LABORATORY MANUAL

Branch Instrumentation Engineering

INSTRUMENTATION LAB-II

4th semester CODE: IE181417

Do’s

- ❖ Be punctual.
- ❖ Maintain discipline & silence.
- ❖ Keep the Laboratory clean and tidy.
- ❖ Enter Laboratory with shoes.
- ❖ Handle instruments with utmost care.
- ❖ Come prepared with circuit diagrams, writing materials and calculator.
- ❖ Follow the procedure that has been instructed.
- ❖ Return all the issued equipments properly.
- ❖ Get the signature on experiment result sheet daily.
- ❖ For any clarification contact faculty/staff in charge only.
- ❖ Shut down the power supply after the experiment

Don’ts

- ❖ Avoid unnecessary chat or walk.
- ❖ Playing mischief in the laboratory is forbidden.
- ❖ Disfiguring of furniture is prohibited.
- ❖ Do not start the experiment without instructions.
- ❖ Avoid using cell phones unless absolutely necessary.
- ❖ Avoid late submission of laboratory reports.

IE181417	Instrumentation Laboratory II	Semester 4	L-T-P 0-0-2	Credit 1

Experiment No.	Title of Experiment	Objectives of the Experiment
1	Speed Control of DC motor by field resistance control.	To obtain the speed vs armature current characteristic
2	To measure the level using capacitive principle.	1.To obtain change in level in terms of change in capacitance 2.The characteristic to be plotted a Level vs. capacitance graph b. level vs. current graph and study them.
3	To understand the working principle of LVDT.	1.Study the relation between core displacement and output of LVDT 2.Understand the effect of change in supply frequency on LVDT performance 3.Understand the effect of change in excitation (supply) voltage on LVDT performance
4	To study the vibration characteristics of an aluminium cantilever beam using piezoelectric-ceramic (PZT) sensor.	To obtain the vibration characteristic of cantilever beam

5	**Simulation of Active filters in multi sim**	**To study and calculate the transfer function of Active filters.** **To simulate the filters using Multisim** **To obtain characteristics** **a. frequency vs magnitude** **b. Frequency vs phase**
6	**Characterize strain gauge.**	**1.Plot the characteristics of Strain gauge.** **2. Understand the effect of various parameters on the strain gauge performance.**
7	**Simulation of Instrumentation Amplifier in multi sim and find its gain.**	**1. To deduce the gain of the Instrumentation Amplifier** **2. Simulate the IA and obtain the characteristic and analyze the same**
8	**: To understand photoelectric effect**	**To understand the effect of photoelectric effect as a whole**

Text Books

1. Electronic Instrumentation and Measurement by David A Bell.
2. Fundamentals of Instrumentation and Measurement.

Student Profile	
Name	
Roll no.	
Department and year	

Students Performance

Experiment No.	Title of Experiment	Remarks
1	Speed Control of DC motor by field resistance control.	
2	To measure the level using capacitive principle.	
3	To understand the working principle of LVDT.	
4	To study the vibration characteristics of an aluminium cantilever beam using piezoelectric-ceramic (PZT) sensor.	
5	Simulation of Active filters in multi sim.	
6	Characterize strain gauge.	
7	Simulation of Instrumentation Amplifier in multi sim and find its gain.	
8	: To understand photoelectric effect	

Office Use:

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Grade ……………………………………….

Signature………………………………………

Experiment No. 1

Aim of the Experiment

Speed Control of DC motor by field resistance control

Theory- We know that the speed of shunt motor is given by:

$$\mathbf{N = (V - I_a R_a)/k\Phi}$$

Where, V_a is the voltage applied across the armature and φ is the flux per pole and is proportional to the field current If. As explained earlier, armature current Ia is decided by the mechanical load present on the shaft. Therefore, by varying Va and If we can vary n. For fixed supply voltage and the motor connected as shunt we can vary Va by controlling an external resistance connected in series with the armature. If of course can be varied by controlling external field resistance Rf connected with the field circuit.

Thus for shunt motor we have essentially two methods for controlling speed, namely by:

1. Varying armature resistance.
2. Varying field resistance.

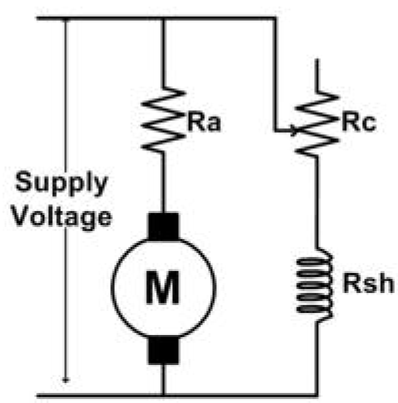


Figure 1: Equivalent circuit for field control of DC motor

Speed control by varying field current:

In this method field circuit resistance is varied to control the speed of a dc shunt motor. Let us rewrite the basic equation to understand the method.

N = (V-IaRa)/kΦ

If we vary I f, flux φ will change, hence speed will vary. To change If an external resistance is connected in series with the field windings. The resistance is called the shunt field regulator the field coil produces rated flux when no external resistance is connected and rated voltage is applied across field coil. We can only decrease flux from its rated value by adding external resistance. Thus, the speed of the motor will rise as we decrease the field current and speed control above the base speed will be achieved. Speed versus armature current characteristic has to be plotted.

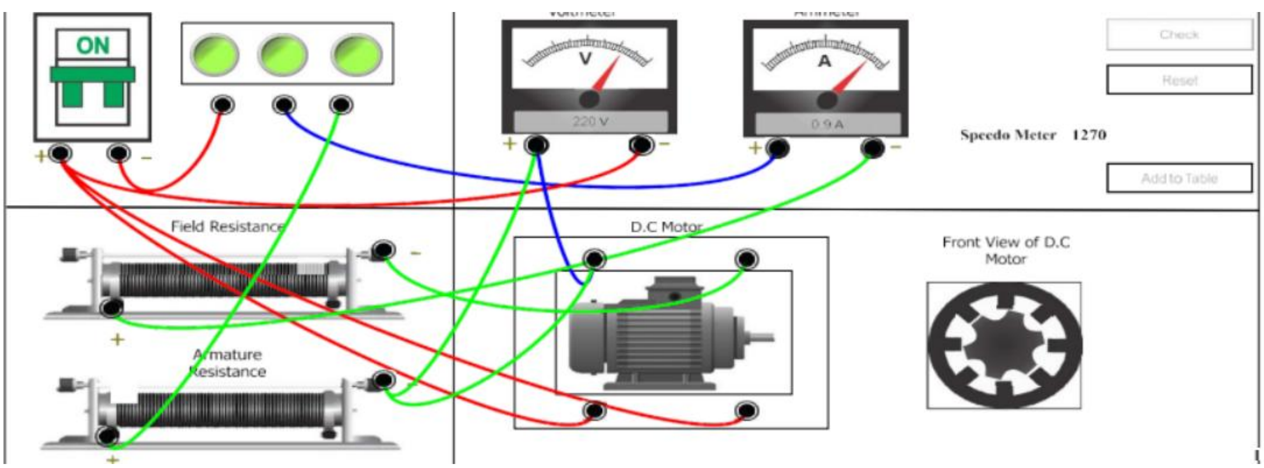
PROCEDURE

1. Connect all dots in the following manner:
   (a) A to K
   (b) A to Y
   (c) A to J
   (d) B to P
   (e) E to M

   (f) F to D
   (g) G to R

   (h) H to I
   (i) I to C
   (j) C to H
   (k) Q to L

Then Check the connections by clicking on Check Button.



Observation Table:

Speed	Armature Current

Experiment 2:

To measure the level using capacitive principle.

Aim: Measure the change in level in terms of change in capacitance.

THEORY

1. **Level measurements**

In industry, liquids such as water, chemicals, and solvents are used in various processes. The amount of such liquid stored can be found by measuring level of the liquid in a container or vessel. The level affects not only the quantity delivered but also pressure and rate of flow in and out of the container. Level sensors detect the level of substances like liquids, slurries, granular materials, and powders. The substance to be measured can be inside a container or can be in its natural form (e.g. a river or a lake). The level measurement can be either continuous or point values.

Continuous level sensors measure the level to determine the exact amount of substance in a continuous manner.

Point-level sensors indicate whether the substance is above or below the sensing point. This is essential to avoid overflow or emptying of tanks and to protect pumps from dry run.

The selection criteria for level sensor include:

- The physical phase (liquid, solid or slurry)
- Temperature
- Pressure or vacuum
- Chemistry
- Dielectric constant of medium
- Density (specific gravity) of medium
- Agitation (action)
- Acoustical or electrical noise

- Vibration
- Mechanical shock
- Tank or bin size and shape

From the application point of view the considerations are :

- Price
- Accuracy
- Response rate
- Ease of calibration
- Physical size and mounting of the instrument
- Monitoring or control of continuous or discrete levels Level

measurements are broadly classified in two groups:

- Direct methods
- Indirect methods

In direct methods, the level is indicated directly by means of simple mechanical devices. The measurement is not affected by changes in material density. Few examples are:

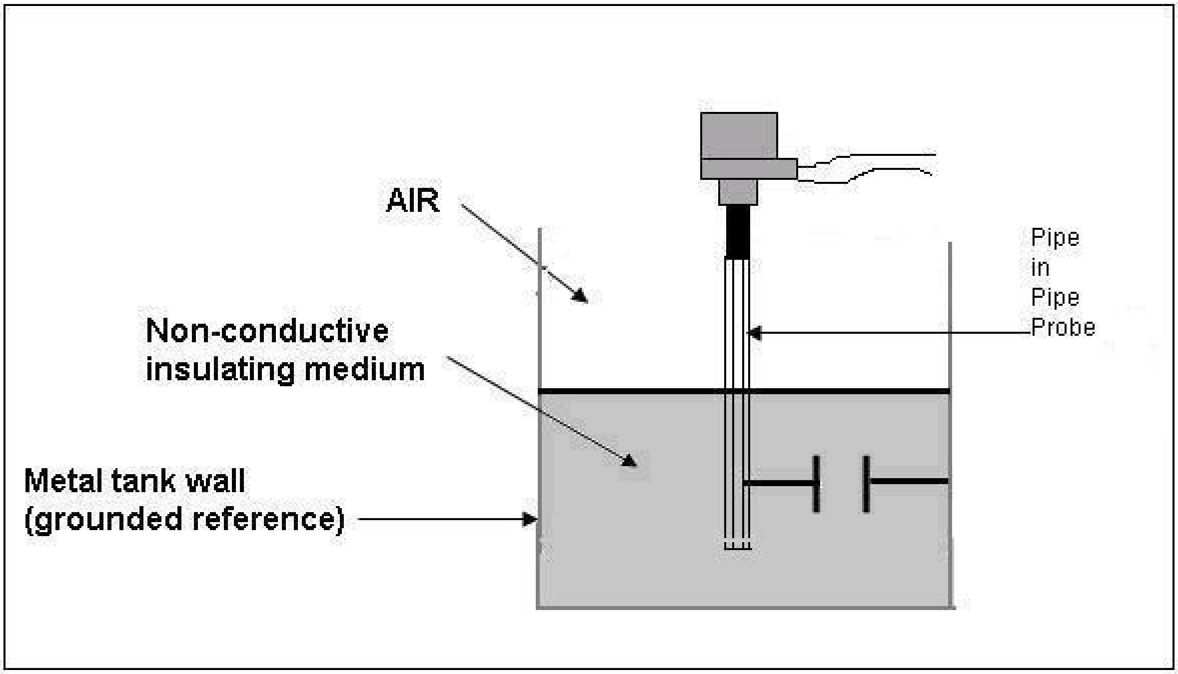
- Dip Stick
- Resistance Tapes
- Sight Glass
- Floats
- Ultrasonic
- Radar

In Indirect methods, the level is converted in a measurable signal using a suitable transducer. Change in the material affects the measurement. A corrective factor must be used in recalibrating the instrument. Few examples are:

- Hydrostatic head methods
- Load cell

- Capacitance
- Conductivity

Capacitance Level Measurement: Capacitive level transducer is an example of indirect measurement of level



Capacitance level sensors are used for wide variety of solids, aqueous and organic liquids, and slurries. The technique is frequently referred as RF as radio frequency signals applied to the capacitance circuit. The sensors can be designed to sense material with dielectric constants as low as 1.1 (coke and fly ash) and as high as 88 (water) or more. Sludges and slurries such as dehydrated cake and sewage slurry (dielectric constant approx. 50) and liquid chemicals such as quicklime (dielectric constant approx. 90) can also be sensed. Dual-probe capacitance level sensors can also be used to sense the interface between two immiscible liquids with substantially different dielectric constants.

Since capacitance level sensors are electronic devices, phase modulation and the use of higher frequencies makes the sensor suitable for applications in which dielectric constants are similar.

Working Principle: The principle of capacitive level measurement is based on change of capacitance. An insulated electrode acts as one plate of capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. The capacitance depends on the fluid level. An empty tank has a lower capacitance while a filled tank has a higher capacitance. A simple capacitor consists of two electrode plate separated by a small thickness of an insulator such as solid, liquid, gas, or vacuum. This insulator is also called as dielectric. Value of C depends on dielectric used, area of the plate and also distance between the plates.

$$C = E\,(K\,A/d)$$

Where: C = capacitance in Pico farads (pF) E = a constant known as the absolute permittivity of free space K = relative dielectric constant of the insulating material A = effective area of the conductors d = distance between the conductors This change in capacitance can be measured using AC bridge.

Measurement: Measurement is made by applying an RF signal between the conductive probe and the vessel wall. The RF signal results in a very low current flow through the dielectric process material in the tank from the probe to the vessel wall. When the level in the tank drops, the dielectric constant drops causing a drop in the capacitance reading and a minute drop in current flow. This change is detected by the level switch's internal circuitry and translated into a change in the relay state of the level switch in case of point level detection. In the case of continuous level detectors, the output is not a relay state, but a scaled analog signal.

Level Measurement can be divided into three categories:

- Measurement of non-conductive material
- Measurement of conductive material
- Non-contact measurement

Non-conducting material: For measuring level of non-conducting liquids, bare probe arrangement is used as liquid resistance is sufficiently high to make it dielectric. Since the electrode and tank are fixed in place, the distance (d) is constant, capacitance is directly proportional to the level of the material acting as dielectric.

Conducting Material: In conducting liquids, the probe plates are insulated using thin coating of glass or plastic to avoid short circuiting. The conductive material acts as the ground plate of the capacitor.

Proximity measurements (Non-contact type measurements): In Proximity level measurement is the area of the capacitance plates is fixed, but distance between plates varies. Proximity level measurement does not produce a linear output and are used when the level varies by several inches.

Advantages of Capacitive level measurement:

- Relatively inexpensive
- Versatile
- Reliable
- Requires minimal maintenance
- Contains no moving parts
- Easy to install and can be adapted easily for different size of vessels
- Good range of measurement, from few cm to about 100 m
- Rugged
- Simple to use
- Easy to clean

- Can be designed for high temperature and pressure applications

Applications:

Capacitance Level Probes are used for measuring level of

- Liquids
- Powered and granular solids
- liquid metals at very high temperature
- Liquefied gases at very low temperature
- Corrosive materials like hydrofluoric acid
- Very high pressure industrial processes.

Disadvantages:

Light density materials under 20 lb/ft3 and materials with particle sizes exceeding 1/2 in. in diameter can be a problem due to their very low dielectric constants (caused by the large amount of air space between particles).

Step by step Procedure:

- Study the given diagram completely.
- Select the height of the tank in centimeters
- The value of radius of outer cylinder/pipe for pipe in pipe type probe r2 is fixed 2.5cm.
- Select the value of radius of inner cylinder/pipe for pipe in pipe type probe r1 in centimeters.
- **Span** value will get displayed. Span is 90% of the height of the tank.
- Select the service for which capacitance probe is to be used.
- Click on **'Configure System'**. It will ask for confirmation.
- After confirming, select the fluid level from drop down menu for selected service.
- Enter the calculated user output capacitance in µF. Using formula calculate the value of the output capacitance for the corresponding level and enter the answer in the box provided (upto 2 decimals with rounding off).

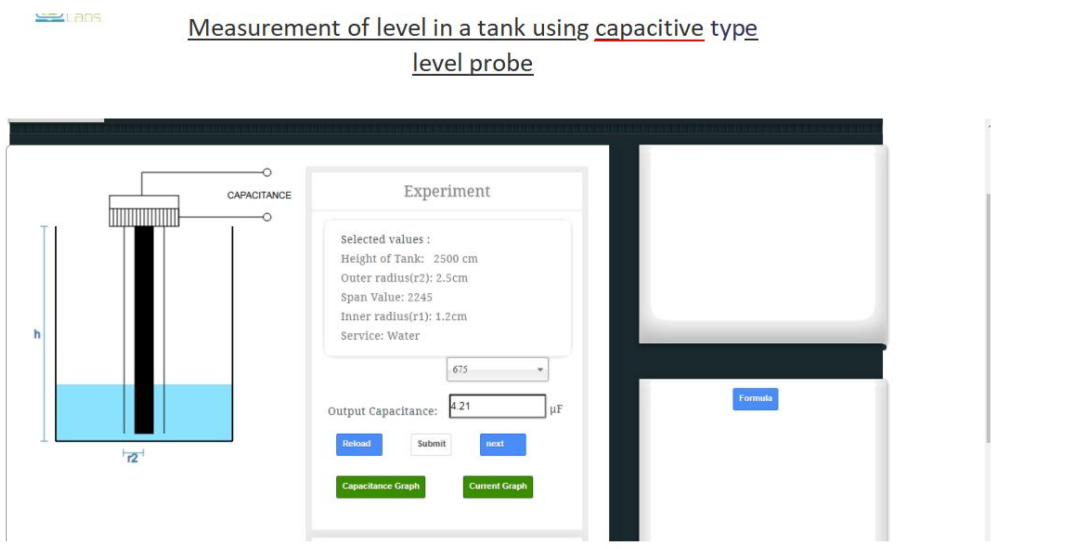
Study the graphs for RTD performance with different reference resistance values and different materials. If your calculation is correct it will be displayed on the screen. Minimum three calculations are necessary to plot the graph. The characteristic has to be plotted

1. Level vs. capacitance graph 2. level vs. current graph and study them.

Observation:

Level	**Capacitance**

Level	Current



Experiment 3

Aim: To understand working principle of LVDT

Objective:-

- Study the relation between core displacement and output of LVDT
- Understand the effect of change in supply frequency on LVDT performance
- Understand the effect of change in excitation (supply) voltage on LVDT performance

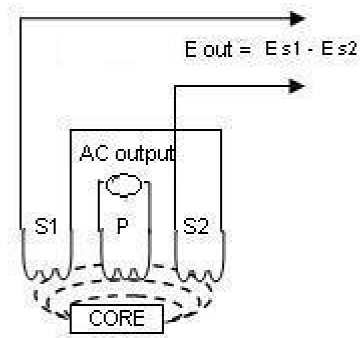
THEORY

Construction:

LVDT is made of two main components: the movable armature and the outer transformer windings. LVDT consists of 3 windings. Centre one is Primary winding while the other two are secondary windings. The secondary's are identical and placed symmetrical about the primary. The secondary coils are connected in series-opposition. Moving element of LVDT is called core. It is a cylindrical armature made of ferromagnetic material. It is free to move along the axis of the tube. At one end, the core is coupled to an object whose displacement is to be measured, while the other end moves freely inside the coil's hollow bore.

Working:

An alternating current is connected to the primary. This current must be of appropriate amplitude and frequency. It is also called as Primary Excitation. The frequency is usually in the range 1 to 10 kHz. This current causes a voltage to be induced in each secondary proportional to its mutual inductance with the primary. While the frequency of induced voltage is same as that of excitation frequency, its amplitude varies with the position of the iron core. As the core moves, the voltages induced in the secondary's changes due to change in mutual inductance. The coils are connected in series but in opposite phase, so that the output voltage is the difference between the two secondary voltages. When the core is exactly at central position, i.e. at equal distance from the two secondaries, equal but opposite voltages are induced in these two coils, so the output voltage is zero. When the core is displaced in one direction, the voltage in one coil increases with respect to the other, causing the output voltage to increase from zero to a maximum value. This voltage is in phase with the primary voltage. When the core moves in the other direction, the output voltage also increases from zero to a maximum value, but the phase is opposite to that of the primary. The magnitude of the output voltage is proportional to the distance moved by the core. The phase of the voltage indicates the direction of the displacement.



Case 1: When no displacement is applied to the core and the core remains in the null position without any movement then the voltage induced in both the secondary windings is equal which results in net output is equal to zero

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i.e., E s1 - E s2 = 0
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Case 2:

When displacement is applied in such a way that the core moves in the left direction then the voltage induced in that (left) secondary coil is greater as compared to the emf induced in the other secondary coil. Therefore the net output is E s1-E s2

Case 3:

When force is applied to core such that it moves in the right hand side direction then the emf induced in the secondary coil 2 is greater compared to the emf voltage induced in the secondary coil 1, therefore the net output voltage is E s2- E s1.

As seen, the voltage undergoes 180 degrees phase shift while going through null. The output E is out of phase with the excitation. Usually this AC output voltage is converted by suitable electronic circuitry to high level DC voltage or current that is more convenient to use.

Residual Voltage:

Output voltage at the null position is ideally zero. But because of harmonics in the excitation voltage and stray capacitance coupling between primary and secondary a non-zero voltage exists at null position. This is called residual voltage. If it is less than 1 % of full scale output voltage (which is the normal case) it is in the acceptable limits.

Eddy Currents:

When alternating current is passed through the coil, a magnetic field is generated in and around the coil. When a rod is brought in close proximity to a conductive material, the rod's changing magnetic field generates current flow in the material. These are called as eddy currents. The eddy currents produce their own magnetic fields that interact with the primary magnetic field of the coil. As the eddy current flows through conducting core, it creates heat. This causes power loss in the core. To reduce the eddy current losses, the core is provided with a slot. This slot cut the magnetic field created hence reducing the flux. Laminated core is also used for the same purpose.

Types of LVDT based on applications:

- General Purpose LVDT: for use in many industrial and research applications.
- Precision LVDT: for sensitive gauging and quality control applications
- Submersible LVDT: Hermetically sealed for use in industrial and research environments involving corrosive fluids and gases, high temperature and vibrations, etc.

Types of LVDT based on range of operation:

1. Short stroked: full-scale linear ranges from ±0.01 inch (±0.25 mm) to ±0.5 inch (±12.7 mm)
2. Long stroked: full-scale linear ranges from ±0.5 inch (±12.7 mm) to ±18.5 inch (±470 mm)

Types of LVDT based on excitation used

1. AC LVDT: AC LVDTs are excited by a AC voltage having frequency between 50 hertz and 25 Kilohertz with 2.5 Kilohertz as a nominal value. The carrier frequency is generally selected to be at least 10 times greater than the highest expected frequency of the core motion. AC-operated LVDT's are generally smaller in size and more accurate than DC versions. They are able to tolerate the extreme variations in operating temperature than the DC LVDT. Modern circuits often supply phase detection circuits along with the LVDT. A phase sensitive detector circuit (PSD) is useful to make the measurement direction sensitive. It is connected at the output of the LVDT and compares the phase of the secondary output with the primary signal to judge the direction of movement. The output of the phase sensitive detector after passing through low pass filter is in the dc voltage form used for steady deflection.

2. DC LVDT: The DC LVDT is provided with onboard oscillator, carrier amplifier, and demodulator circuitry. The major advantages of DC- operated ("DC-to-DC") LVDT's are ease of installation and signal conditioning, the ability to operate from dry cell batteries in remote locations, and lower system cost (especially in multipoint applications). The DC LVDT is temperature limited operating from typically - 40 deg C to + 120 deg C

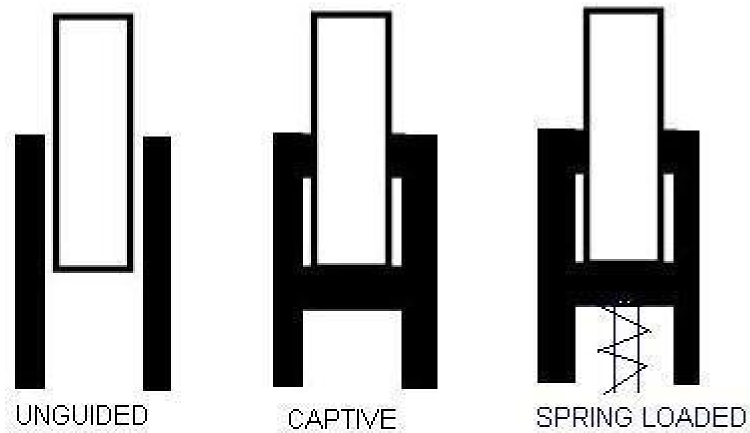
Types of LVDT based on armature:

1. Unguided Armature: This is simplest configuration in which armature fits loosely in the cavity of the coils bore. This requires proper installation to ensure proper movement along the axis. This allows frictionless movement with no wear. This type have unlimited fatigue life, good repeatability with infinite resolution. Free armature is mainly suitable for short range, high speed applications.

2. Guided (Captive) Armature: In this type, armature is restrained and guided by low friction bearing assembly. These are suitable for long working ranges. To avoid possibility of misalignment the armature is guided.

3. Spring Extended Armature – This armature is similar to guided armature LVDT with an addition that , it has internal spring to push the armature continuously to its fullest possible extension. This maintains light and reliable contact with the measured object.

Most suitable for static or slow moving applications.



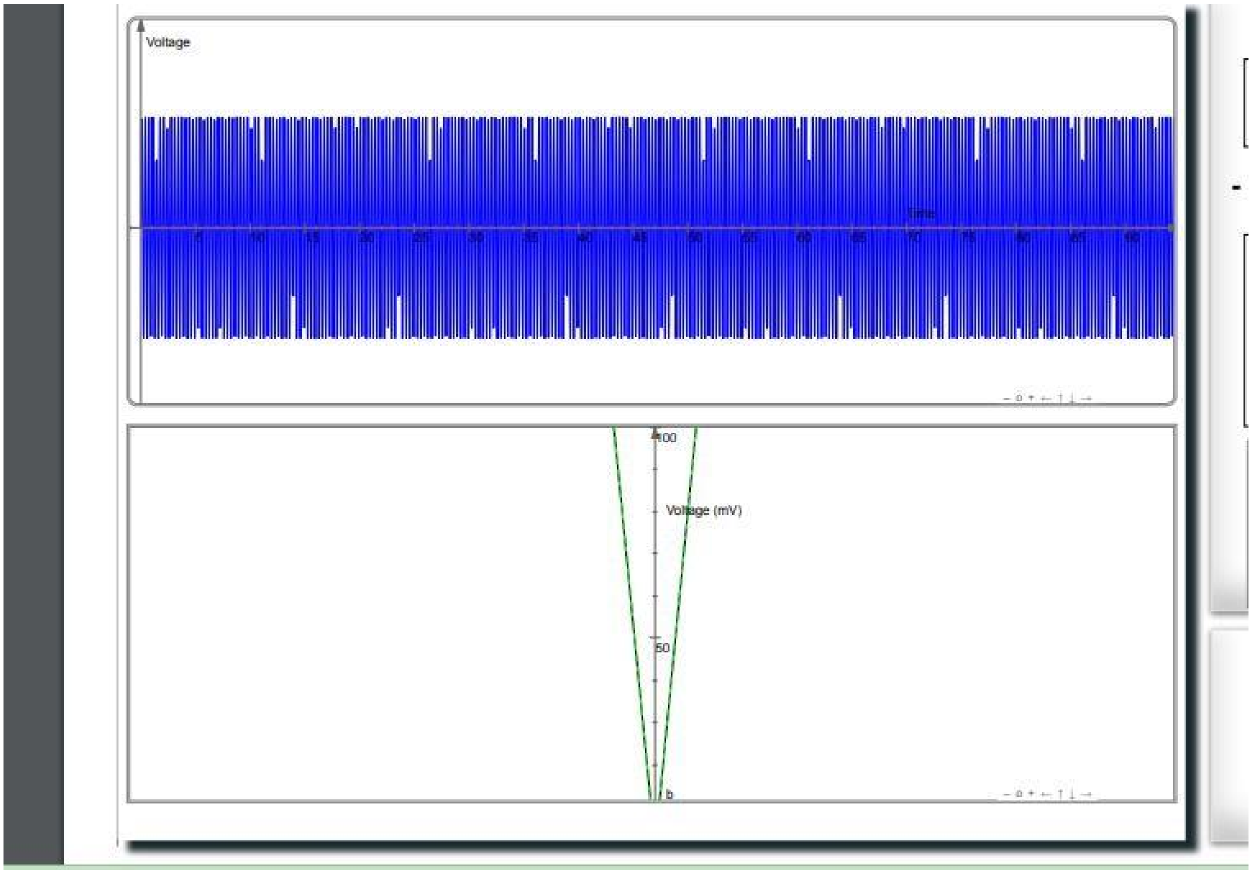
Applications:

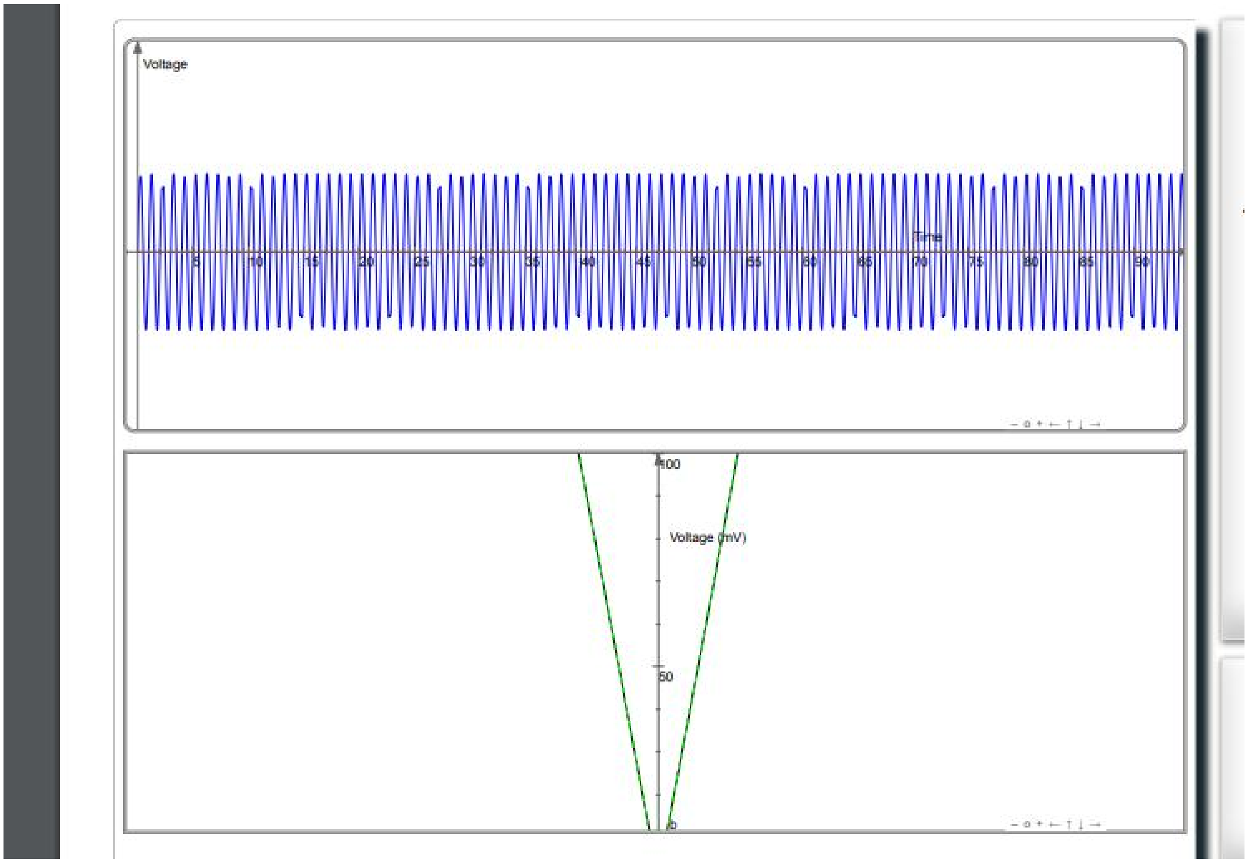
LVDTs are commonly used for:

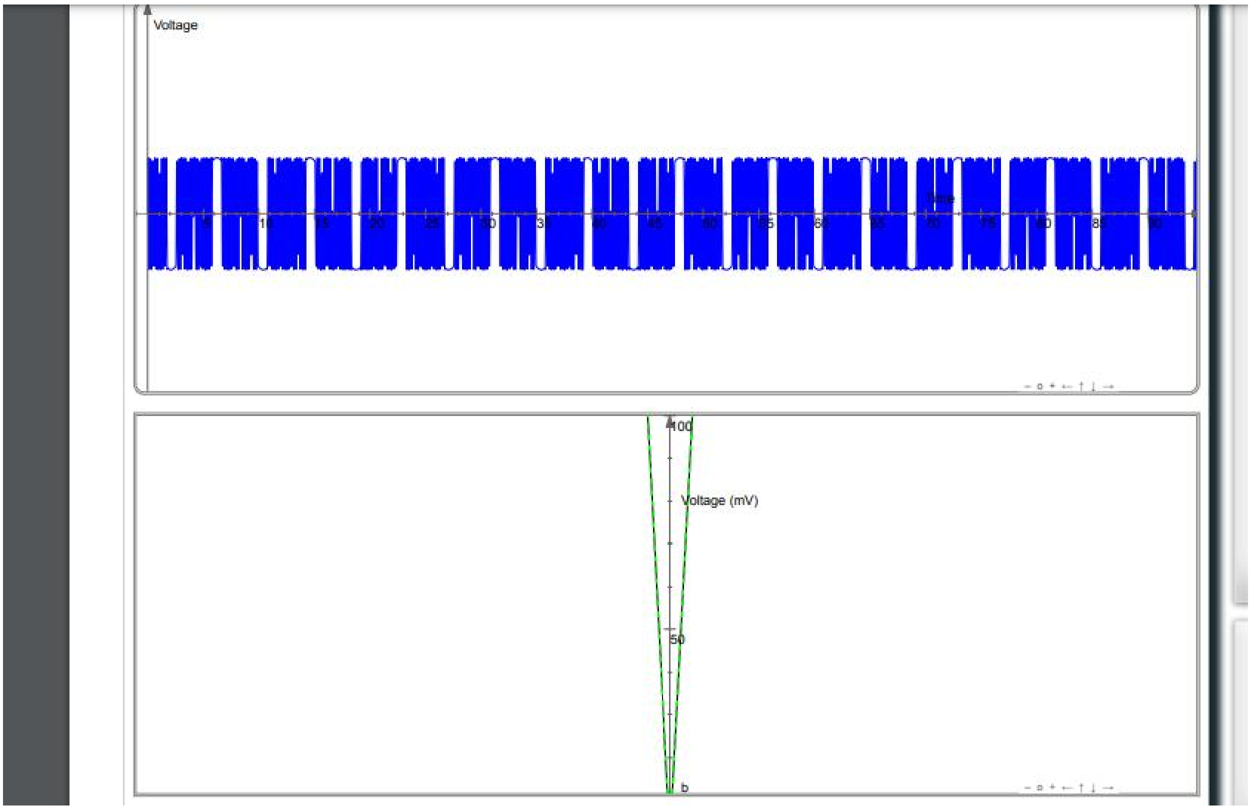
- Position feedback in servomechanisms
- Automated measurement in machine tools and many other industrial and scientific applications.
- Measurement of displacement ranging from fraction of mm to cm
- Acting as a secondary transducer, it can be used for force, weight and pressure measurement.

Procedure:

1. First you need to configure the LVDT. Click on ' Show panel' tab at the right bottom For making the circuit, drag and drop the primary coil, Armature and secondary coils at the locations shown on left hand side.
2. Now select No of Turns, peak to peak supply voltage and frequency from the drag and drop menu, available below LVDT diagram. Click on configure block to configure LVDT.
3. Now click on the black rectangular core placed between primary and secondary windings.
4. Drag the core to left hand side and observe the effect on the output magnitude. This can be observed on the time vs output voltage waveform and on the Distance vs output voltage graph. The core displacement is indicated in the square box below the diagram
5. Drag the core to right hand side and observe the effect on the output magnitude. Also observe the change in the phase.
6. Repeat steps 2 to 4 by changing supply voltage keeping frequency and no of turns constant.
7. Study the effect on the output voltage. For this click on blue color 'Configure' tab in the right side panel. You need to select required parameter value from drop down menu. After selecting the values click on green ' Configure' tab to set the parameter values.
8. Repeat steps 2 to 4 by changing supply frequency keeping and no of turns constant. Study the effect on the output voltage. Now keep supply voltage and frequency constant. Change the no of turns and observe the effect on the output voltage by repeating steps 2 to 4.


Voltage
Voltage (mV)
100
50
0


Voltage
Time
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
100
Voltage (mV)
50
0



Observation:

Displacement(mm)	**Output voltage(mV)**

EXPERIMENT N0.4

Aim of the Experiment

This experiment aims to study the vibration characteristics of an aluminium cantilever beam using piezoelectric-ceramic (PZT) sensor**.**

Theory

This virtual experiment simulates vibrations of a cantilever beam under external excitation induced using a hammer, this type of excitation is called impact excitation. The simulated experimental setup is as shown in Fig. 1. It consists of a cantilevered aluminium beam of dimensions 300 × 18.2 × 2.15 mm with a piezoelectric ceramic (PZT) patch sensor bonded on the surface near the point of fixity. The wires from the patch are connected to digital multi meter (DMM).

The cantilever beam is excited into free-damped vibrations through an automatic mechanical exciter at regular intervals. As the beam vibrates, the surface strain fluctuates between compression and tension, thereby developing sinusoidally varying charge (and hence voltage) across the electrodes of the PZT patch sensor through the direct piezoelectric effect to learn more about piezoelectricity). The instantaneous voltage developed across the piezoelectric sensor is measured at the user specified time interval using the DMM. The dialogue box enables downloading the time and the frequency domain data in the computer of the user.

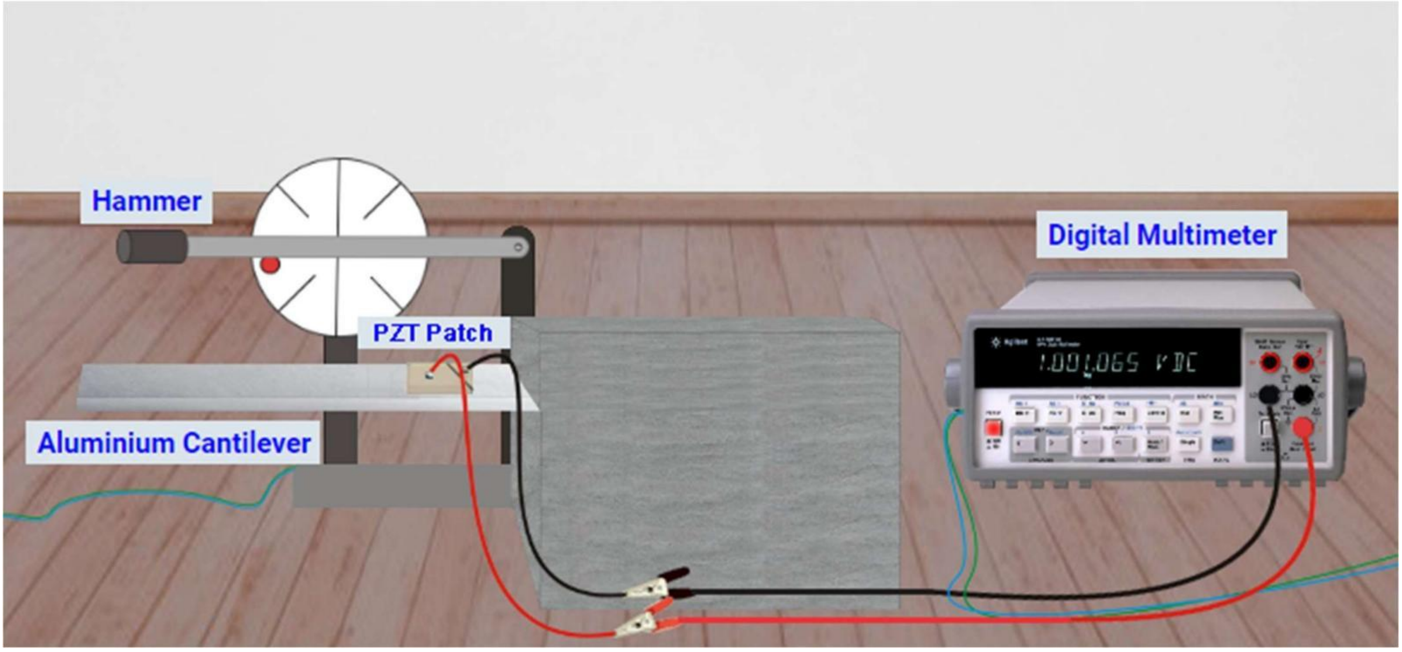


Fig. 1 Experimental set up

The user may plot the time domain data in excel to visualize the free damped oscillations more minutely. At the same time, through fast Fourier transform, the user can convert the time domain data (as an array of voltage output, *V_time*) in the frequency domain. If using MATLAB, following commands can be used:

$$V\_fft = abs(fft(V\_time)) \qquad (1)$$

This command will produce an array of voltage values in the frequency domain.The corresponding array of frequencies can be obtained by using following command

$$f = (0{:}N\text{-}1)/(N^*T) \qquad (2)$$

where *N* is the total number of samples in the time domain and *T* the sampling interval (here 0.001 second). The user may use it directly if MATLAB is not available. Fig. 2 shows typical time and frequency domain responses expected if the experiment is correctly performed.

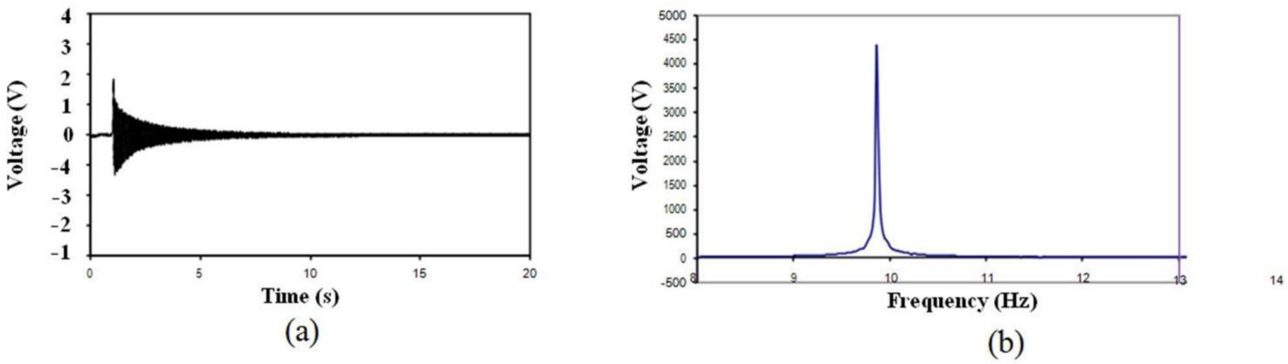


Fig. 2 Expected sensor response (a) Time domain (b) Frequency domain

From the frequency plot, the user can identify the natural frequency of the beam as the frequency corresponding to which peak voltage response is observed. The damping ratio can be calculated using the half power band method (Paz, 2004) as

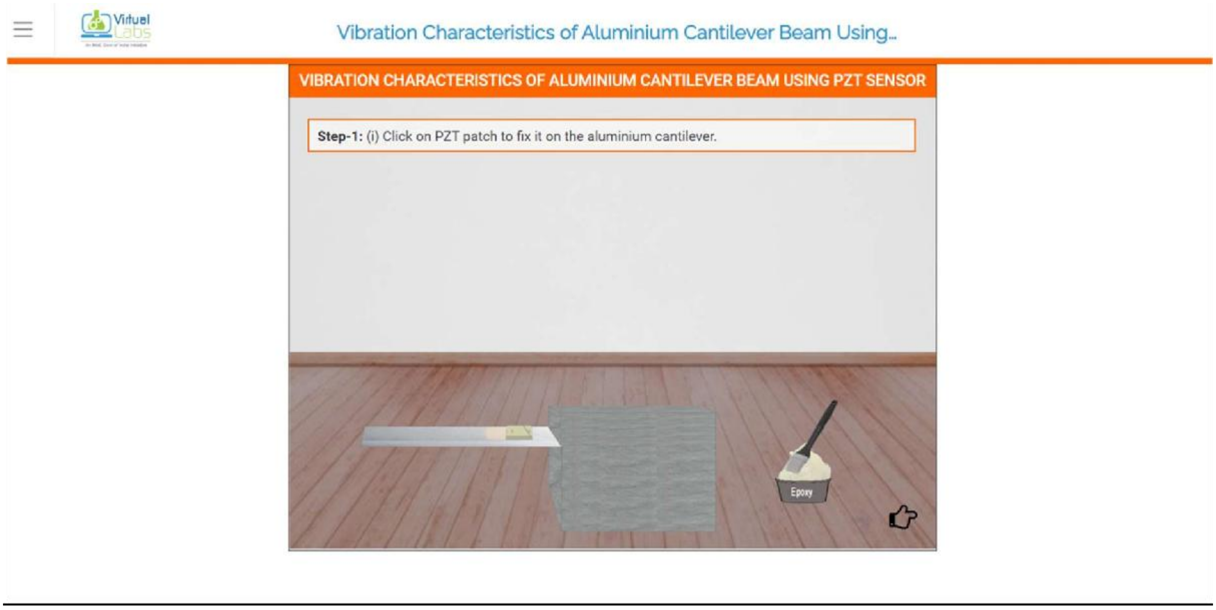
$$\xi = \frac{f_2 - f_1}{2 f_n} \qquad (3)$$

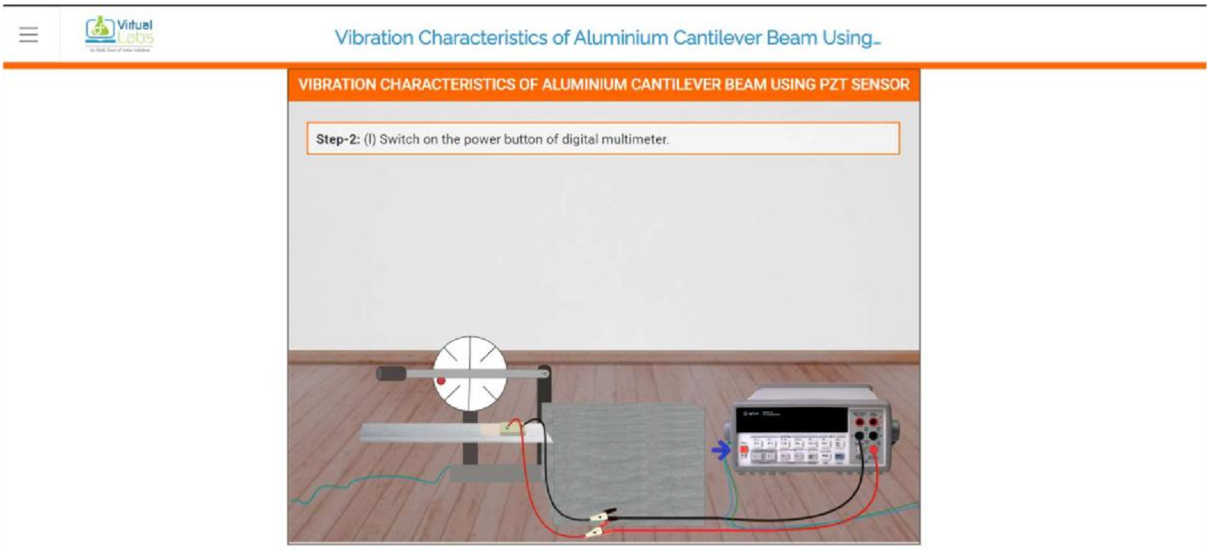
where f_n is the frequency corresponding to peak response and f_1 and f_2 represent the frequencies corresponding to 0.707 of the peak response *($f_2 > f_n > f_1$)*. The user may compare the values obtained through this experiment with damping ratio available from the literature and the theoretical frequency given below (Paz, 2004).

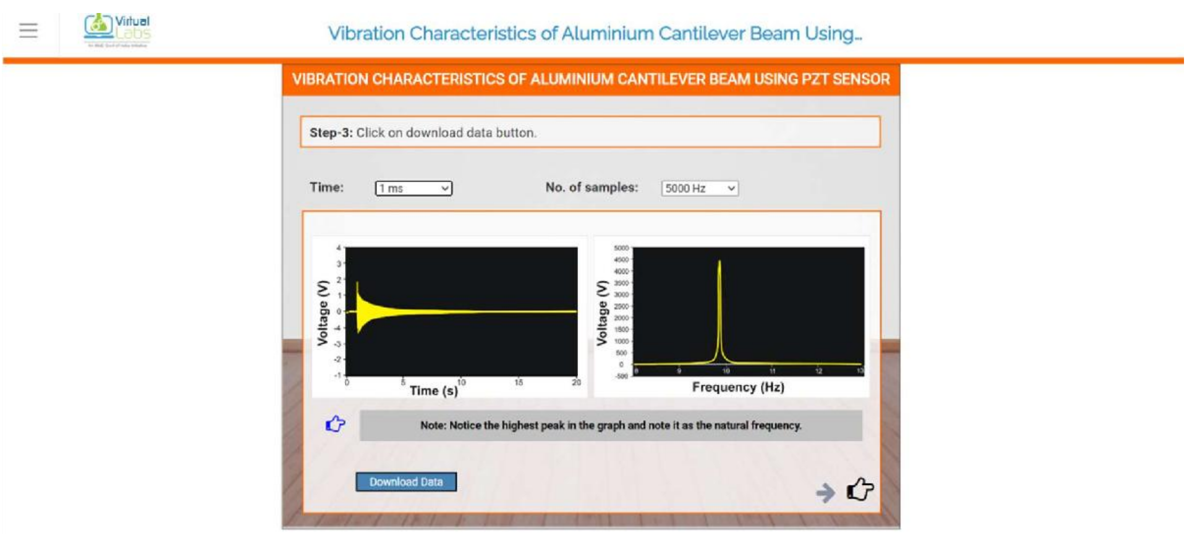
$$f_1 = \frac{3.516}{2\pi L^2}\sqrt{\frac{EI}{\rho A}} \qquad (4)$$

where *E* denotes the young's modulus of elasticity of the beam, *I* the moment of inertia, *ρ* the material density and *L* the length of the beam.

SIMULATION:


Virtual Labs
Vibration Characteristics of Aluminium Cantilever Beam Using...
VIBRATION CHARACTERISTICS OF ALUMINIUM CANTILEVER BEAM USING PZT SENSOR
Step-1: (i) Click on PZT patch to fix it on the aluminium cantilever.
Epoxy





The characteristic plots to be obtained are 1. Time vs voltage 2. Frequency vs voltage

Observation:

Time	**Voltage**

Frequency	**Voltage**

EXPERIMENT NO. 5

Aim of the experiment:

Simulation of Active filters in multisim

THEORY:

Active filters involve use of operational amplifiers along with resistors and capacitors. These filters provide a response similar to LRC filters without using inductors which make the latter bulky at low frequencies.

A. Butterworth Low Pass Filter (LPF)

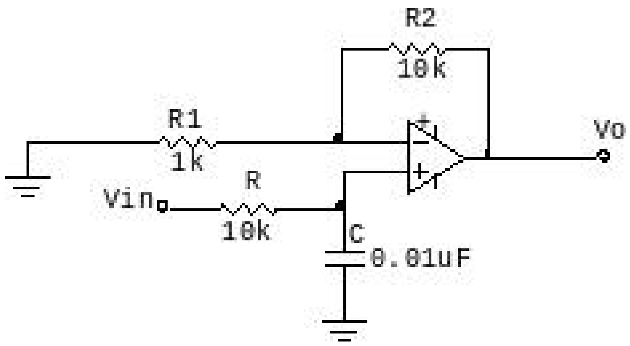


Figure1

For the Butterworth LPF shown in Fig. 1, the transfer function is as follows:

$$V_0/V_i = (1 + R_2/R_1)\ (1/\ 1 + sRC) \qquad (1)$$

where, the first term is the passband gain k given by

$$k = (1 + R_2/\ R_1) \qquad (2)$$

Solving Eq. 1 for the cutoff frequency results in the following

$$f_c = 1/2\pi RC \qquad (3)$$

Given the specifications of cutoff frequency fc and passband gain k, the filter can be designed.

1. Design Steps:

1) Choose a value of C and get the value of R for a given cutoff frequency using Eq. 3. Choice of C is done first due to the larger available range in R values.

2) The passband gain can be used to find the values of R1 and R2 by choosing one resistor and using Eq. to calculate the other.

B. Butterworth High Pass Filter (HPF)

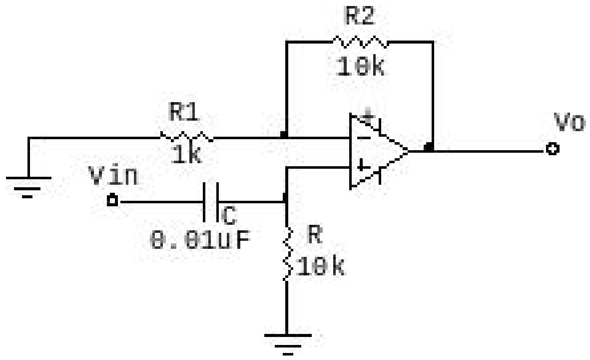


Figure2

For the Butterworth HPF shown in Fig. 2, the transfer function obtained is

$$V_0/V_i = (1 + R_2/R_1)(sRC/1 + sRC) \quad (4)$$

Solving for the cutoff frequency and passband gain results in the same equations as in the case of LPF. Design steps for the filter remain the same as LPF.

C. Wide Band Pass Filter (BPF)

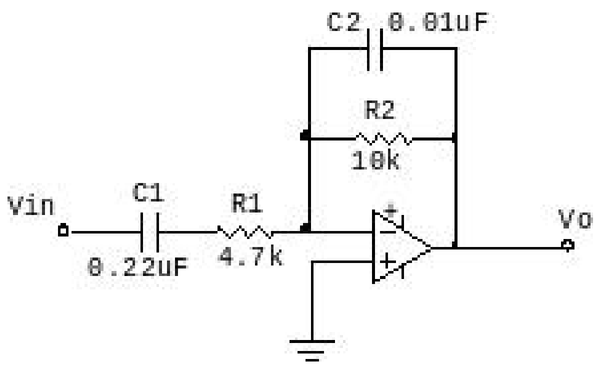


Figure3

The transfer function for the wide BPF shown in Fig. 3 is as follows

$$V_0/V_i = -sR_2C_1/S^2R_1R_2C_1C_2 + s(R_1C_1 + R_2C_2) + 1 \quad (5)$$

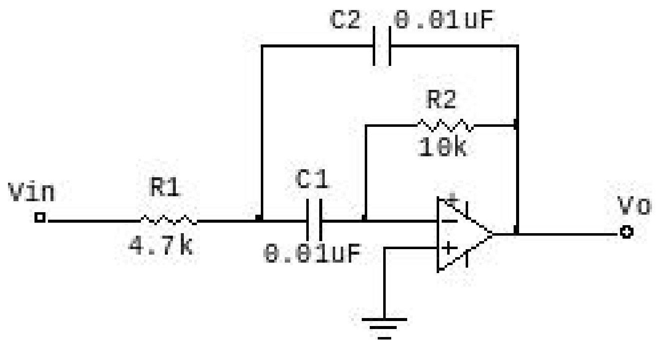


Figure4

D. Multiple Feedback BPF

The multiple feedback BPF shown in Fig. 4, has the transfer function as follows,

$$V0/V1 = -s R2C1/ \ S^2R1R2C1C2 + sR1(C1 + C2) + 1 \quad (6)$$

Choosing C1=C2=C and solving Eq. 6 gives us the following

$$fm = 1 \ 2\pi C\sqrt{} R1R2 \quad (7)$$

$$k = - R2/ 2R1 \quad (8)$$

$$B.W. = 1 /\pi R2 \ C \quad (9)$$

where, k is the gain at mid-frequency fm and B.W. is the bandwidth.

1. Design Steps:

1) Choose a value of C and get the value of R1 and R2 for a given mid-band frequency and mid- band gain using Eq. 7 and 8.

1. Plot the characteristics of Frequency Vs Magnitude
2. Frequency Vs phase

3. Obtain the characteristics for filters of all types

STIMULATION:

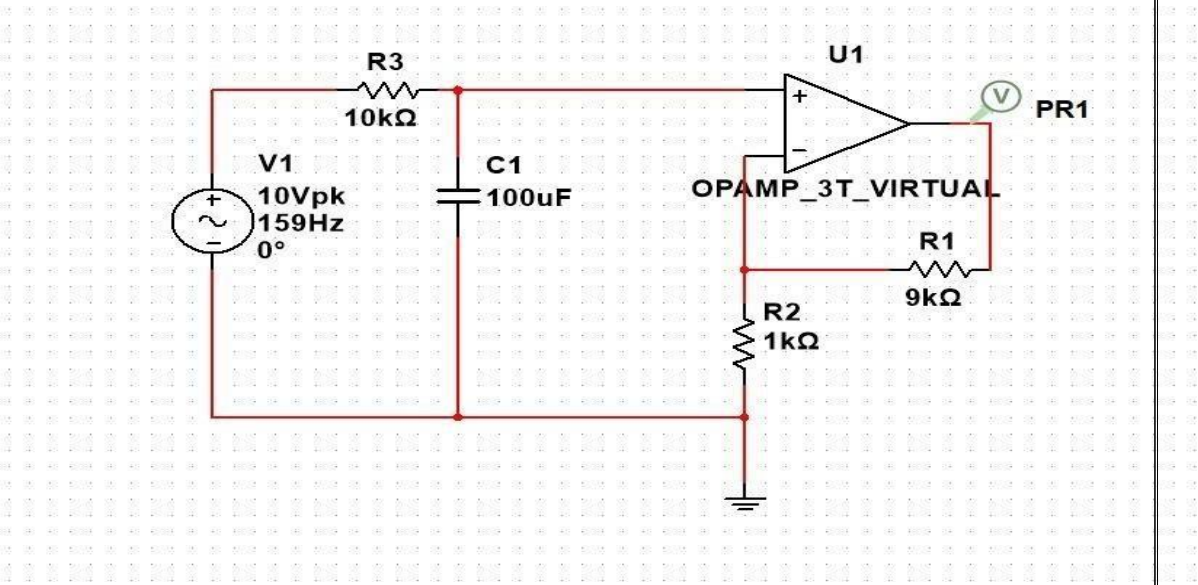
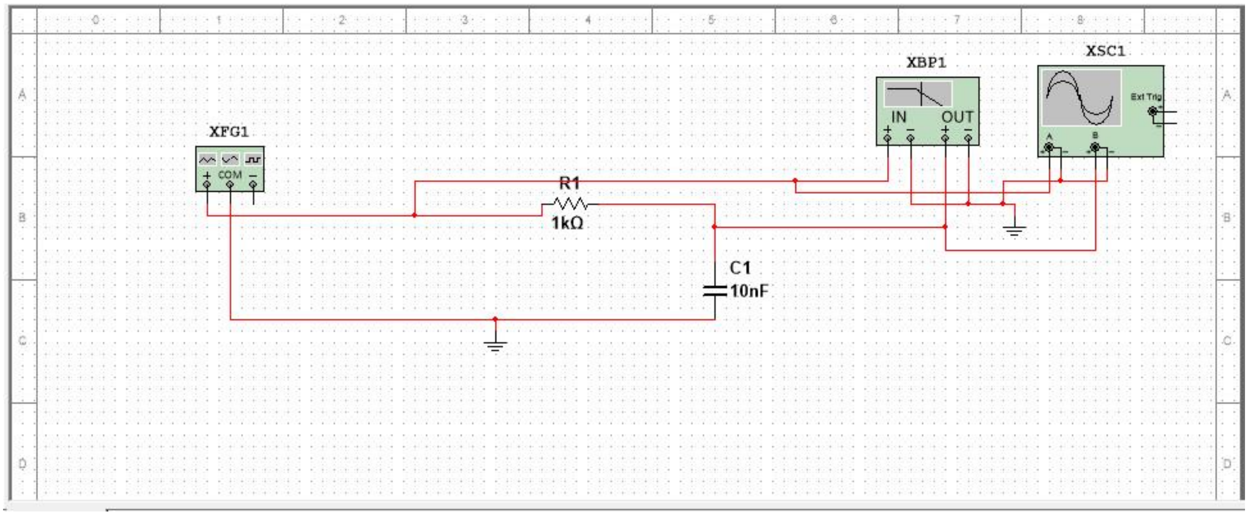
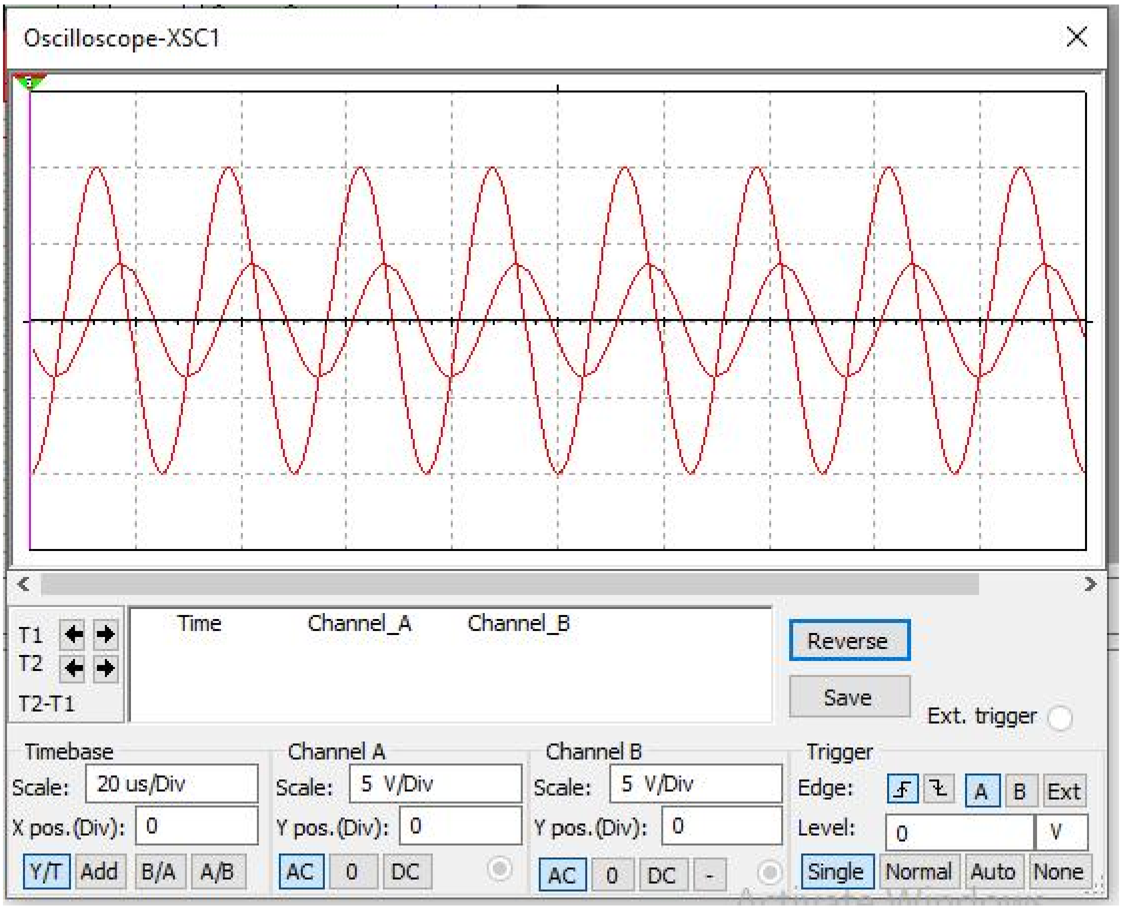
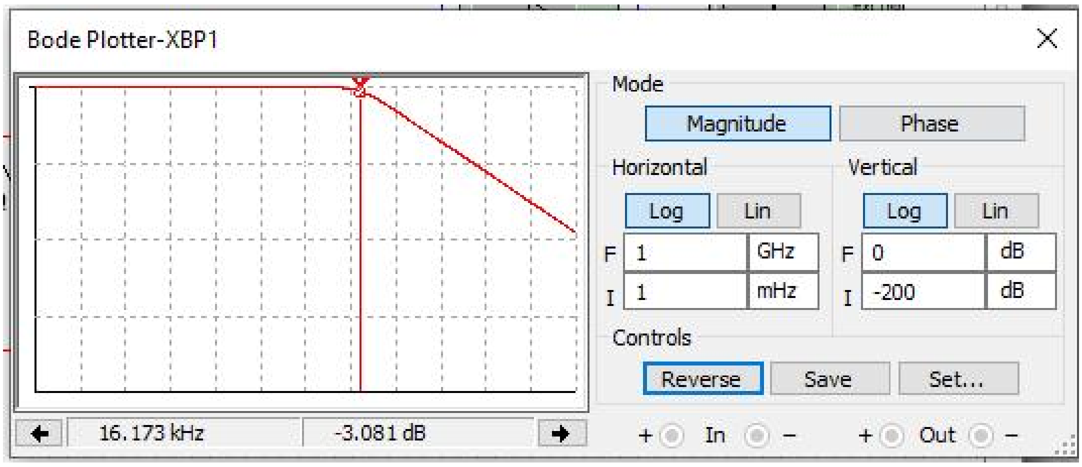


Fig: high pass filter


XBP1
IN
OUT
XSC1
Ext Trig
XFG1
COM
R1
1kΩ
C1
10nF


Oscilloscope-XSC1
T1
T2
T2-T1
Time
Channel_A
Channel_B
Reverse
Save
Ext. trigger
Timebase
Scale: 20 us/Div
X pos.(Div): 0
Y/T Add B/A A/B
Channel A
Scale: 5 V/Div
Y pos.(Div): 0
AC 0 DC
Channel B
Scale: 5 V/Div
Y pos.(Div): 0
AC 0 DC -
Trigger
Edge:
A B Ext
Level: 0 V
Single Normal Auto None


Bode Plotter-XBP1
Mode
Magnitude
Phase
Horizontal
Log Lin
F 1 GHz
I 1 mHz
Vertical
Log Lin
F 0 dB
I -200 dB
Controls
Reverse
Save
Set...
16.173 kHz
-3.081 dB
+ In -
+ Out -

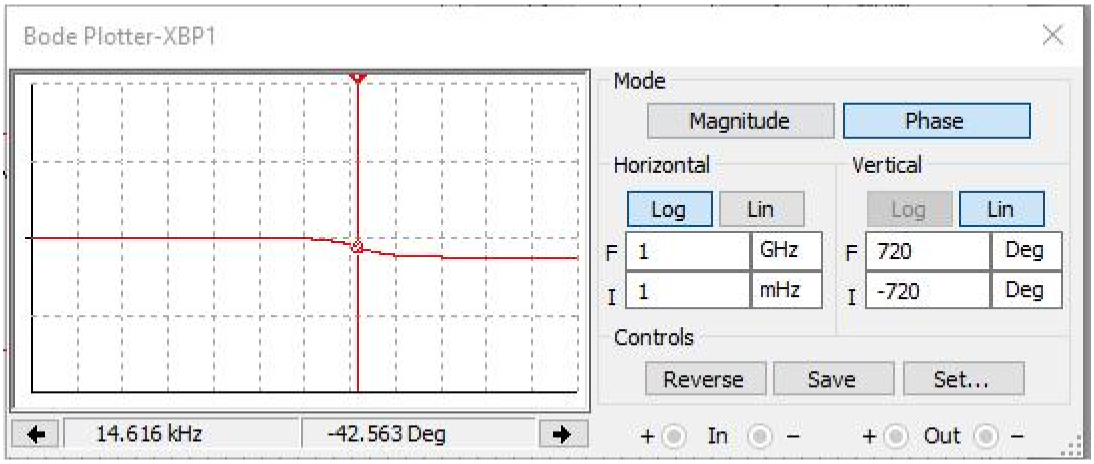
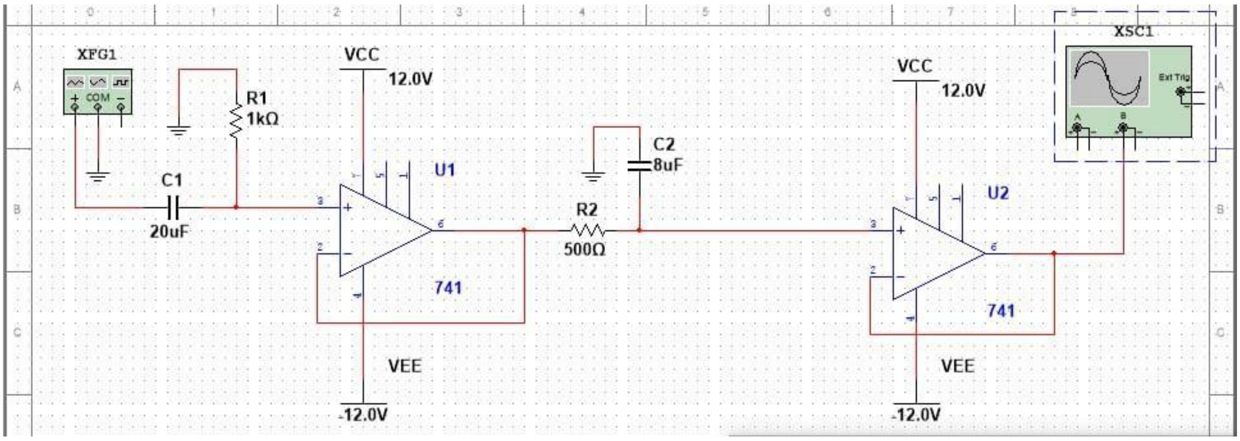


Fig: Low pass filter



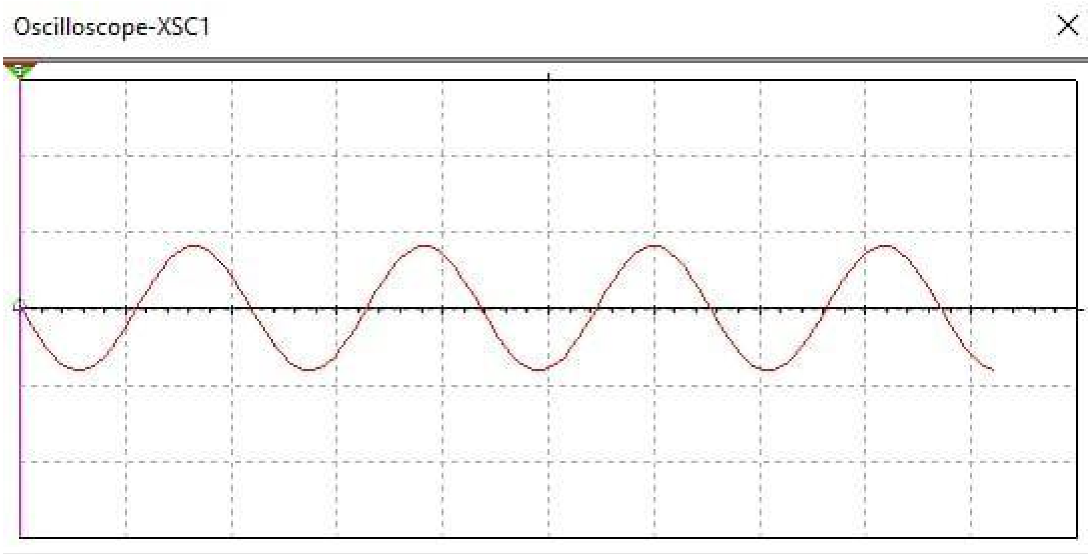


Fig: band pass filter

EXPERIMENT NO. 6

Aim of the Experiment:

To understand the working principle of Strain gauge

Objectives

1. Plot the characteristics of Strain gauge.
2. Understand the effect of various parameters on the strain gauge performance.

Theory –

What do we mean by Stress?

Stress is the force generated inside an object in response to an applied external force. This internal force divided by the cross-sectional area of the object is called stress, which is expressed in Pa (Pascal) or N/m2.If the direction of the external force is vertical to the cross-sectional area, the stress is called **vertical stress**.

What do we mean by strain?

When a bar is pulled, it causes change in its length by ΔL, making its new length = L (original length) + ΔL (change in length). The ratio of this change in length ΔL, to the original length, L, is called strain. The strain is expressed in ε (epsilon): $\varepsilon = \Delta L / L$ Strain in the same direction as the external force is called longitudinal strain. Since strain is a ratio, it is an absolute number having no unit. Strain in the direction perpendicular to the external force is called lateral strain. Each material has a certain ratio of lateral strain to longitudinal strain. This ratio is called Poisson's ratio.

$V = -(d\varepsilon(trans)/ d\varepsilon(axial))$

where V is the resulting **Poisson's ratio**, **ε(trans)** is transverse strain (negative for axial tension (stretching), positive for axial compression) **ε(axial)** is axial strain (positive for axial tension, negative for axial compression). The value of stress is directly proportional to the strain. Thus, we can find the stress in a material if we can find the strain initiated by external force.

Introduction to Strain Gauge

Strain gauge transducer transforms mechanical elongation and compression into measurable value.

Types of Strain Gauges based on principle of working:

1. **Mechanical:** It is made up of two separate plastic layers. The bottom layer has a ruled scale on it and the top layer has a red arrow or pointer. One layer is glued to one side of the crack and one layer to the other. As the crack opens, the layers slide very slowly past one another and the pointer moves over the scale. The red crosshairs move on the scale as the crack widens. Some mechanical strain gauges are even more crude than this. The piece of plastic or glass is stick across a crack and observed its nature.

2. **Electrical:** The most common electrical strain gauges are thin, rectangular-shaped strips of foil with maze-like wiring patterns on them leading to a couple of electrical cables. When the material is strained, the foil strip is very slightly bent out of shape and the maze-like wires are either pulled apart (so their wires are stretched slightly thinner) or pushed together (so the wires are pushed together and become slightly thicker). Changing the width of a metal wire changes its electrical resistance. This change in resistance is proportional to the stress applied. If the forces involved are small, the deformation is elastic and the strain gauge eventually returns to its original shape.
3. **Piezoelectric:** Some materials such as quartz crystals and various types of ceramics, are effectively "natural" strain gauges. When pushed and pulled, they generate tiny electrical voltages between their opposite faces. This phenomenon is called piezoelectricity. By measuring the voltage from a piezoelectric sensor, we can easily calculate the strain. Piezoelectric strain gauges are the most sensitive and reliable devices.

Electrical Strain Gauge: A strain gauge takes advantage of the physical property of electrical conductance. It does not depend on merely the electrical conductivity of a conductor, but also the conductor's geometry. When an electrical conductor is stretched within the limits of its elasticity such that it does not break or permanently deform, it will become narrower and longer. Similarly, when it is compressed, it will broaden and shorten. The change in the resistance is due to variation in the length and cross-sectional area of gauge wire.

Gauge Factor:

The characteristics of the strain gauges are described in terms of its sensitivity (gauge factor). Gauge factor is defined as unit change in resistance for per unit change in length of strain gauge wire given as

G.F. = (ΔR/RG) / ε where, **ΔR** - the change in resistance caused by strain, **RG** - is the resistance of the unreformed gauge, and **ε** - is strain.

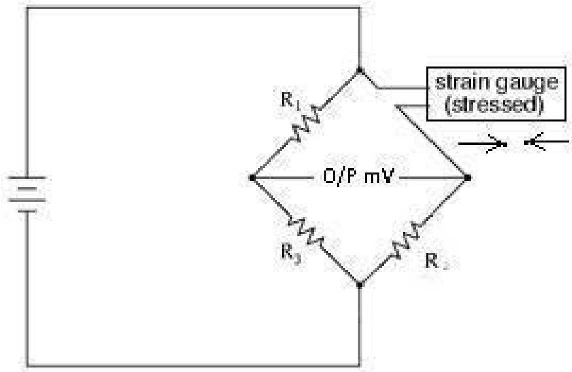
Effect of Temperature:

The resistive type strain gauges are sensitive to temperature variation; therefore, it becomes necessary to account for variations in strain gauge resistance due to temperature changes. Using dummy gauge in opposite arm of the active gauge compensates the temperature variation.

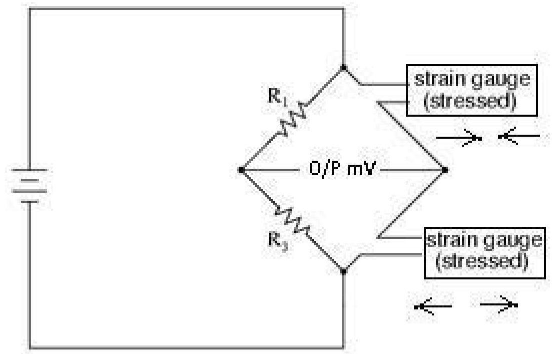
Arrangement:

In certain applications where equal and opposite strains are known to exist it is possible to attach similar gauges in way that one-gauge experiences positive strain and other negative strain. Depending on the number of gauges used the bridge, the circuit configurations are:

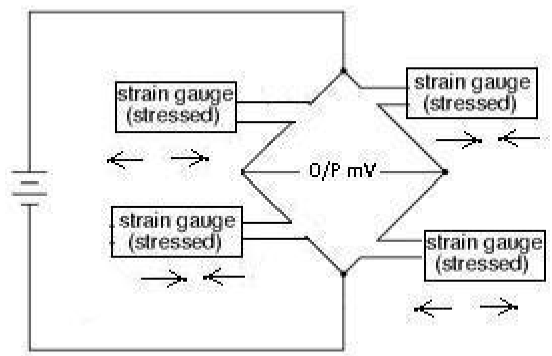
1. Quarter Bridge:


strain gauge
(stressed)
R1
O/P mV
R3
R2

2. Half Bridge:



3. Full Bridge:



In Quarter Bridge, the strain gauge is connected in one arm as shown in the above diagram. In half bridge arrangement two active gauges are used, while in case of full bridge all the gauges are active. In this arrangement two acts in tension while other two are compression. With the help of this type of arrangement temperature compensation is also achieved. When possible, the full-bridge configuration is the best to use. This is true not only because it is more sensitive than the others, but because it is linear while the others are not. Quarter-bridge and half-bridge circuits provide an output (imbalance) signal that is only approximately proportional to applied strain gauge force. Linearity, or proportionality, of these bridge circuits is best when the amount of resistance changes due to applied force is very small compared to the nominal resistance of the gauge(s). With a full-bridge, however, the output voltage is directly proportional to applied force, with no approximation.

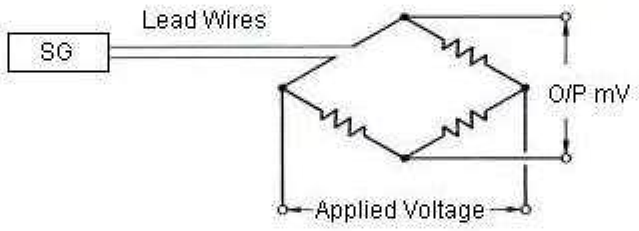
Effect of Lead-Wire:

Strain gauges are sometimes mounted at a distance from the measuring equipment. This increases the possibility of errors due to temperature variations, lead desensitization, and lead-wire resistance changes.

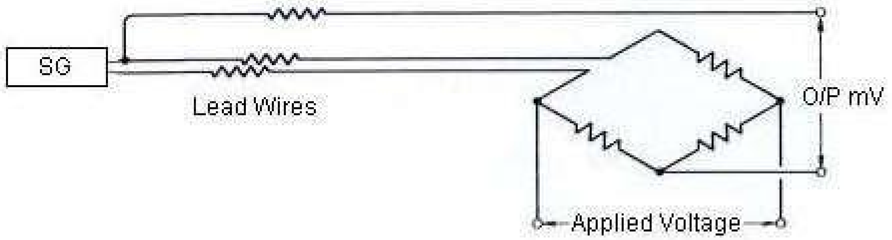
Two wire:

In a **two-wire installation**, as shown in figure, the two leads are in series with the strain-gauge element, and any change in the lead-wire resistance (R1) will be indistinguishable from changes in the resistance of the strain gage (Rg). In two-wire installations, the error introduced by lead-wire resistance is a function of the resistance ratio R1/Rg. The lead error is usually not significant if the lead-wire resistance (R1) is small in comparison to the gage resistance (Rg), but if the lead-wire resistance exceeds 0.1% of the nominal gage resistance, this source of error becomes significant.

Therefore, in industrial applications, lead-wire lengths should be minimized or eliminated by locating the transmitter directly at the sensor.



2 Wire Configuration



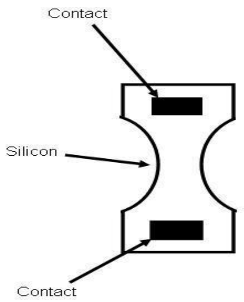
3 Wire Configuration

Three wire:

To correct for lead-wire effects, an additional, third lead can be introduced to the top arm of the bridge, **as shown in the above Figure**. In this configuration, wire C acts as a sense lead with no current flowing in it, and wires A and B are in opposite legs of the bridge. This is the minimum acceptable method of wiring strain gages to a bridge to cancel at least part of the effect of extension wire errors. Theoretically, if the lead wires to the sensor have the same nominal resistance, the same temperature coefficient, and are maintained at the same temperature, full compensation is obtained. In reality, wires are manufactured to a tolerance of about 10%, and three-wire installation does not completely eliminate two-wire errors, but it does reduce them by an order of magnitude. If further improvement is desired, four-wire and offset- compensated installations should be considered.

Types of strain gauge based on construction:

Optical sensors are sensitive and accurate, but are delicate and not very popular in industrial applications. They use interference fringes produced by optical flats to measure strain. Optical sensors operate best under laboratory conditions. **The photoelectric gauge** uses a light beam, two fine gratings, and a photocell detector to generate an electrical current that is proportional to strain. The gage length of these devices can be as short as 1/16 inch, but they are costly and delicate. **Semiconductor strain gauges:** For measurements of small strain, semiconductor strain gauges, so called piezo resistors, are often preferred over foil gauges. Semiconductor strain gauges depend on the piezoresistive effects of silicon or germanium and measure the change in resistance with stress as opposed to strain. The semiconductor bonded strain gauge is a wafer with the resistance element diffused into a substrate of silicon. The wafer element usually is not provided with a backing, and bonding it to the strained surface requires great care as only a thin layer of epoxy is used to attach it. The size is much smaller and the cost much lower than for a metallic foil sensor. The same epoxies that are used to attach foil gages are used to bond semiconductor gages. The advantages are higher unit resistance and sensitivity whereas, greater sensitivity to temperature variations and tendency to drift are disadvantages in comparison to metallic foil sensors. Another disadvantage of semiconductor strain gages is that the resistance-to-strain relationship is nonlinear. With software compensation this can be avoided.



Thin-film strain gauge: These gauges eliminate the need for adhesive bonding. The gauge is produced by first depositing an electrical insulation (typically a ceramic) onto the stressed metal surface, and then depositing the strain gauge onto this insulation layer. Vacuum deposition or sputtering techniques are used to bond the materials molecularly. Because the thin-film gauge is molecularly bonded to the specimen, the installation is much more stable and the resistance values experience less drift. Another advantage is that the stressed force detector can be a metallic diaphragm or beam with a deposited layer of ceramic insulation.

Diffused semiconductor strain gauges: This is a further improvement in strain gage technology as they eliminate the need for bonding agents. By eliminating bonding agents, errors due to creep and hysteresis also are eliminated. The diffused semiconductor strain gage uses photolithography masking techniques and solid-state diffusion of boron to molecularly bond the resistance elements. Electrical leads are directly attached to the pattern.

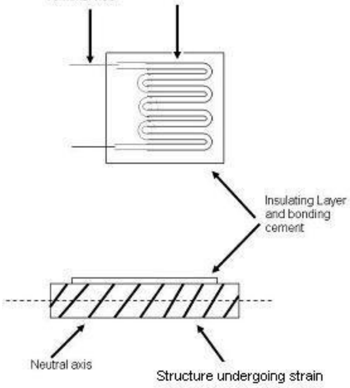
The diffused gauge is limited to moderate-temperature applications and requires temperature compensation.

Diffused semiconductors often are used as sensing elements in pressure transducers. They are small, inexpensive, accurate and repeatable, provide a wide pressure range, and generate a strong output signal. Their limitations include sensitivity to ambient temperature variations, which can be compensated for in intelligent transmitter designs.

Types of strain gauge based on mounting:

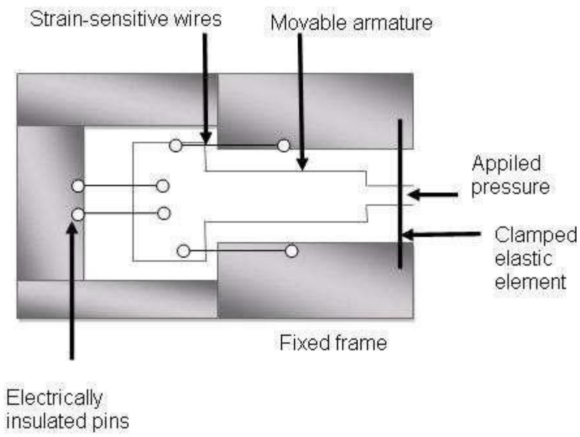
Bonded strain gauge:

A bonded strain-gage element, consisting of a metallic wire, etched foil, vacuum-deposited film, or semiconductor bar, is cemented to the strained surface.



Unbonded Strain Gauge:

The unbonded strain gage consists of a wire stretched between two points in an insulating medium such as air. One end of the wire is fixed and the other end is attached to a movable element.



Strain gauge selection criteria:

- Gauge Length
- Number of Gauges in Gauge Pattern
- Arrangement of Gauges in Gauge Pattern
- Grid Resistance
- Mass
- Stability
- Temperature sensitivity
- Carrier Material
- Gauge Width
- Availability
- Low cost
- Effect of ambient conditions

Procedure:

1. First select the material of the strain gauge from the available drop-down menu.
2. Select the value of input voltage V for the bridge in which strain gauge is connected.
3. Select the strain gauge resistance in ohms.
4. Select the bridge configuration. Observe the connection diagram, by changing the selected configuration.
5. Select the gauge factor value from available drop-down menu.
6. Click on **Configure** tab. The system is configured once the user confirms the values.
7. Now the weight tab gets enabled. Select the weight in Kg to be applied to the cantilever beam. Now the value of Rg is displayed.
8. Enter the expected **output value (e) in millivolts**. For calculations of output, click on **formula**

tab.

9. Using formula, calculate the value of the output voltage and enter the answer in the box provided (0.00 format). Submit the answer using submit button.
10. If your calculation is correct, you will get the message accordingly. If not, you need to repeat the calculations.
11. Change the value of **weight** and repeat the steps 7 to 10.
12. Minimum three calculations are necessary to plot the graph. After three calculations, the **Plot** tab will be activated.
13. Click on **Plot** to see the graph. Study the graph of output voltage variation when weight is changed.
14. Hide the graph and repeat the experiment by varying the values of inputs or bridge types. Observe the graphs. For this use **' Next set of values'** tab which is enabled now. Otherwise go to next level by clicking **'Level 2'** enabled tab.

Level 2

Study of effect of change in position of weight applied on Strain Gauge performance

1. When you move from level 1 to level 2, the configuration and selected weight remains same.
2. Now you can select the position of the weight attached to the beam. Originally the distance between strain gauge and the applied weight is 16 cm. Now if 14 cm position is selected the distance is reduced by 2 cm i.e., the distance between strain gauges fixed on the beam and the applied weight is 14 cm. You can observe this change in available diagram.
3. **Observe** the displayed output value. Compare this value with previous value. Refer to **formula** tab for calculations.
4. Minimum three calculations are necessary to plot the graph. After three calculations the **Plot** tab will be activated.
5. Click on **Plot** to see the graph. Study the graph of output voltage variation when position is changed. Observe the graph carefully.
6. Hide the graph and move on to next level by clicking on **'Level3'** tab.

Level 3

Study of effect of change in temperature on the performance of Strain Gauge

1. When you move from level 2 to level 3, all the parameters including the position of the weight for level 1 and level 2 freeze. The user can now select the **temperature** to which strain gauges are exposed i.e., ambient temperature.

2. Select the temperature in °C from the drop-down menu. The reference temperature considered for previous level calculations is 20 °C

3. **Observe** the displayed value of Rgi.e., Resistance of strain gauge. Compare this value with previous value. Refer to **formula** tab for calculations.

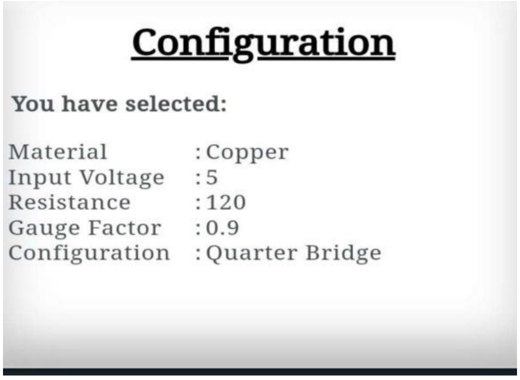
4. Minimum three calculations are necessary to plot the graph. After three calculations the **Plot** tab will be activated.

5. Click on **Plot** to see the graph. Study the graph of Rg value variation with change in

temperature. After completion of all the parts, you can proceed to Post Test to find if you have understood all aspects of the experiment.

STIMULATION:

QUARTER BRIDGE:



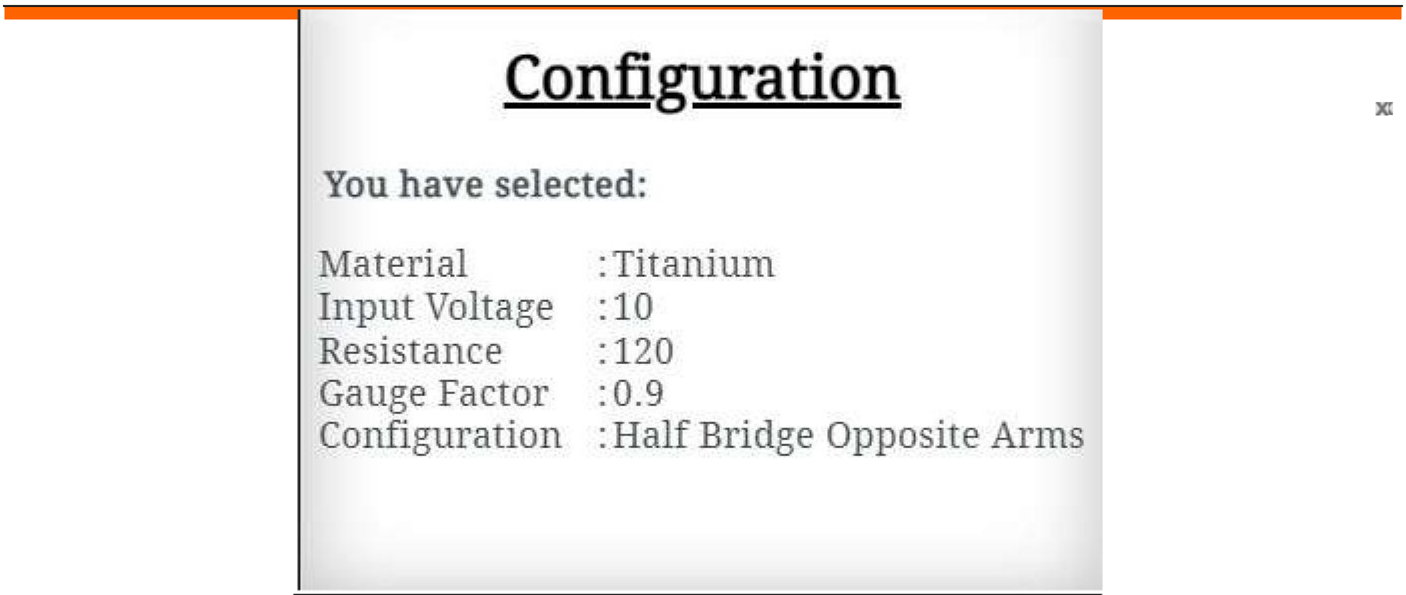
Obtain the following characteristics for quarter, half and full bridge

1. The characteristic plot of position (cm) Vs output(mV) .

2. Weight (kg) Vs output (mV)

3. Temperature (^{0}C)Vs strain gauge resistance(ohm)

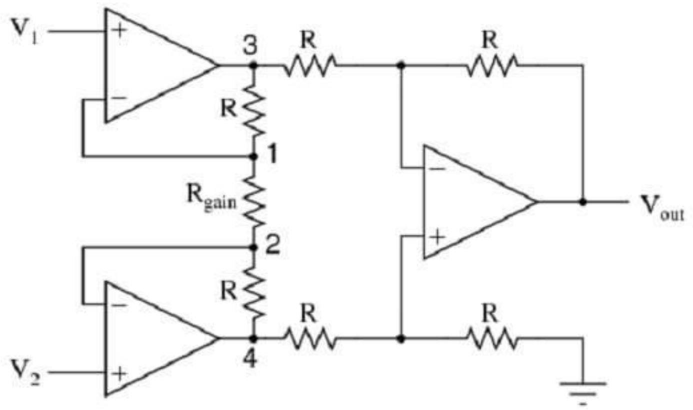
Half Bridge



Experiment No.7

Aim: Simulation of Intrumentation Amplifier and Find its gain

Theory:



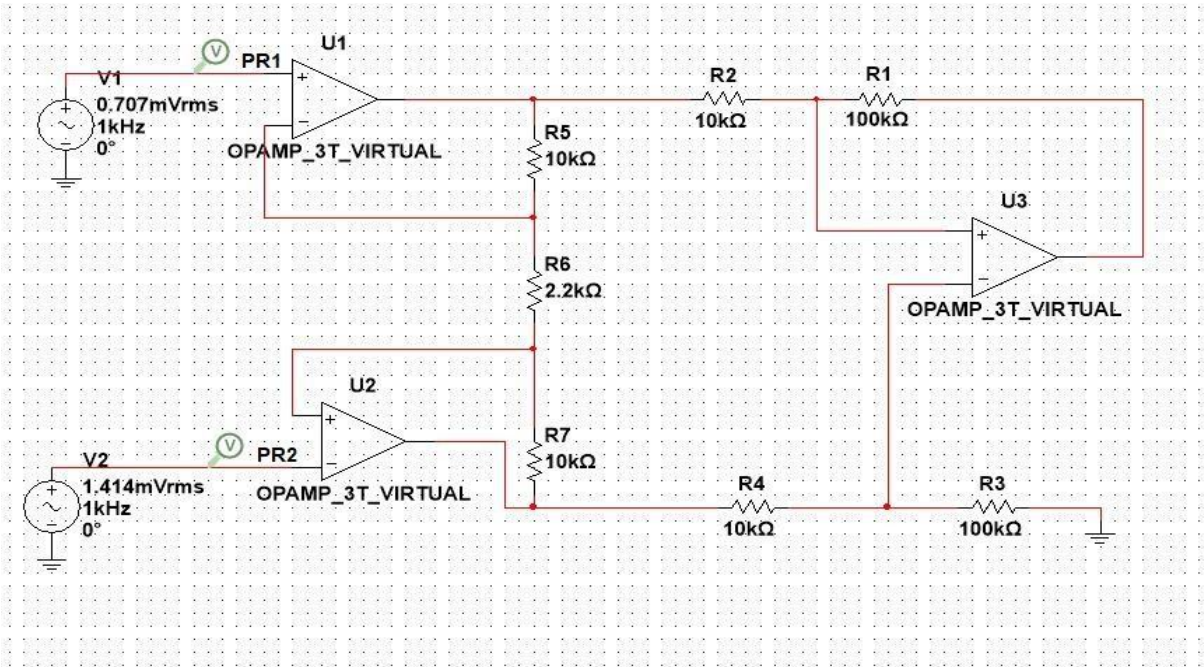
The figure shows a differential instrumentation amplifier using a transducer bridge. Resistance is a resistance of which changes proportional with some physical quantity Such as temperature, pressure, light intensity etc. is the resistance of the transducer & R is the change in the resistance. A DC or AC voltage source can excite the bridge under balanced conditions.

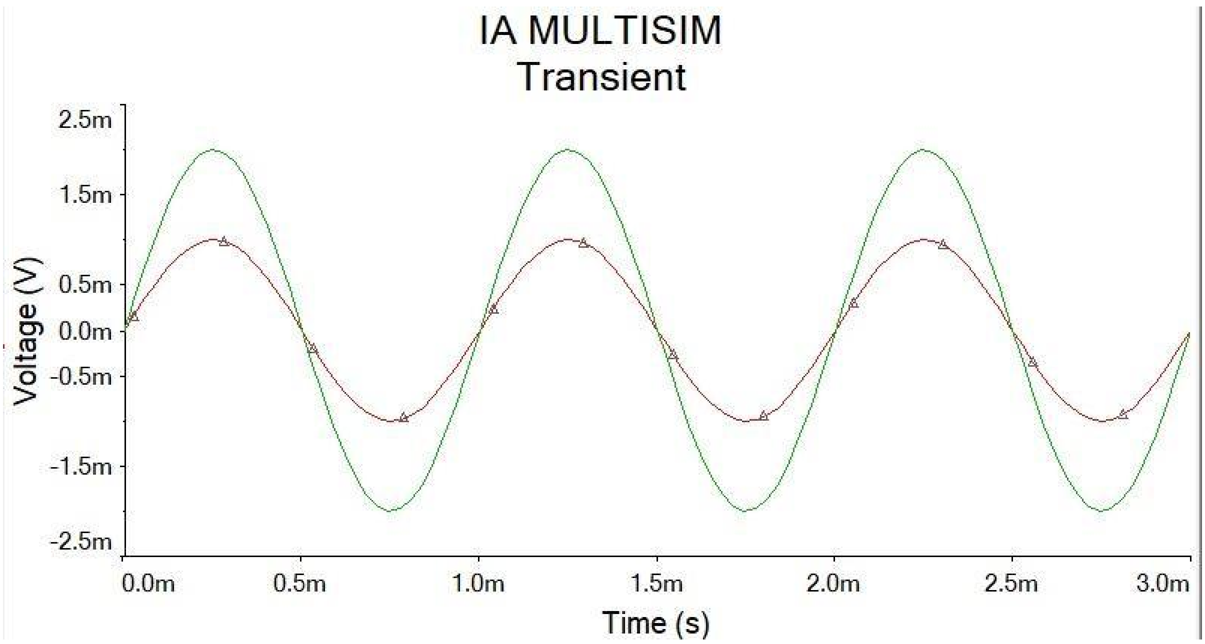
Procedure:

1. From the dropdown list select any desired component and place it on the canvas. Select the gain resistor from the list to set the gain of the amplifier.
2. Repeat the above step till all the required components are placed on the canvas. Select the type of input from the dropdown list.
3. Now click on the 'Connect' button and then click on the bubbles of the respective component to establish a connection between them.
4. Move' button helps to relocate the components. Click on the button and then click on the component to be moved on the canvas

NB: Deduce the gain of the Instrumentation Amplifier and then verify with the gain obtained by simulation.

STIMULATION:


V1
0.707mVrms
1kHz
0°
PR1
U1
OPAMP_3T_VIRTUAL
R2
10kΩ
R1
100kΩ
R5
10kΩ
R6
2.2kΩ
U3
OPAMP_3T_VIRTUAL
U2
R7
10kΩ
V2
1.414mVrms
1kHz
0°
PR2
OPAMP_3T_VIRTUAL
R4
10kΩ
R3
100kΩ


IA MULTISIM
Transient
Voltage (V)
Time (s)
2.5m
1.5m
0.5m
0.0m
-0.5m
-1.5m
-2.5m
0.0m
0.5m
1.0m
1.5m
2.0m
2.5m
3.0m

EXPERIMENT NO. 8

Aim of the experiment

To understand the phenomenon Photoelectric effect as a whole.

Theory:

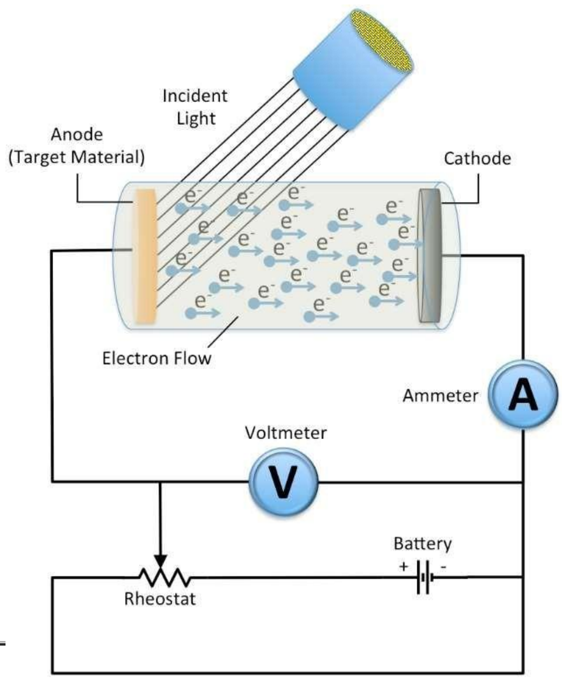
During his experiments on electromagnetic radiation (to demonstrate light consists of e-m waves), Hertz noticed a spark between the two metallic balls when a high frequency radiation incident on it. This is called photoelectric effect. Photoelectric effect is the emission of electrons when electromagnetic radiations having sufficient frequency incident on certain metal surfaces. We call the emitted electrons as photoelectrons and the current they constitute as photocurrent. The phenomenon was first observed by Heinrich Hertz in 1880 and explained by Albert Einstein in 1905 using Max Planck's quantum theory of light. As the first experiment which demonstrated the quantum theory of energy levels, photoelectric effect experiment is of great historical importance.

The important observations on Photoelectric effect which demand quantum theory for its explanation are:

1. The Photoelectric effect is an instantaneous phenomenon. There is no time delay between the incidence of light and emission of photoelectrons.
2. The number of photoelectrons emitted is proportional to the intensity of incident light. Also, the energy of emitted photoelectrons is independent of the intensity of incident light.
3. The energy of emitted photoelectrons is directly proportional to the frequency of incident light.

The basic experimental set up which explains Photoelectric effect is as given below,

It has been observed that there must be a minimum energy needed for electrons to escape from a particular metal surface and is called work function



Metal	Work function (e V)
Platinum(Pt)	6.4
Silver(Ag)	4.7
Sodium(Na)	2.3
Potassium(K)	2.2
Cesium(Cs)	1.9

ν_0 'W' for that is the threshold frequency (minimum frequency for photoelectric effect).

The work function for some metals are listed in the table.

According to Einstein the Photoelectric effect should obey the equation,

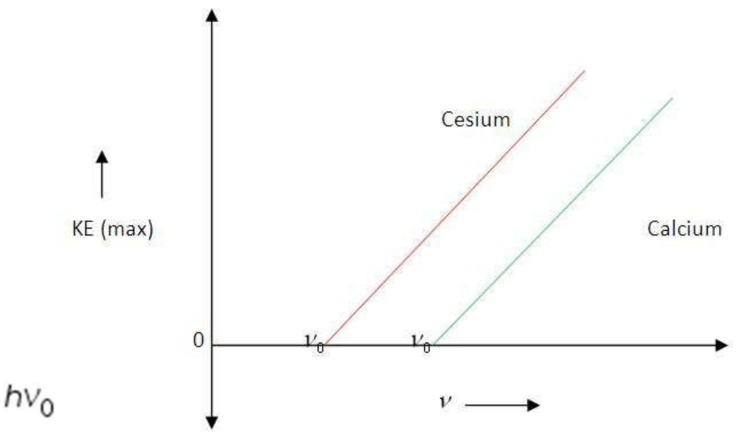
$$h\nu = KE_{max} + W \text{ ....(2)}$$

From the above expression,

$$KE_{max} = h\nu - h\nu_0$$

$$KE_{max} = h(\nu - \nu_0) \text{ ....(3)}$$

Graph connecting 'KE$_{max}$' and frequency:

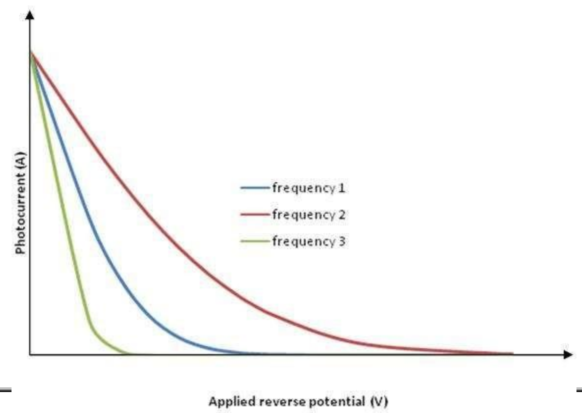


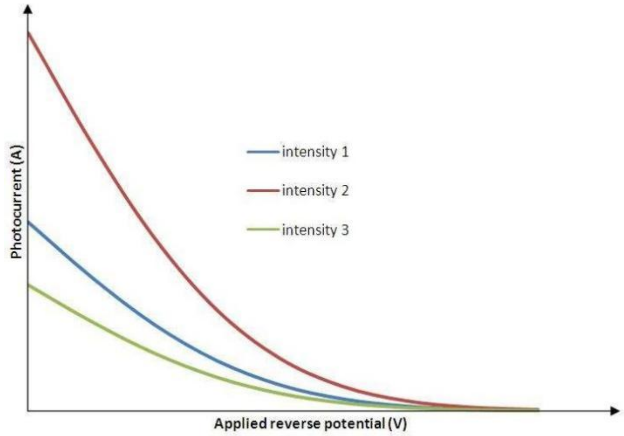
Maximum kinetic energy of photoelectrons versus frequency of incident radiation graph

Now, if we increase the reverse potential, the photocurrent gradually decreases and becomes zero at a particular reverse potential. This minimum applied reverse potential is called ***stopping potential V0***. Hence the maximum kinetic energy of photoelectrons can be written as,

$$KE_{max} = eV_0 \text{ ....(4)}$$

Graph connecting photocurrent and applied reverse potential :





For constant frequency and different intensities

For performing the simulation:

1. Select the material for studying photoelectric effect.

2. Select area of the material, wavelength, intensity of incident light.

3. Switch on the light source.

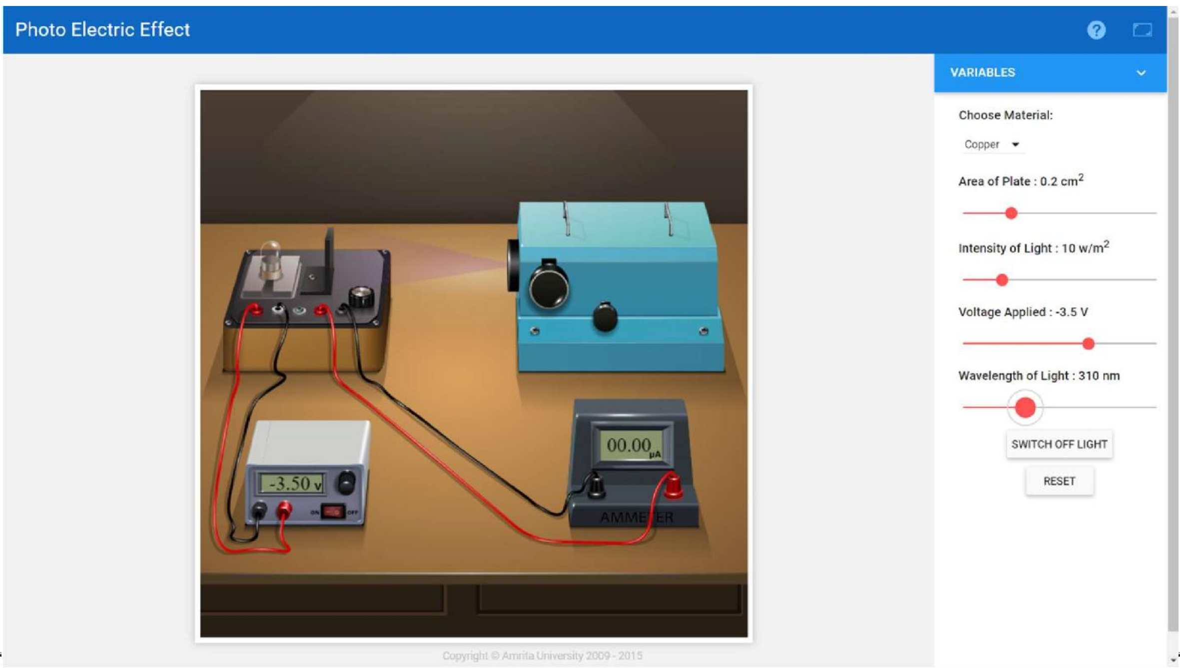
4. Measure the reverse current for various reverse voltages.

5. Plot the current-voltage graph and determine the threshold voltage.

6. Repeat the experiment by varying the intensity for a particular wavelength of incident light.

7. Repeat the experiment by varying the wavelength for a particular intensity of the incident light.

<u>STIMULATION:</u>



References:

3. vlabs.iitkgp.ernet.in
4. Vlabs.iitb.ac.in
5. https://www.vlab.co.in/
6. Electronic Instrumentation and Measurement by David A Bell.
7. Fundamentals of Instrumentation and Measurement.

Note: The students should explore the theory of each experiment and obtain the characteristic graphs and analyze.