DEPT. OF ELECTRICAL & ELECTRONICS ENGINEERING
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY, Kattankulathur – 603203.

Title of Experiment	: **9. Displacement measurement using LVDT and pressure measurement using Strain gauge**
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Register Number	: RA2111028010094
Date of Experiment	: 02-12-2021
Date of submission	: 10-12-2021

Sl. No.	Marks Split up	Maximum marks (50)	Marks obtained
1	Pre Lab questions	5	
2	Preparation of observation	15	
3	Execution of experiment	15	
4	Calculation / Evaluation of Result	10	
5	Post Lab questions	5	
Total		**50**	

Staff Signature

Experiment No. 9 a) **Date:** 02/12/2021	**Displacement measurement using Linear Variable Differential Transformer**

Aim: To measure the displacement and to determine the characteristics of LVDT (Linear Variable Differential Transformer).

Apparatus required: LVDT, Digital displacement indicator, Calibration jig (with micrometer).

THEORY: LVDT (LINEAR VARIABLE DIFFERENTIAL TRANSFORMER)

The most widely used inductive transducer to translate the linear motion into electrical signals is the linear variable differential transformer (LVDT). The basic construction of LVDT is shown in Figure 1.

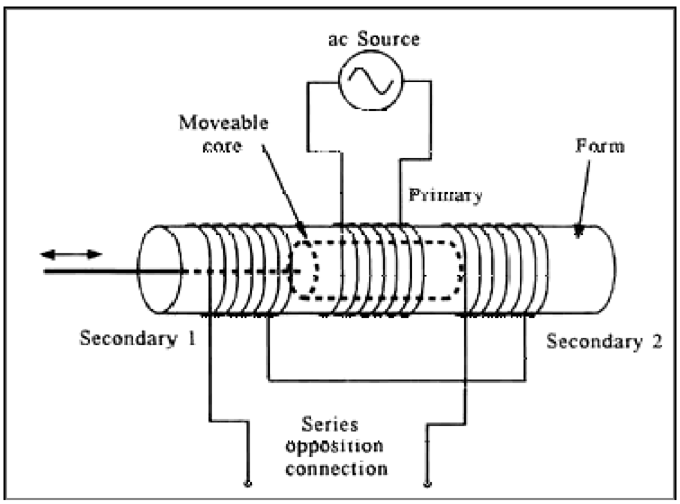


Figure 1. Linear Variable Differential Transformer

The transformer consists of a single primary P and two secondary windings S1 and S2 wound on a cylindrical former. The secondary windings have equal number of turns and are identically placed on either side. A moveable soft iron core is placed inside the transformer. The displacement to be measured is applied to the arm attached to the soft iron core. In practice the arm is made of highly permeability, nickel iron which is hydrogen annealed. This gives low harmonics low null voltage and high sensitivity. This is slotted longitudinally to reduce eddy current losses. The assembly is placed in stainless steel housing and the end leads provides electrostatic and electromagnetic shielding. The frequency of AC applied to primary windings may be between 50 Hz to 20 kHz. Since the primary winding is excited by an alternating source, it produces an alternating magnetic field which in turn induces alternating current voltage in the two secondary windings. Figure 2 depicts a cross-sectional view of an LVDT. The core causes the magnetic field generated by the primary winding to be coupled to the secondary. When the core is centered perfectly between both secondary and the primary as shown, the voltage induced in each secondary is equal in amplitude and 180 degrees out of phase. Thus, the LVDT output (for the series-opposed connection shown in this case) is zero because the voltage cancels each other. E0 = Es1 - Es2 = 0.

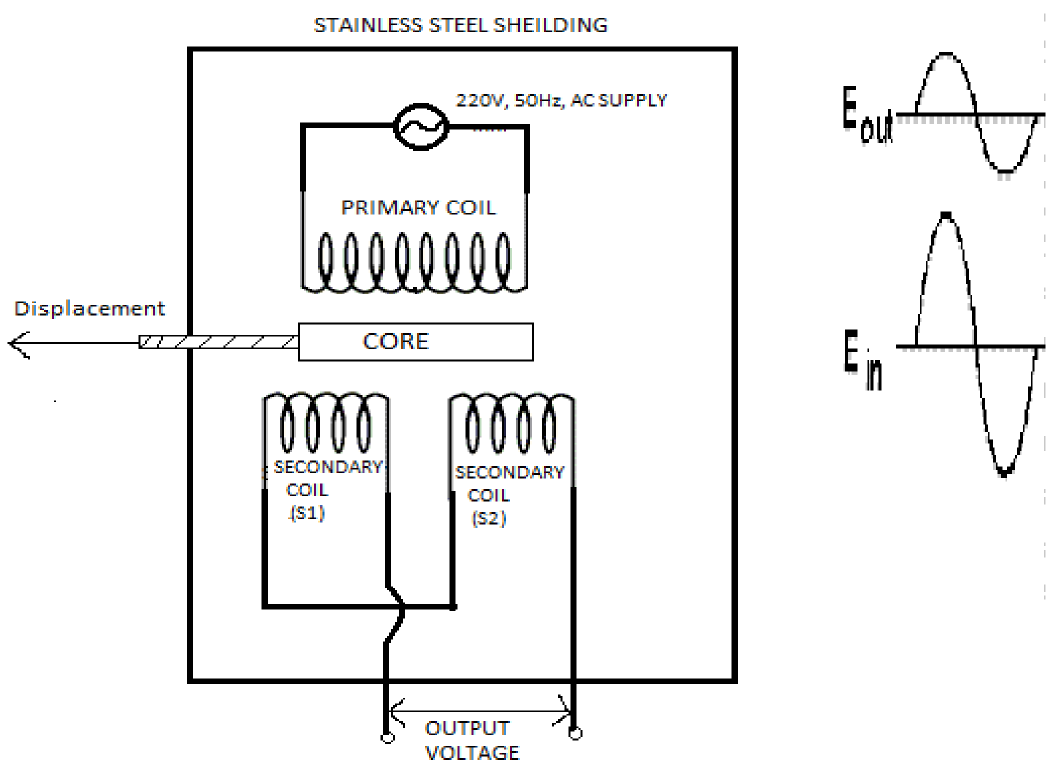


Figure 2. View of LVDT Core and Windings

Displacing the core to the left causes the first secondary to be more strongly coupled to the primary than the second secondary. The resulting higher voltage of the first secondary in relation to the second secondary causes an output voltage that is in phase with the primary voltage.

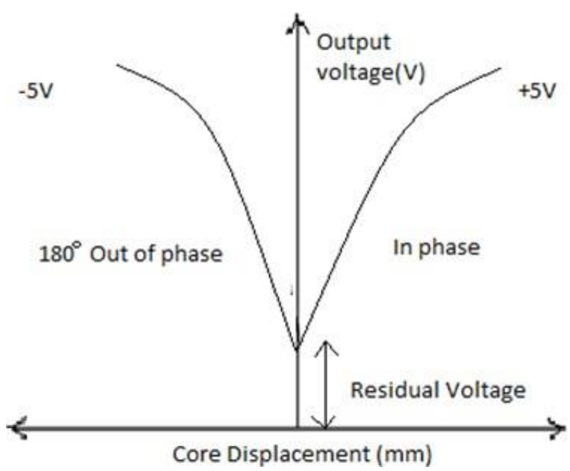
Likewise, displacing the core to the right causes the second secondary to be more strongly coupled to the primary than the first secondary. The greater voltage of the second secondary causes an output voltage to be out of phase with the primary voltage.

Procedure:

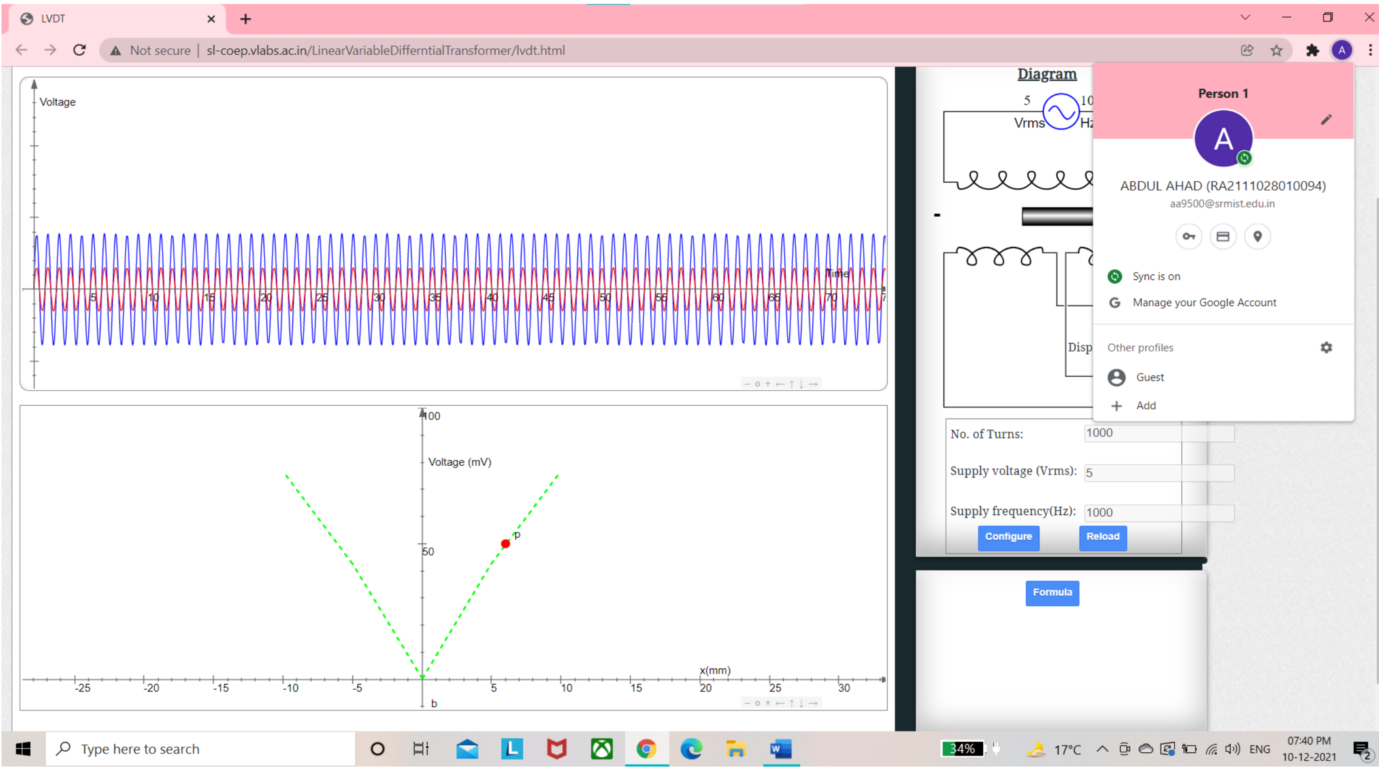
1. Plug power chord to AC mains 230 V, 50 Hz and switch on the instrument.
2. Place the READ/CAL switch at READ position.
3. Balance the amplifier with the help of zero knob so that display should read zero without connecting the LVDT to instrument.
4. Replace the READ/CAL switch at CAL position.
5. Adjust the calibration point by rotating CAL knob so display should read 10.00 i.e., maximum calibration range.
6. Again keep the READ/CAL switch at READ position and connect the LVDT cable to instrument.
7. Make mechanical zero by rotating the micrometer. Display will read (00.00) this is null balancing.
8. Give displacement with micrometer and observe the digital readings.
9. Plot the graph of micrometer reading v/s digital reading.

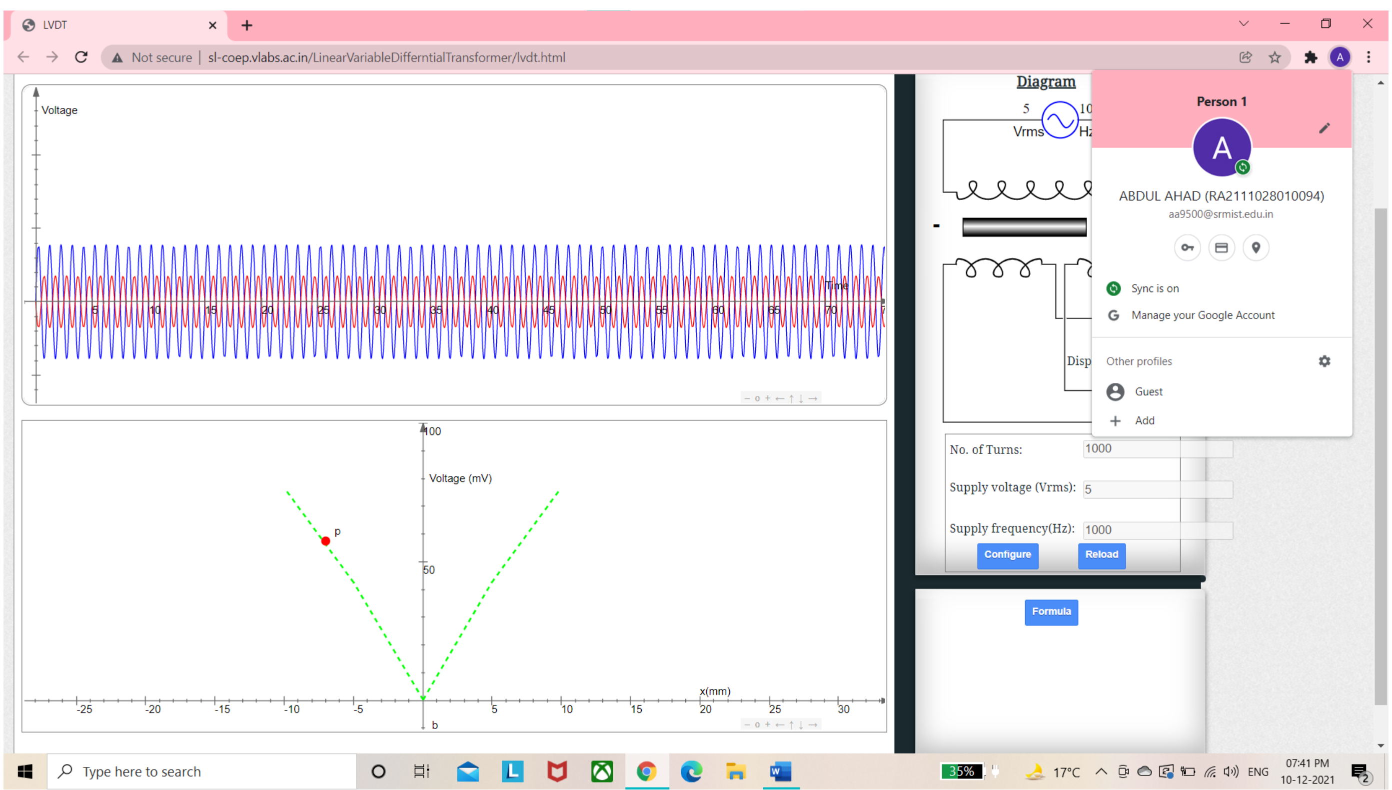
Simulation circuits

Model Graph:



Simulated circuits

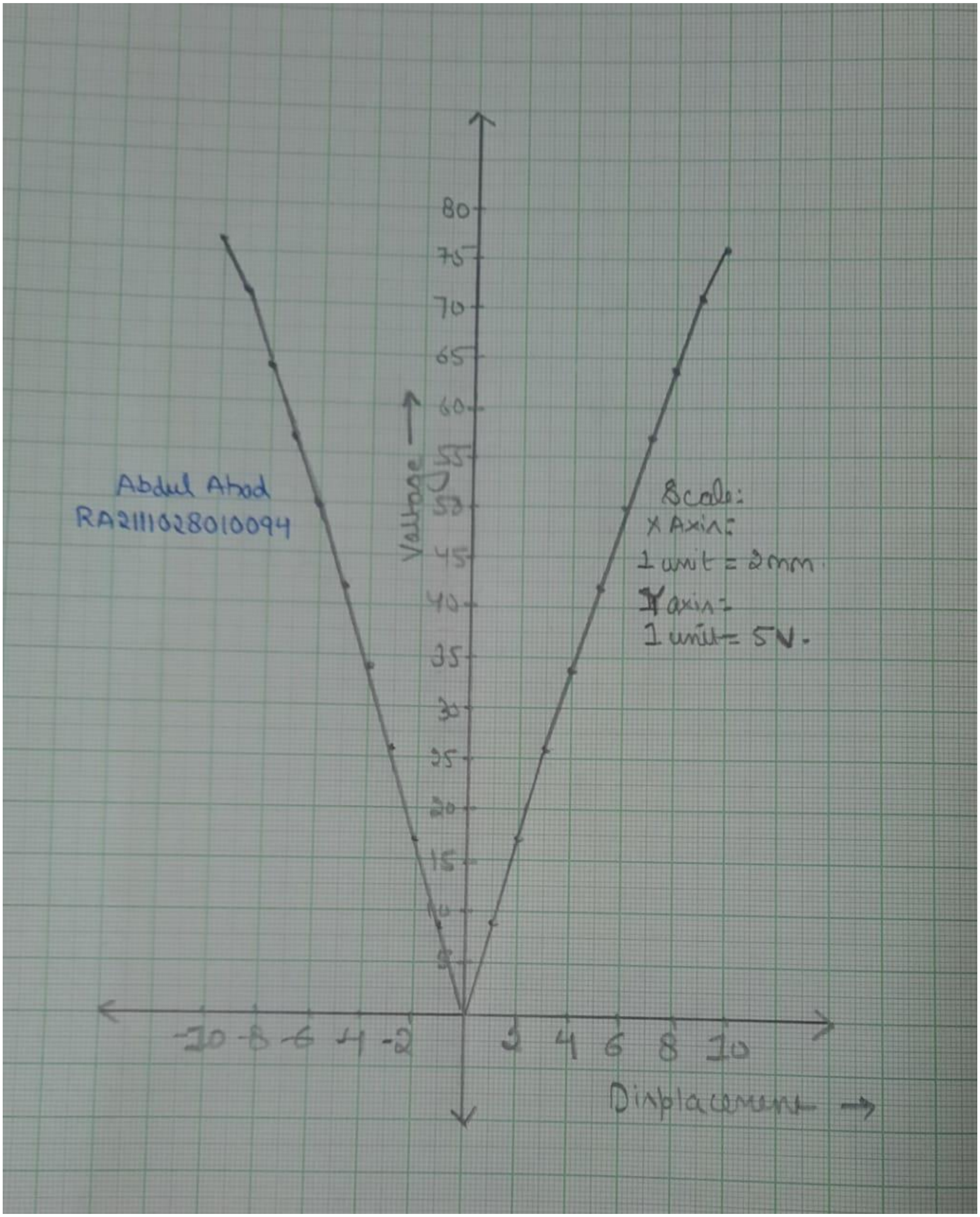




Tabulations:

CORE DISPLACEMENT (mm)	SECONDARY OUTPUT VOLTAGE (V)
10	76.43
8	64.29
6	50.05
4	34.24
2	17.38
0	0
-1	08.72
-3	25.91
-5	42.31
-7	57.40
-9	70.66

Graph:



Result: LVDT has been studied and the graph has been plotted.

POST LAB QUESTIONS:

1. What are the three principles of Inductive transducers?

Inductive transducers work on the principle of change in self-inductance of one coil, change in mutual inductance of two-coils and eddy current production. The voltage difference and change in inductance result due to the change in flux in the coils (Secondary or primary coils).

2. What are the limitations of LVDT?

Limitations of LVDT are:

AC Power Required: One of the most well-known limitations of LVDT sensors is that they require AC power of frequency and amplitude. Since this is vastly different from standard power lines, this means that there may be some situations in which installing an LVDT sensor is not feasible.

Temperature Limitations: Additionally, although LVDTs can be used in extremely high temperatures, even that has a limit. In particular, they can be used in environments that include a Cryogenic temperature range of -238°F (-150°C) to 1000°F (537°C).

3. Where LVDT is used?

LVDTs have been widely used in applications such as power turbines, hydraulics, automation, aircraft, satellites, nuclear reactors, and many others. These transducers have low hysteresis and excellent repeatability.

4. What are the different types of transducers used for displacement measurement?

Most of displacement transducers are classified as resistive, capacitive, inductive, and Ultrasonic, according to their principle of operation.

5. What is the difference between variable resistance & variable inductance displacement transducer?

Variable resistors mean that a resistor can change its resistance value through the control of a person or himself. Fixed resistance means that it cannot change its value. The fixed resistance has only one value and never changes (except through temperature, age, etc.), whereas in variable inductance displacement transducers are based on a change in the magnetic characteristic of an electrical circuit in response to a measurand which may be displacement, velocity, acceleration, etc. Relative motion between a conductor and a magnetic field of the coils of the transducer

PRE-LAB QUESTIONS (Strain gauge):

1. How does a strain gauges work?

A Strain gauge is a sensor whose resistance varies with applied force; It converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured. When external forces are applied to a stationary object, stress and strain are the result.

2. What is piezo-resistive effect?

The piezoresistive effect is a change in the electrical resistivity of a material (e.g., semiconductor, metal) when mechanical strain is applied. The electrical resistance change is due to two causes; geometry change and conductivity change of the material.

3. What are the types of strain gauge?

The three types of strain gage configurations, quarter-, half-, and full-bridge, are determined by the number of active elements in the Wheatstone bridge, the orientation of the strain gages, and the type of strain being measured.

4. Define gauge factor

Gauge factor (GF) or strain factor of a strain gauge is the ratio of relative change in electrical resistance R, to the mechanical strain ε.

5. Mention some practical applications of strain gauge.

Strain gauge can be used to test vehicles, ship hulls, dams, and oil drilling platforms. A simple civil engineering application using strain gauge technology is to install strain gauges on structural components in a bridge or building to measure stress and compare them to analytical models and stress calculations.

Experiment No. 9 b) Date: 02/12/2021	Strain measurement using Strain gauge

Aim: To measure the strain using strain gauge.

Apparatus Required: Strain gauge, weight, LABVIEW software.

Theory: Strain is the amount of deformation of a body due to an applied force. More specifically, strain (e) is defined as the fractional change in length, Strain can be positive (tensile) or negative (compressive). Although dimensionless, strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small. Therefore, strain is often expressed as microstrain (me), which is e x 10-6. When a bar is strained with a uniaxial force, as in Figure 1, a phenomenon known as Poisson Strain causes the girth of the bar, D, to contract in the transverse, or perpendicular, direction. The magnitude of this transverse contraction is a material property indicated by its Poisson's Ratio. The Poisson's Ratio n of a material is defined as the negative ratio of the strain in the transverse direction (perpendicular to the force) to the strain in the axial direction (parallel to the force), or n = eT/e. The most widely used gage is the bonded metallic strain gage. The metallic strain gauge consists of a very fine wire or, more commonly, metallic foil arranged in a grid pattern. The grid pattern maximizes the amount of metallic wire or foil subject to strain in the parallel direction (Figure 2). The cross-sectional area of the grid is minimized to reduce the effect of shear strain and Poisson Strain. The grid is bonded to a thin backing, called the carrier, which is attached directly to the test specimen.

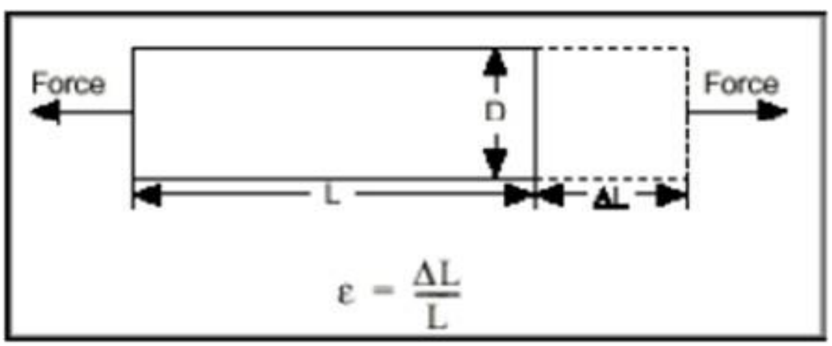


Figure 1. Strain measurement

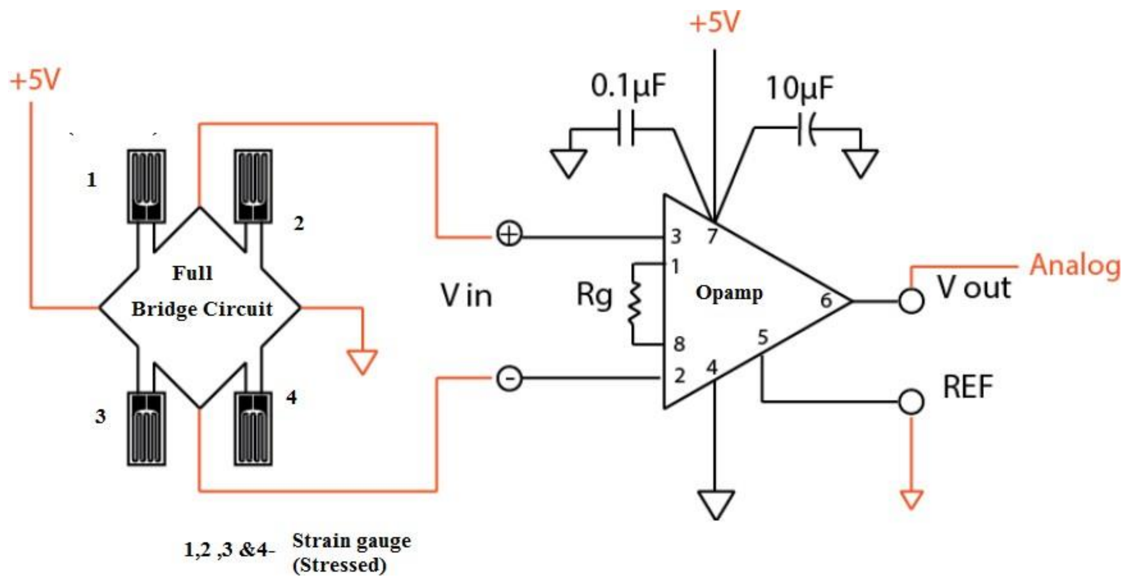
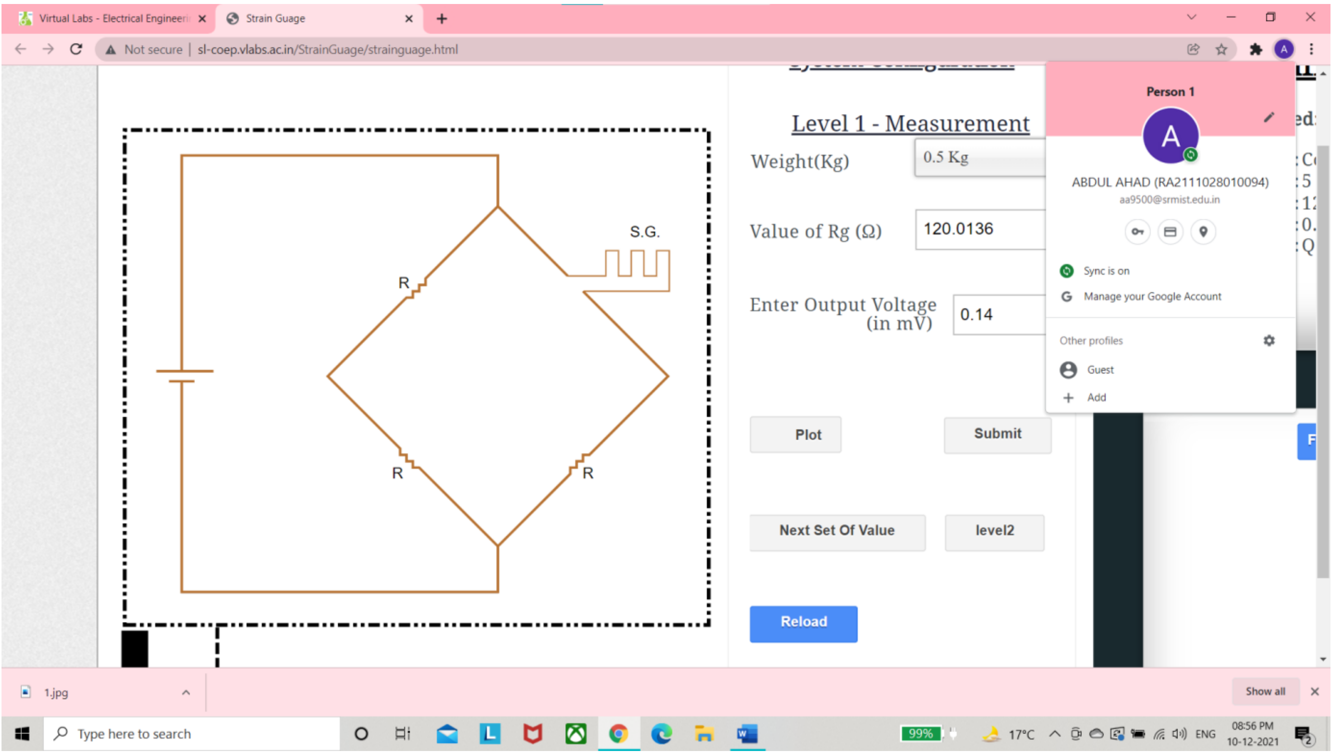


Figure 2. Full- Bridge Strain gauge circuit

Procedure:

1. Connect the cantilever strain measurement assembly to the main trainer and switch ON the trainer
2. Connect the multi meter at the Instrument output with multimeter in DC VOLTAGE mode and 20 V Range.
3. Connect this STRAIN output also to display section marked Vout.
4. Now without any strain or load in the cantilever beam. So adjust the OFFSET CONTROL to 0 volts at the output.
5. Now place 500 grams weights on the pan suspended n the beam and adjust the gain or call control to read 0.5 volt by multimeter at the strain output terminal.
6. Now remove the weight from the pan and the output must be 0 volt. IF not then readjust OFFSET Control
7. Table the readings for different weight or strain on the load cell as well as display readings.

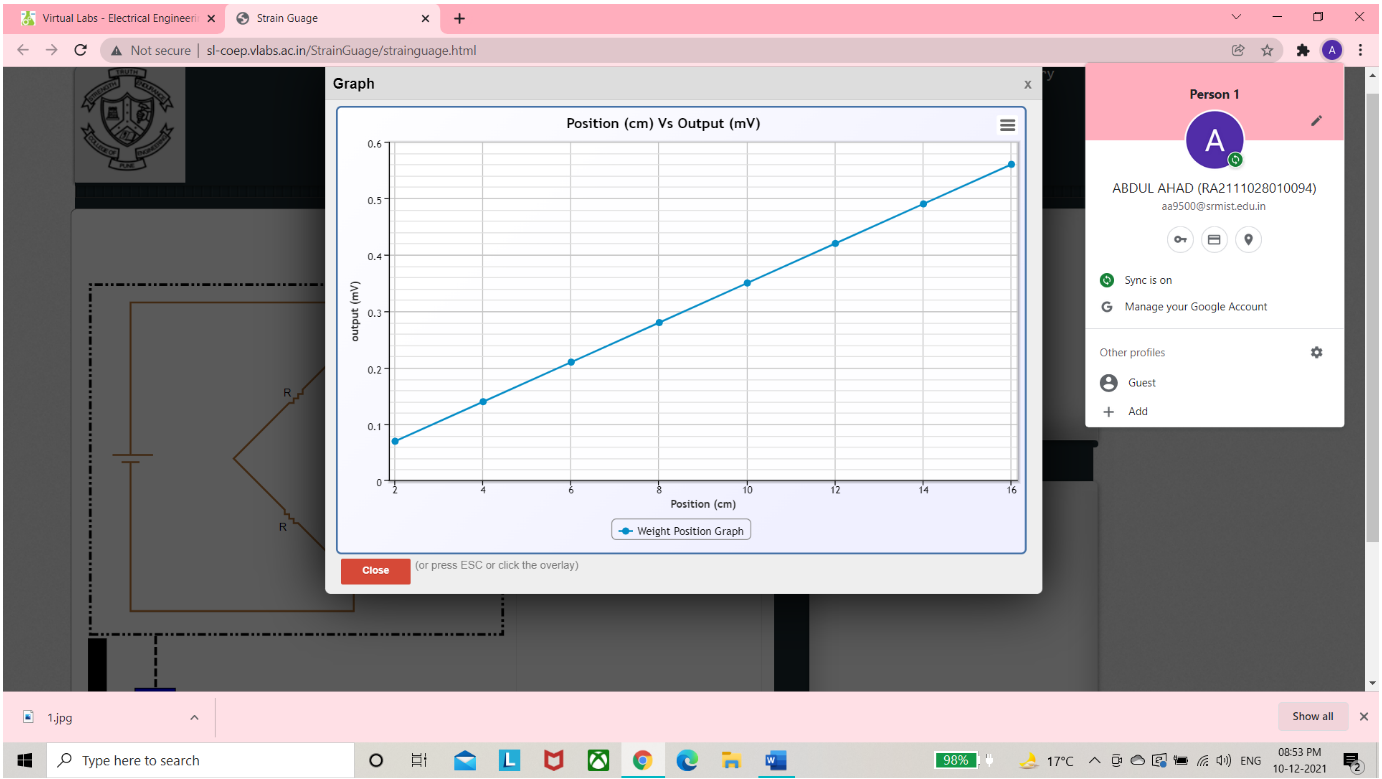
Simulation circuits



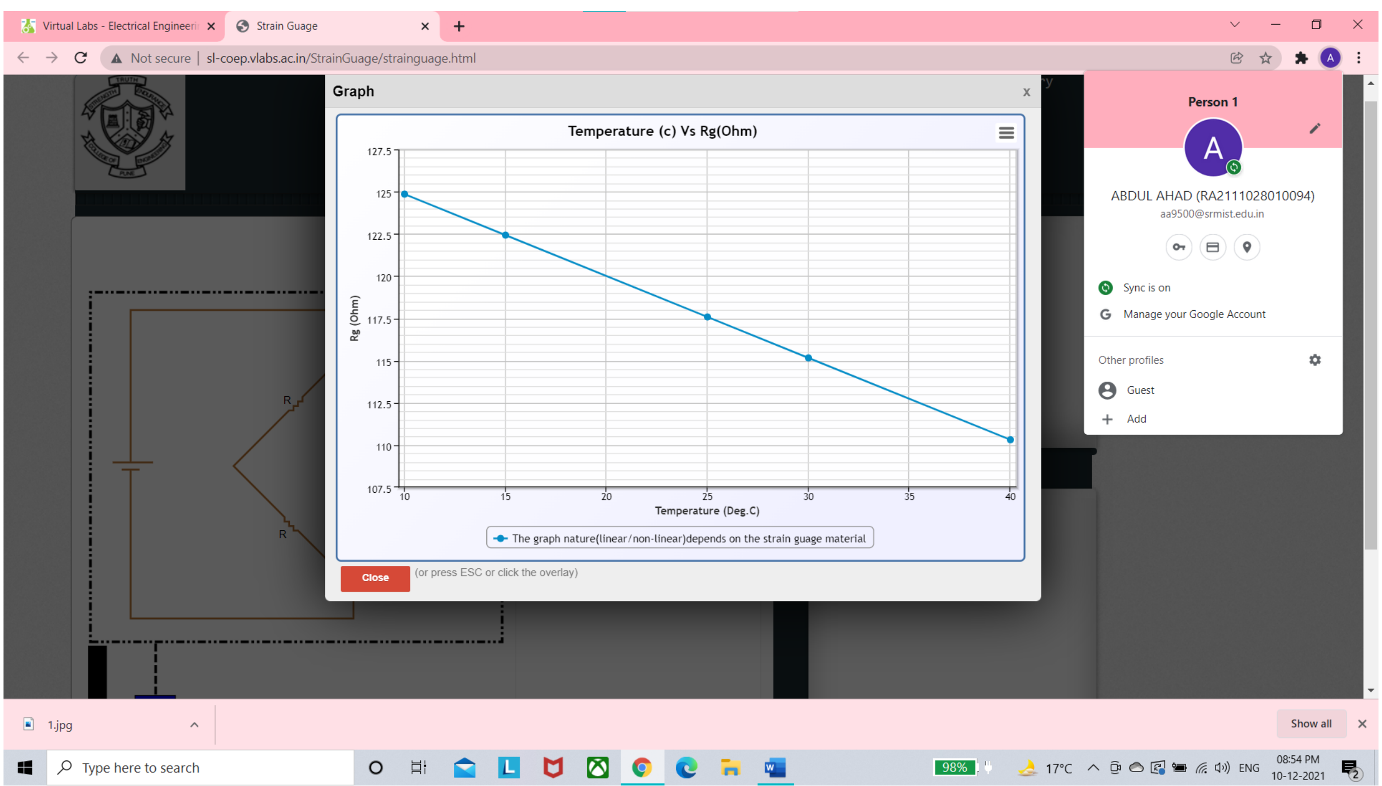
Simulated graphs

Weight (kg) vs output (mV)

Position (cm) vs Output (mV)



Temperature(C) vs Rg (ohm)



Model calculations:

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Resistance (R) = 120Ω

Input Voltage = 5V

Gauge Factor = 0.9

Weight = 0.5 Kg

Rg (Ω) = 120.0136 Ω

$$M = wl = (0.5 \times 9.8)(16 \times 10^{-2})$$
$$= 78.48 \times 10^{-2} N$$

$$\frac{dL}{L} = \frac{M}{2 \times 4\mu} = \frac{1}{Z \times 4} = \frac{1}{0.53 \times 10^{-6} \times 1.9 \times 10^{11}}$$
$$= \frac{10^{-5}}{1.007} = 1.612 \times 10^{-4} m$$

$$dR = G.F \times \frac{dL}{L} \times R$$
$$dR = 1.612 \times 10^{-4} \times 0.5 \times 120$$
$$= 0.013 \Omega$$

$$Z = \frac{1}{6} \times \frac{2}{100} \times \frac{0.16}{10000} \quad \left[Z = \frac{1}{6} \times b \times h^2\right]$$
$$= 0.053 \times 10^{-6}$$

where,
width (b) = $2 \times 10^{-2} m$
thickness (h) = $0.4 \times 10^{-2} m$

Now,
Young modulus of strain gauge material (copper)
= 1.7×10^{11} Pascal.

∴ Output voltage in quarter bridge,

$$\Rightarrow e = \frac{1}{2} \times \left(\frac{dR}{R}\right) \times E$$
$$= \frac{1}{4} \times \frac{dR}{R} \times E$$
$$= \frac{1}{4} \times \frac{0.736}{120} \times 5$$
$$= 1.416 \times 10^{-4} V = 0.141 mV$$

Hence Output voltage is 0.141mV.

Result: Measured strain using strain gauge.

POST-LAB QUESTIONS:

1. How can you apply the principle of stain gauge?

The gauge is attached to the object under stress using an adhesive. The deformation in the object causes the foil to get distorted which ultimately changes the electrical resistivity of the foil. This change in resistivity is measured by a Wheatstone bridge which is related to strain by a quantity called, Gauge Factor.

2. What is meant by passive transducer?

The passive transducer is a device that converts the given non-electrical energy into electrical energy by an external force. Resistance strain gauge, Differential Transformers are examples of Passive transducers.

3. What is sensitivity of strain gauge?

The strain sensitivity k of a strain gauge is the proportionality factor between the relative change in resistance $\Delta R/R0$ and the strain ε to be measured: $\Delta R/R0 = k \cdot \varepsilon$. The strain sensitivity yields a dimensionless number and is designated as the gauge factor. Es V: Apparent strain Maximum permissible eff. Es B: Apparent strain Bridge factor Es ε: Apparent strain.

4. What is a microstrain?

A strain expressed in terms of parts per million. Strain is sometimes expressed in units such as in./in. or mm/mm. In practice, the magnitude of measured strain is very small, so it is often expressed as microstrain ($\mu\varepsilon$), which is $\varepsilon \times 10^{-6}$.

5. What are the limitations of a strain gauge?

- Strain gauges require the surface on which they are applied to be of a very good finish and clean. Otherwise, the output can be pretty sketchy.
- The direction of strain that is measured is generally in a longer direction of the strip means it cannot measure multi-direction loads.
- They are sensitive to overload and get damaged.
- Their performance is affected by humidity, temperature, hysteresis, and repeatability and accuracy drops with prolonged use.