantage of changes in resistance and, thus, the voltage by the stretching of a resistors, and calibrate a strain gauge using the above concepts.

1 Description

In this lab, a strain gauge circuit that is capable of reflecting voltage changes according to the mass them was built on the breadboard. The circuits were constructed based on the schematics provided in the lab description. A circuit without an integrated circuit was first used to zero the measurement as close as possible by turning the potentiometer in series with the strain gauge itself. Then, the integrated circuit AD623 was included to amplify the signal and make taking measurement for V_{out} easier. A calibration curve would be created by adding washers of different masses to a paper clip tie to one end of the strain gauge.



(a) The schematics of the strain gauge lab provided in the lab material.



(b) The real world setup of the lab.

Figure 1: The strain gauge setup.

2 Evidence

The following is a table displaying the measured voltages and added mass in the lab process. Since almost all washers are of different masses, some measurements might be more spaced out than others.

Table 1: Measured Voltages and Mass

Mass(g)	0	8.6	27.8	45.3	56.4	65	77.5	90.5	101.6	179.1
Voltages(mV)	120	170	330	450	550	630	690	810	890	1450

Based on the data obtained, a best fitting line describing the relationship between expected voltage and mass is found to be the following and plotted in the accompany figure:

$$voltage = 7.4988 \times mass + 120mV \tag{1}$$

where voltage is in millivolt(s) and mass is in gram(s). The curve has an R^2 of .999.

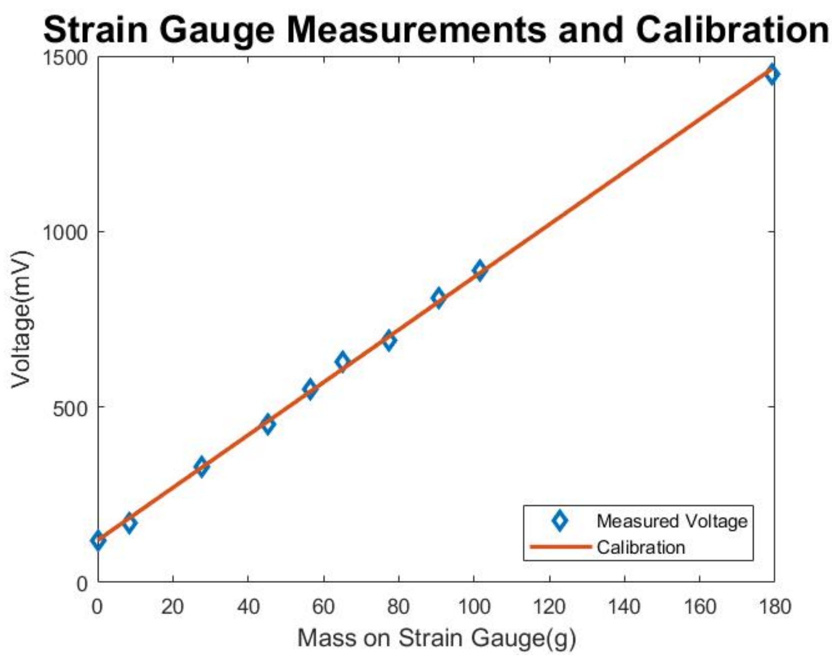


Figure 2: Both the data points in blue diamonds and the calibration curve in red generated based on them are shown in the plot.

The result looks to be very linear and makes it quite easy to invert the equation to calculate mass from measured voltage.

3 Interpretation

As the relationship in the plot suggests, when the washers on one end of the washers bent the metal bar the strain gauge was attached to, the resistance of the strain gauge went up as the side to which the gauge was glued stretched slightly longer and the resistance of the strain gauge increased.

The change in resistance is directly proportional to the change in length of the bar through

$$\frac{\Delta R}{R} = G\frac{\Delta L}{L} \tag{2}$$

where G is the constant "gauge factor" that is related to the width and thickness of the wires. In addition, according to the calibration equation, for every gram increase in mass, the output voltage would increase by about 7.4988 mV, so it can be concluded that the strain gauge built in this lab is quite sensitive.

3.1 20mV change in the output voltage

The equation to calculate the gain G (different from the G gauge factor in Equation (2)) of the AD263 is given in the data sheet, and it is related to the resistance between Pin 1 and Pin 8. Since a 220 Ω resistor was in connecting Pin 1 and Pin 8 of the integrated circuit, the gain of this particular case is:

$$G = 1 + \frac{100000\Omega}{R_G} = 1 + \frac{100000}{200} = 501 \tag{3}$$

Since the output voltage was amplified 501 times, the actual change in voltage is still 501 times smaller than 20 mV. With the voltage divider's equation, the following relationship can be obtained. Combining Equation (3) and (4) would gives by how much resistance would increase for a 20 mV change in the output voltage.

$$V_{actual} = \frac{20}{501} mV \tag{4}$$

$$V_{actual} = 2.5 - 5 \times \frac{120}{240 + \Delta R} \tag{5}$$

$$\Delta R = \frac{2.5 \times 240 - 600 - 240 \times V_{actual}}{V_{actual} - 2.5} \tag{6}$$

$$= 0.0038323965 \tag{7}$$

As for the mass applied to induce a 20 mV change, the precise value can be calculated by inverting Equation (1) for mass.

$$\Delta V = voltage - 120mV = 7.4988 \times mass \tag{8}$$

$$mass = \frac{1}{7.4988} \times \Delta V \tag{9}$$

Plugging in 20 mV

$$mass = \frac{1}{7.4988} \times 20mV = 2.6671g \tag{10}$$

Thus, it is concluded that in order to receive a 20 mV change in the output voltage, a mass of about 2.6671 g should be applied to the gauge.

3.2 Errors in resistors and voltage supply

When people are calculating various properties of a circuit, such as current, voltage, and resistance, it is assumed that it is a perfect circuit, i.e. voltages, resistance, etc. are all in exact numbers. However, that's never the case. On Page 22, the book walks through calculating voltage change based on the assumptions that V_{in} is exactly 2.5V, and that the nominal resistance of the strain gauge and the resistor is exactly 100 Ω. A 0.1 % increase to the strain gauge's resistance means 0.625 mV decrease to V_{out}.

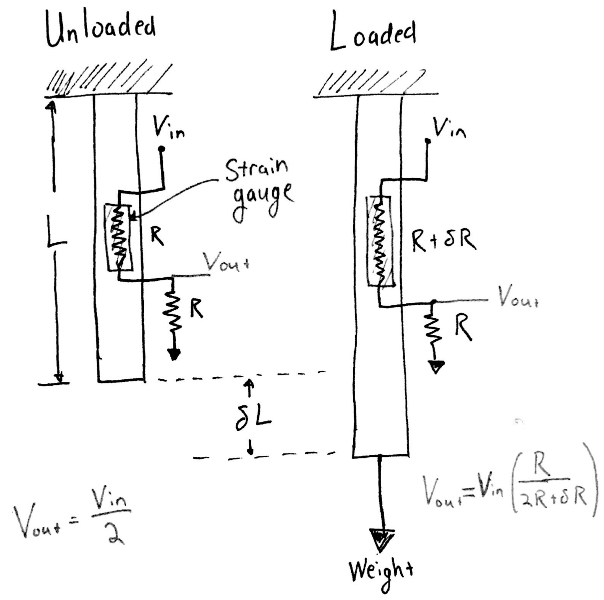


Figure 3: Figure 2.11 on iSIM Textbook Page 21 which the problem of this section is about.

However, it is alleged that the slight imprecision of resistors and voltage supply doesn't affect the final result, but it is the change in resistance that actually matters. Suppose that the voltage supplied is 2.513V, that the fixed resistor is 101.5 Ω, and that the nominal resistance of the strain gauge is 99.5 Ω. When the strain gauge is at its nominal resistance, with the voltage divider equation we get:

$$V_{out1} = \frac{101.5}{101.5 + 99.5} \times 2.513 = 1.269002488V \tag{11}$$

After the strain gauge get 0.1% increase in resistance, V_{out} is as follows:

$$V_{out2} = \frac{101.5}{101.5 + 99.6} \times 2.513 = 1.268371457V \tag{12}$$

Subtract V_{out2} from V_{out1}, we get the voltage difference:

$$V_{out1} - V_{out2} \approx 0.631mV \tag{13}$$

which is only .96% error from the "perfect" 0.625mV. Therefore, it is safe to say that the minor uncertainty in various electrical components won't affect results in a major way. It holds significance to this particular lab in that it uses a strain gauge and the voltage divider theory as posed by the question from the book.