ELECTROMECHANICAL ANALYSIS LAB
EMET 3424_70
TUESDAY, FEBUARY 18, 2001
8:00 – 9:50AM, SET 363

LAB#2A & 2B

SIGNAL CONDITIONGING CIRCUITS

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TABLE OF CONTENTS

LAB OBJECTIVE

The objective of this laboratory experiment is to gain experience and practice working with electrical devises. We plan to use the experiments in this lab to form a basis for all generalized measuring systems. In addition, we will identify how systems are constructed such that we can isolate a single input and measure the resulting outputs. All this will be done while be working with the basic theory's of converting a "change in resistance" to a "change in voltage" with the use of a voltage-divider bridge circuit.

The equipment used in this lab is listed but limited to this list.

- Hewlett Packard 34401A Multimeter, S/N 3146A29090
- Resistors: 1 KΩ & 560 Ω.
- Potentiometer
- Null Potentiometer, S/N: K7104571524
- Breadboard
- Power Supply from SL10
- TQ SL10 Vibrating Beam, Tec Quipment Ltd., Model/Serial: L10/L5619/10
- Micrometer (mm), More & Wright: Sheffield, England
- Semiconductor Strain Gauge on SL10
- SLI System Laboratory S/N: SLI/L5517/9
- Multiple Outlet Strip, Sockets Plus, Perma Power, Serial: 265-8533 (Mov Surge Protected)

PART A-1: VOLTAGE-DEVIDER CIRCIT

THEORY

Voltage divider circuit is a way to take a source voltage and divide it up so you can pick off a lower voltage. With this setup, we can convert a change in resistance to a change in voltage. Given a specified voltage and knowing the resistance we should be able to determine the output with the use of a simple equation. This equation is as follows.

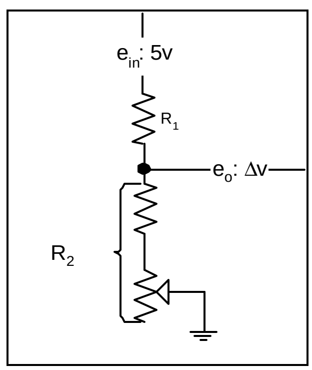
FIGURE A1.1 EQATION

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

This equation finds output voltage in terms of R_1, R_2, and V_{in}. When we look at the units we see that ohms divide out and we our left with an output in volts.

SCHEMATIC

FIGURE: A1.2 CIRCUIT



PROCEDURE/DATA COLLECTION

The circuit is constructed. The full range resistances of the resistors are measured while voltage is off. We calculate our minimum and maximum values of output voltage. Voltage is turned on with a set input of 5 volts. Output voltage is read from the DMM and reported for the first resistances. Resistance is then changed by way of the potentiometer. The new resistance of resistor two is measured while voltage is off. Voltage is turned back on. A second output voltage is read from the DMM and reported. These steps are repeated until ten data points have been reported.

The potentiometer is replaced with the semiconductor strain gauge on the SL10. The previous procedure is repeated with the exception of the way in that the residence is changed. A force by way of the micrometer is applied to the cantilever beam, changing the dimensions of the strain gauge and raising resistance.

CALCULATIONS

Minimum Output Voltage

$$R_1 := 922$$

$$R_2 := 22 + 549$$

$$V_{in} := 5$$

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

$$e_o = 1.912$$

Maxmum Output Voltage

$$R_1 := 922$$

$$R_2 := 568 + 549$$

$$V_{in} := 5$$

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

$$e_o = 2.739$$

Minimum Output Voltage
/w Strain Gauge

$$R_1 := 922$$

$$R_2 := 910.2$$

$$V_{in} := 5$$

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

$$e_o = 2.484$$

Maximum Output Voltage
/w Strain Gauge

$$R_1 := 922$$

$$R_2 := 930$$

$$V_{in} := 5$$

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

$$e_o = 2.511$$

RESULTS SUMMARY

TABLE: A1.1 VOLTAGE-DIVIDER CIRCUIT

Calculated	
V_0 (V)	R_2 (Ω)
1.912	571
2.739	1117

Measured	
V_0 (V)	R_2 (Ω)
2.643	1108
2.488	979
2.420	928
2.338	870
2.288	834
2.221	792
2.139	739
1.993	656
1.870	587
1.846	580

FIGURE: A1.3 VOLTAGE-DIVIDER

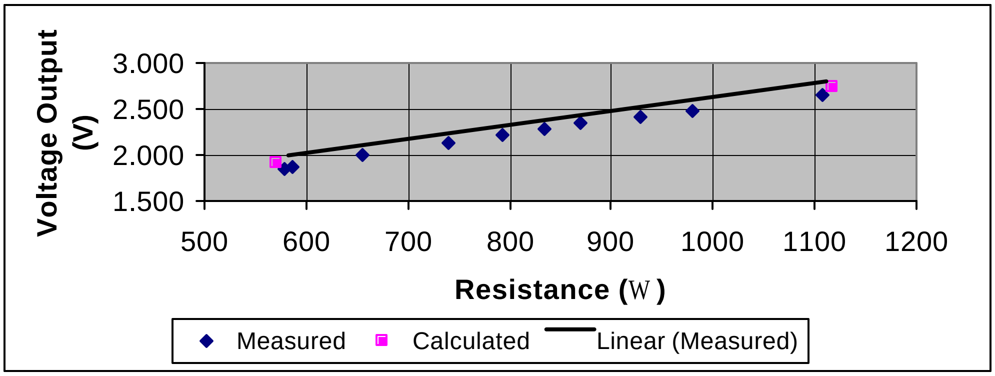
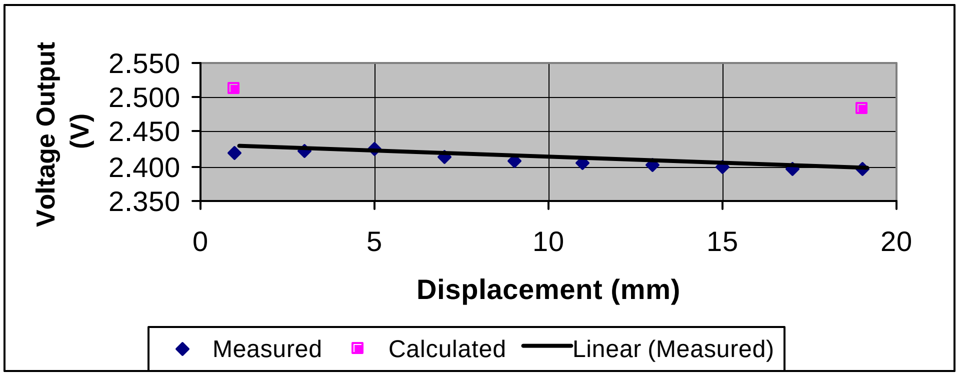


TABLE: A1.2 VOLTAGE-DIVIDER CIRCUIT W/ STRAN GUAGE

Calculated		
R_2 (Ω)	V_0 (V)	Dis (mm)
930	2.511	1
910	2.484	19

Measured		
R_2 (Ω)	V_0 (V)	Dis (mm)
930	2.420	1
927	2.423	3
925	2.426	5
923	2.413	7
920	2.409	9
918	2.406	11
915	2.403	13
913	2.399	15
911	2.397	17
910	2.396	19

FIGURE: A1.4 VOLTAGE-DIVIDER W/ STRAN GUAGE



As can be seen from Figure: A1.2 our measured minimum and maximum values have fallen within close range of our calculated values. This means we have verified our equation and are able to determine the effects of a change in resistance with the use of a voltage-divided.

PART A-2: VOLTAGE-DEVIDER CIRCIT W/ NULL POTENTIOMETER

THEORY

When dealing with sets of number it is important to be able to analyze the data. Often this is the hardest part. To simplify the impetration we sometimes like to start at a zero point to determine a pattern. To do this we must null or zero the output while the input is at zero. This is done with a null potentiometer. This equation is as follows.

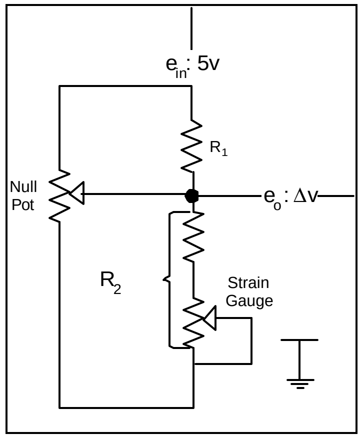
FIGURE A2.1 EQUATION

$$e_o := \left[\frac{R_2}{\left(R_1 + R_2 - \frac{1}{2}\right)}\right] \cdot V_{in}$$

This equation is different from our first (*see Figure A1.1*) in that we subtract one half ohms from our total to create a zeroing effect. When data is plotted, it should reveal a linear relationship with a y-intercept at zero. This has no effect on our outcome units.

SCHEMATIC

FIGURE: A2.2 CIRCUIT W/ NULL POT



PROCEDURE / DATA COLLECTION

A null potentiometer is added to the circuit. The full range resistances of the resistors are measured while voltage is off. We calculate our minimum and maximum values of output voltage. Voltage is turned on with a set input of 5 volts. The cantilever beam is set to at level position. The potentiometer is adjusted such that the output voltage is equal to zero. Output voltage is read from the DMM and reported for the first resistances. Resistance is then changed by applying a force by way of the micrometer the cantilever beam, changing the dimensions of the strain gauge and raising resistance. The new resistance of resistor two is measured while voltage is off. Voltage is turned back on. A second output voltage is read from the DMM and reported. These steps are repeated until ten data points have been reported.

CALCULATIONS

Minimum Output Voltage
/w Strain Gauge

$$R_1 := 922$$

$$R_2 := 910.2$$

$$V_{in} := 5$$

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

$$e_o = 2.484$$

Maximum Output Voltage
/w Strain Gauge

$$R_1 := 922$$

$$R_2 := 930$$

$$V_{in} := 5$$

$$e_o := \left(\frac{R_2}{R_1 + R_2}\right) \cdot V_{in}$$

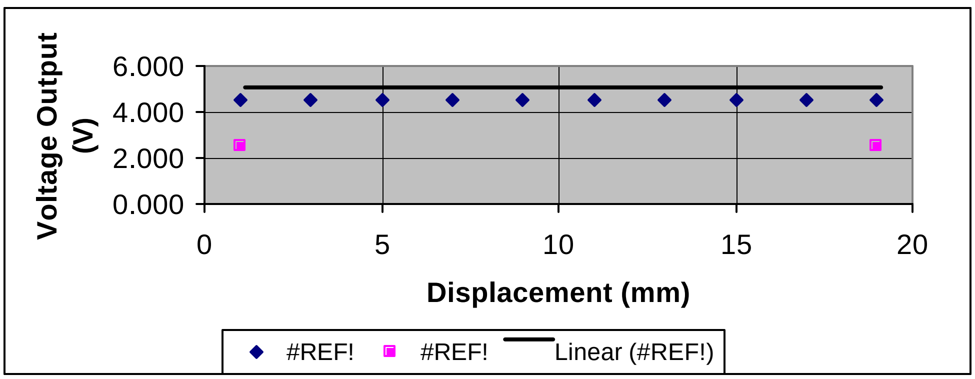
$$e_o = 2.511$$

RESULTS SUMMARY

TABLE: A2.1 VOLTAGE-DIVIDER CIRCUIT W/ NULL POTENTIOMETER

Calculated			Measured	
V_0 (V)	Dis (mm)		V_0 (V)	Dis (mm)
2.511	1		4.528	1
2.484	19		4.528	3
			4.525	5
			4.524	7
			4.524	9
			4.524	11
			4.521	13
			4.521	15
			4.519	17
			4.513	19

FIGURE: A2.3 VOLTAGE-DIVIDER W/ NULL POTENTIOMETER



As can be seen from Figure: A.2 our measured minimum and maximum values have fallen within close range of our calculated values. This means we have verified our equation and are able to determine the effects of a change in resistance with the use of a voltage-divided.

PART B-1 (A): QUARTER BRIDGE CONFIGURATION

THEORY

Due to their outstanding sensitivity, Wheatstone Bridge Circuits are very advantageous for the measurement of resistance, inductance, and capacitance. Wheatstone bridges are widely used for strain measurements. It consists of four resistors arranged in a diamond orientation. An input DC voltage, or excitation voltage, is applied between the top and bottom of the diamond and the output voltage is measured across the middle. When the output voltage is zero, the bridge is said to be balanced. One or more of the legs of the bridge may be a resistive transducer, such as a strain gage. The other legs of the bridge are simply completion resistors with resistance equal to that of the strain gage(s). As the resistance of one of the legs changes, by a change in strain from a resistive strain gage for example, the previously balanced bridge is now unbalanced. This unbalance causes a voltage to appear across the middle of the bridge. This induced voltage may be measured with a voltmeter or the resistor in the opposite leg may be adjusted to rebalance the bridge. In either case, the change in resistance that caused the induced voltage may be measured and converted to obtain the engineering units of strain. This equation is as follows.

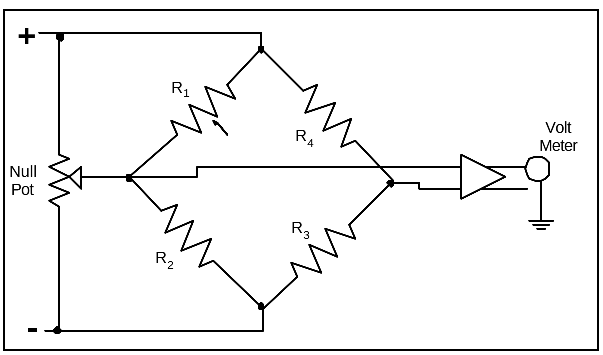
FIGURE B1.1 EQUATION

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

This equation is different from our first (*see Figure A1.1*) in that we find the ratio of resistance of one side of the bridge circuit and subtract it from the other. When data is plotted, it should reveal a linear relationship with a y-intercept at zero. This has no effect on our outcome units.

SCHEMATIC

FIGURE: B1.2 QUARTER BRIDGE CIRCUIT



PROCEDURE / DATA COLLECTION

The full range resistances of the resistors are measured while voltage is off. We calculate our minimum and maximum values of output voltage. Voltage is turned on with a set input of 5 volts. The cantilever beam is set to at level position. The null potentiometer is adjusted such that the output voltage is equal to zero. This is known as the offset. We then add end resistors to reduce the sensitivity of the null pot. Output voltage is read from the DMM and reported for the first resistances. Resistance is then changed by applying a force by way of the micrometer the cantilever beam, changing the dimensions of the strain gauge, and raising resistance. The new resistance of resistor two is measured while voltage is off. Voltage is turned back on. A second output voltage is read from the DMM and reported. These steps are repeated until ten data points have been reported. Strain vs. Output Voltage is then plotted creating a linear relationship. The slope is determined with the creation of a treandline. This slope can be expressed as the sensitivity of the circuit.

CALCULATIONS

Maxmum Output Voltage

$$R_1 := 379$$

$$R_2 := 448$$

$$R_3 := 379$$

$$R_4 := 489$$

$$E := 5$$

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

$$V_o = -0.10824$$

Minmum Output Voltage

$$R_1 := 359$$

$$R_2 := 448$$

$$R_3 := 379$$

$$R_4 := 489$$

$$E := 5$$

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

$$V_o = -0.04111$$

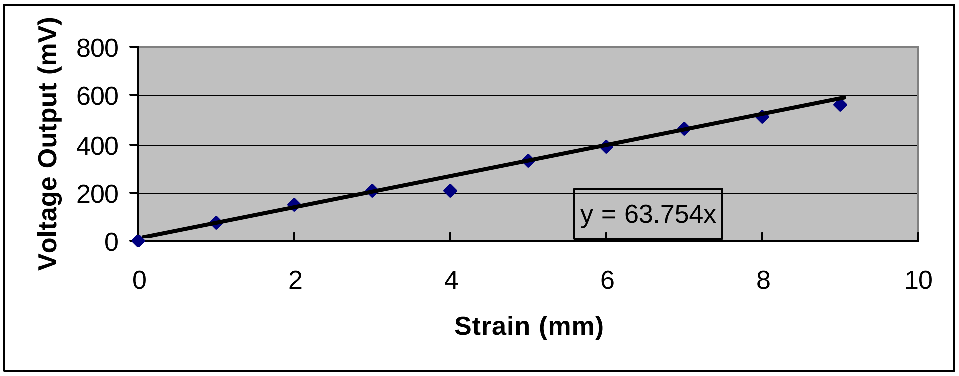
RESULTS SUMMARY

TABLE: B1.1 QUARTER BRIDGE CONFIGURATION CIRCUIT

Calculated		
R_2 (Ω)	V_0 (V)	Dis (mm)
274	-0.59253	0
268	-0.52541	9

Measured		
R_2 (Ω)	V_0 (mV)	Dis (mm)
274	0	0
273	72	1
272	148	2
272	203	3
271	207	4
271	330	5
270	390	6
269	465	7
269	510	8
268	560	9

FIGURE: B1.3 QUARTER BRIDGE CONFIGURATION



As can be seen from Figure: B1.3 our slope is close to 64. This means our sensitivity for the quarter bridge circuit is 64 mV/mm.

PART B-2 (B): HALF BRIDGE CONFIGURATION

THEORY

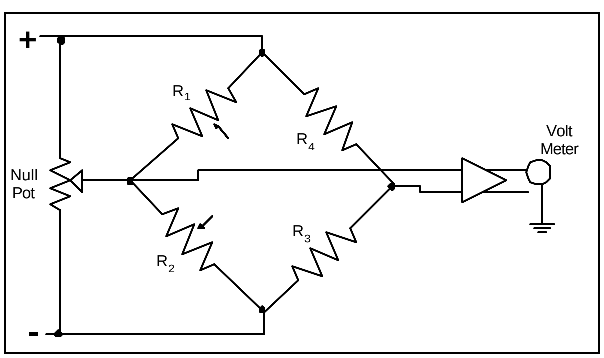
The half bridge configuration is very simpler to the quarter bridge. The only difference is that instead of one variant resistor we now have two variant resistors. This means that we should be able to detect a change in strain with a smaller sensitivity. We will use the same equation to calculate maximum and minimum output voltage.

FIGURE B2.1 EQUATION

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

SCHEMATIC

FIGURE: B2.2 HALF BRIDGE CIRCUIT



PROCEDURE / DATA COLLECTION

The procedure flowed is the same, as done so in B-1. This also applies to the data collection.

CALCULATIONS

Minmum Output Voltage

$R_1 := 379$

$R_2 := 376$

$R_3 := 379$

$R_4 := 489$

$E := 5$

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

$V_o = -0.327$

Maxmum Output Voltage

$R_1 := 359$

$R_2 := 398$

$R_3 := 379$

$R_4 := 489$

$E := 5$

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

$V_o = -0.18802$

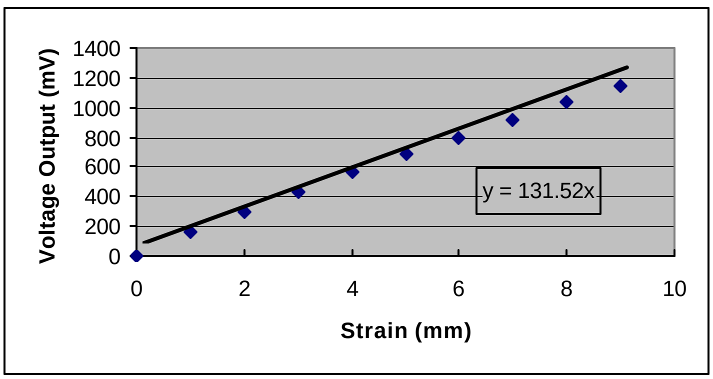
RESULTS SUMMARY

TABLE: B2.1 HALF BRIDGE CONFIGURATION CIRCUIT

Calculated	
V_0 (mV)	Dis (mm)
-445.618	0
-377.953	9

Measured	
V_0 (mV)	Dis (mm)
0	0
163	1
302	2
434	3
568	4
680	5
800	6
914	7
1030	8
1145	9
1270	10

FIGURE: B2.3 HALF BRIDGE CONFIGURATION



As can be seen from Figure: B1.3 our slope is close to 132. This means our sensitivity for the half bridge circuit is 132 mV/mm. If we look back to the results for the sensitivity of the quarter bridge (64 mV/mm), we can see that the half bridge has sensitivity two times that of the quarter bridge. When greater sensitivity is required, the use of the half bridge is expected.

PART B-3 (C): MEASURING SYSTEM APPLICATION

THEORY

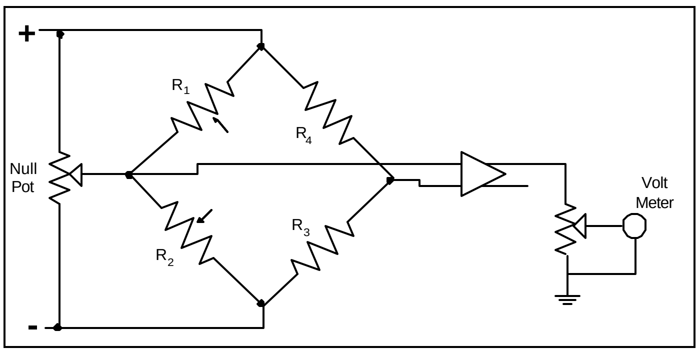
There are times when we may not be able to manual control the strain that is being measured with our strain gauges. If this is the case we would like to be able a one to one collation between inputs and the outputs. This should have little effects on the sanctity of the circuit. We will use the same equation to calculate maximum and minimum output voltage.

FIGURE B3.1 EQUATION

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

SCHEMATIC

FIGURE: B3.2 CIRCUIT HALF BRIDGE VOLTAGE DIVIDER CIRUIT



PROCEDURE / DATA COLLECTION

We will add a potentiometer to our half bridge circuit to create a half bridge, voltage divider circuit. The new output is then taken from the wiper of the new pot. We then calibrate the circuit so 100mV is equal to 1mm. Strain vs. Output Voltage is then plotted creating a linear relationship. The slope is determined with the creation of a treandline. This slope can be expressed as the sensitivity of the circuit.

CALCULATIONS

Minmum Output Voltage

$R_1 := 379$

$R_2 := 376$

$R_3 := 379$

$R_4 := 489$

$E := 5$

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

$V_o = -0.327$

Maxmum Output Voltage

$R_1 := 359$

$R_2 := 398$

$R_3 := 379$

$R_4 := 489$

$E := 5$

$$V_o := E \cdot \left(\frac{R_2}{R_1 + R_2} - \frac{R_4}{R_3 + R_4} \right)$$

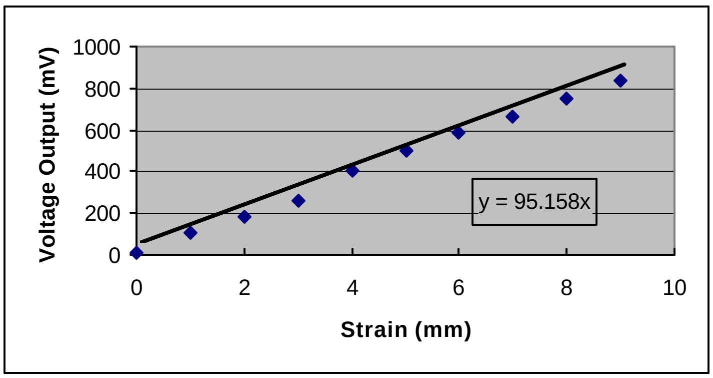
$V_o = -0.18802$

RESULTS SUMMARY

TABLE: B3.1 MEASURING SYSTEM APPLICATION CIRCUIT

Measured	
V_0 (mV)	Dis (mm)
10	0
108	1
185	2
263	3
401	4
500	5
590	6
668	7
750	8
837	9
920	10

FIGURE: B3.3 MEASURING SYSTEM APPLICATION



As can be seen from Figure: B1.3 our slope is close to 95. This means our sensitivity for the circuit is 95 mV/mm.

DISCUSSION

We have see a few examples of how circuit can be set up to take very small monuments to determine output, if we know the inputs and the Signal Conditioning stage.

In Part B, we used Wheatstone Bridge Circuits. We now know that in order to nullify these circuits and create a balance the sum R_1 and R_2 must be equal to the sum of R_3 and R_4. In lab, this was imposable due to the selection of resistors. This does prevent us from balancing the circuit. However, we are still able to receive predictable data.

It is imperative with any lab that we are able to predicate the output data. Hens if there are any errors in the setup they will be recognized and corrected. In this lab I thing it may of helpful If we had a reference book by our side. To visualize the signal conditioning stage.