SRM VALLIAMMAIENGINEERINGCOLLEGE
SRM Nagar, Kattankulathur – 603 203

DEPARTMENTOF

ELECTRONICS ANDINSTRUMENTATION ENGINEERING

LAB MANUAL

VII SEMESTER

1907710– Instrumentation System Design Laboratory

Regulation– 2019

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Prepared by

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1907710 INSTRUMENTATION SYSTEM DESIGN LABORATORY L T P C
0 0 3 2

OBJECTIVES:

To obtain adequate knowledge in design of various signal conditioning circuits, instrumentation Systems, controller and control valve.

LIST OF EXPERIMENTS:

1. Design of Instrumentation amplifier.
2. Design of active filters – LPF, HPF and BPF
3. Design of regulated power supply and design of V/I and I/V converters.
4. Design of linearizing circuits and cold–junction compensation circuit for thermocouples.
5. Design of signal conditioning circuit for Strain gauge and RTD.
6. Design of Orifice plate and Rotameter.
7. Design of Control valve (sizing and flow-lift characteristics)
8. Design of PID controller (using operational amplifier and microprocessor)
9. Design of a multi-channel data acquisition system.
10. Design of multi range DP transmitter.
11. Piping and Instrumentation Diagram – case study.
12. Preparation of documentation of instrumentation project and project scheduling for the above case study. (Process flow sheet, instrument index sheet and instrument specifications sheet, job scheduling, installation procedures and safety regulations).
13. One or two experiments beyond syllabus.

CYCLE 1

1. Design of Instrumentation amplifier.

2. Design of active filters – LPF, HPF and BPF

3. Design of regulated power supply and design of V/I andI/V converters.

4. Design of linearizing circuits and cold–junction compensation circuit for thermocouples.

5. Design of signal conditioning circuit for strain gauge and RTD.

6. Design of orifice plate and rotameter.

7. Design of Control valve (sizing and flow-lift characteristics)

CYCLE 2

8. Design of PID controller (using operational amplifier and microprocessor)

9. Design of a multi-channel data acquisition system

10. Design of multi range DP transmitter

11. Piping and Instrumentation Diagram – case study.

12. Preparation of documentation of instrumentation project and project scheduling for the above case study. (Process flow sheet, instrument index sheet and instrument specifications sheet, job scheduling, installation procedures and safety regulations).

EXPERIMENTS BEYOND SYLLABUS

12. Design of First order active filter.

CONTENTS

Exp. No:1

DESIGN OFINSTRUMENTATION AMPLIFIER

Aim:

To design and construct an instrumentation amplifier.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	Dual RPS	0-30V	1
2.	Operational Amplifier	IC 741	3
3.	Resistors	1KΩ	6
4.	Decade Resistance Box	6 dial	1
5.	Digital Multimeter	-	1
6.	Bread Board & Connecting Wires	-	Sufficient nos.

Theory:

Instrumentation amplifier is an amplifier with high input impedance, very low output impedance, low offset and low drifts voltage. This configuration is better than inverting or non-inverting amplifier because it has minimum non-linearity, stable voltage gain and high common mode rejection ratio (CMRR > 100 dB.). This type of amplifier is used in instrumentation field where the output voltages are very low such as in thermocouples, strain gauges and biological probes.

In this circuit, consider all resistors to be of equal value except for R_g. The negative feedback of the upper-left op-amp causes the voltage at point V_a (top of R_g) to be equal to V_1. Likewise, the voltage at point V_b (bottom of R_g) is held to a value equal to V_2. This establishes a voltage drop across R_g equal to the voltage difference between V_1 and V_2. That voltage drop causes a current through R_g, and since the feedback loops of the two input op-amps draw no current, that same amount of current through R_g must be going through the two "R" resistors above and below it. This produces a voltage drop between points V_1' and V_2' equal to:

$$\mathbf{V_1' - V_2' = (V_2 - V_1)\,[1+(R / R_g)]}$$

The differential amplifier in the circuit diagram takes the voltage drop between $V_1'$and V_2', and amplifies it by a gain of 1 (assuming again that all "R" resistors are of equal value). It possesses extremely high input impedances on V_1 and V_2 inputs (because they connect straightinto the non inverting inputs of their respective op-amps). It also provides the same for the input through adjustable gain resistor. Hence the overall voltage gain in the instrumentation amplifier is,

$$\mathbf{A_v = [1 + (2R/ R_g)]}$$

Circuit Diagram:

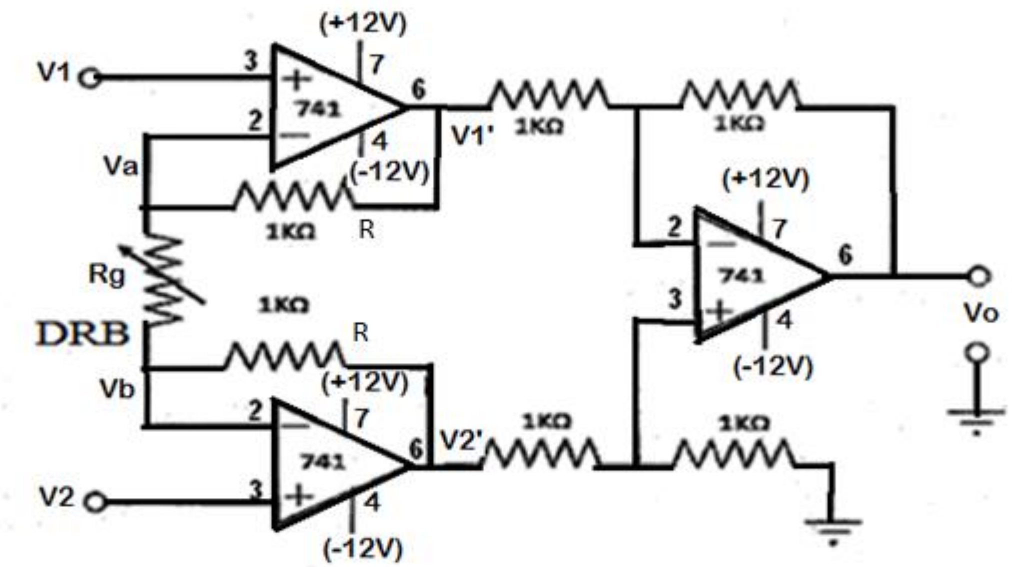


Fig: Instrumentation Amplifier

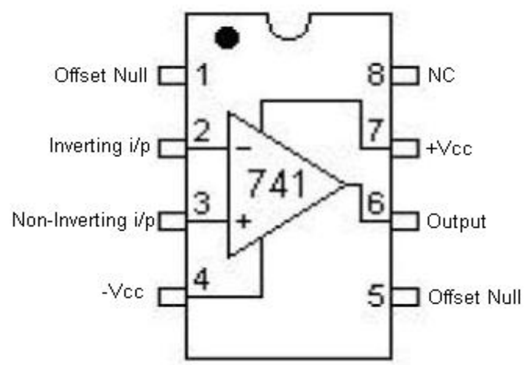


Fig: Pin Diagram of IC 741

Formula used:

$$V_0 = -(R_2/R_1)(1 + 2R_f/R_g)$$

Where,

$V_d = V_2 - V_1$

$V_1' = R/R_g (V_1 - V_2) + V_1$

$V_2' = R/R_g (V_1 - V_2) + V_2$

Procedure:

1. Give the connections as per the circuit diagram.
2. Gain resistance (R_g) is calculated using the design formula and set the value in DRB.
3. Apply the differential input voltage at the input terminals and note the corresponding output value.
4. Repeat the above step for the different values of R_g.

Tabulation:

S. No.	**R_g (Ω)**	**V_1 (Volts)**	**V_2 (Volts)**	**V_1' (Volts)**	**V_2' (Volts)**	**V_d=(V_2 -V_1) Volts**	**Output Voltage (Volts)**	
							V_{th}	**V_p**
1.								
2.								
3.								
4.								
5.								

Model Calculations:

Result:
Thus the Instrumentation Amplifier is designed and tested using 3 Op-amp configuration

Review Questions:

1. What is the difference between instrumentation amplifier and differential amplifier?
2. What are the characteristics of instrumentation amplifier?
3. What is CMRR?
4. What are the applications of instrumentation amplifier?
5. What is the other name of instrumentation amplifier?

Exp. No:2

DESIGN OF ACTIVE FILTERS

Aim:

To design and construct active low pass filter (LPF) & high pass filter (HPF) using operational amplifier

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	IC Power Supply	+/-15V dc	1
2.	Function Generator	1Hz - 1Mhz	1
3.	Cathode Ray Oscilloscope	30MHz	1
4.	Operational Amplifier	IC 741	1
5.	Resistors	1.59KΩ, 10 KΩ, 5.86	2,1,1
6.	Capacitors	0.1μf	2
7.	Bread Board & Connecting	-	Sufficient nos.

Theory:

An improved filter response can be obtained by using a second order active filter. A second order filter consist of two RC pairs has a roll-off rate of –40dB/decade. The transfer function of a Low pass filter

$$H(s) = \frac{A_0 \omega^2 h}{S^2 + \alpha \omega_h S + \omega^2 h}$$

For n=2, the damping factor $\alpha = 1.414$, the pass band gain $A_0 = 3 - \alpha = 1.586$.

Cutoff frequency of the filter, $F_c = \omega_h$

HPF is the complement of the Low pass filter and can be obtained simply by interchanging R and C in the low pass filter configuration.

Design:

F_c = 1 KHz, Assume C = 0.1 μF, R = 1.6 KΩ

Let R_f = 5.86 KΩ , R_i = 10 KΩ; Gain $=A_o$ = [1+5.86/10] = [1+0.586]=1.586.

Circuit Diagram:

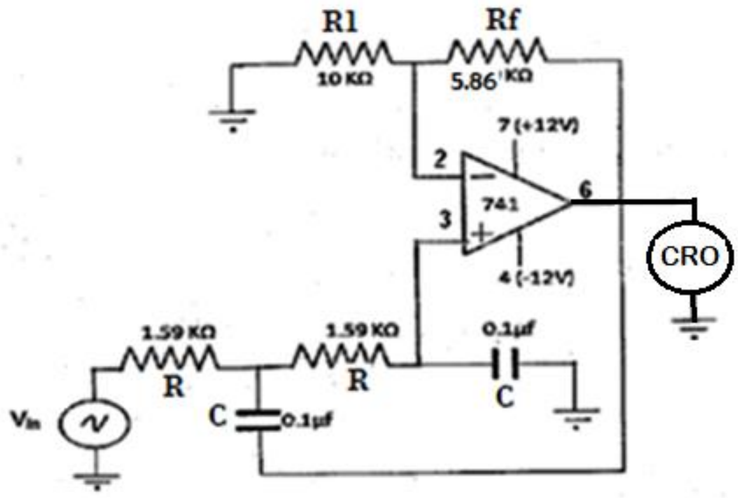


Fig: **Second Order Active Low Pass Filter**

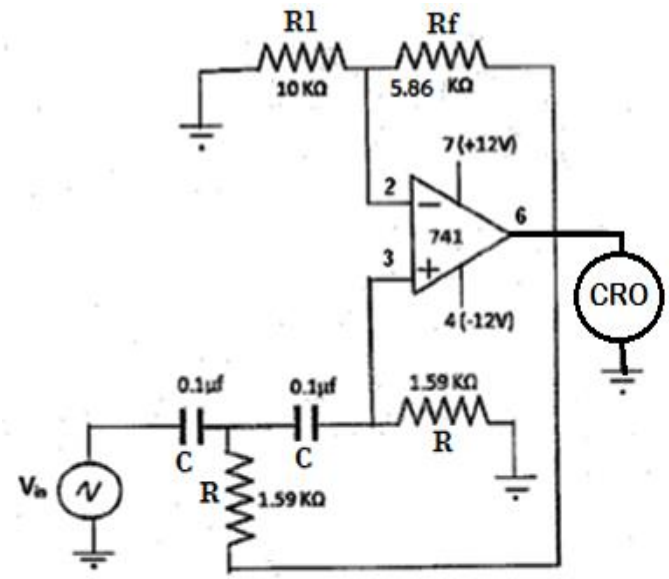


Fig: **Second Order Active High Pass Filter**

Procedure:

1. Connect the low pass filter circuit as shown in the circuit diagram.
2. The value of R is calculated using the design formula and set the proper values in DRB.
3. Set an input voltage of 1V in AFO and obtain the gain for different frequencies.
4. Plot a graph between the gain and frequency and check whether it satisfies the characteristic curve.
5. Repeat the above for HPF.

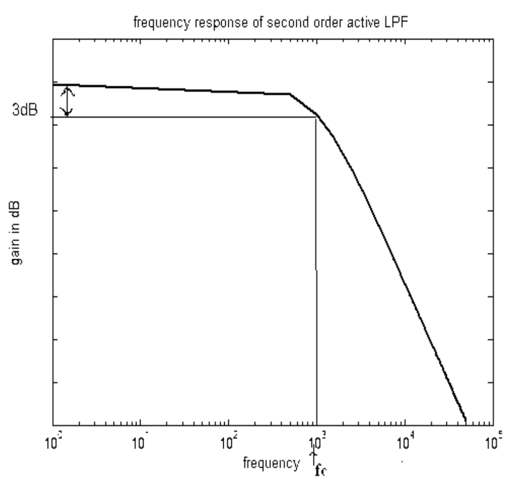
Table 1: Low Pass Filter: **V_{in} = Volts**

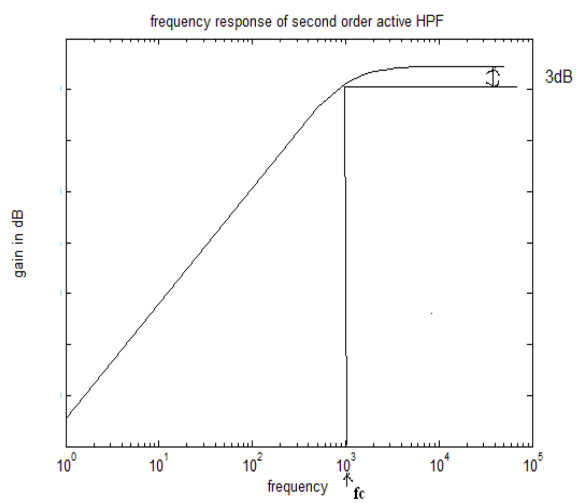
S.No	Frequency (Hz)	Output Voltage (Volts)	Gain = 20log(V_o / V_{in}) (dB)

Table 2: High Pass Filter: V_{in} = Volts

S.No	Frequency (Hz)	Output Voltage (Volts)	Gain = 20log(V_o / V_{in}) (dB)

Model Graph: Low Pass Filter High Pass Filter





Results:

Thus the second order Active low pass filter & high pass filter was designed and the cut-off frequency was calculated from thegraph.

Review Questions:

1. What are the different types of filters?
2. What is cut-off frequency?
3. Draw the first order passive filter.
4. What are the applications of filters?
5. When we will we go for band pass filter?

Exp. No:3(a)

DESIGN OF REGULATED POWER SUPPLY

Aim:

To design and construct a regulated power supply using regulated IC 7805.

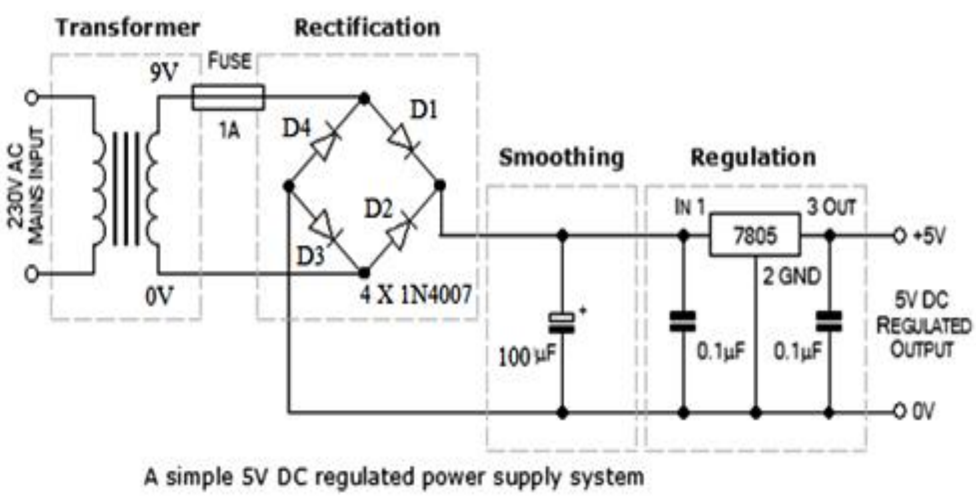
Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	Centre tapped Transformer	9V - 0 - 9V	1
2.	Diodes	1N4007	4
3.	Regulator IC	IC 7805	1
4.	Capacitors	0.1 µF, 100µF	2,1
5.	Digital Multimeter	---	1
6.	Bread Board & Connecting	---	Sufficient

Theory:

A regulated power supply gives a DC output voltage that remains substantially constant even when the AC supply voltage or DC load current changes. It consists of rectifier with filter and a voltage regulator. It transforms the input alternating current (AC) into a direct current (DC) or voltage. The output of rectifier has the fluctuating components of current or voltage called ripple. The filter following the rectifier stage smoothens out the ripples. The output from the filter can vary with the changes in the AC supply voltage or load resistance. The voltage regulator tends to eliminate this fluctuating. Full wave rectifier is also achieved with aid of a bridge circuit employing four diodes. During the positive half cycle of the supply, diodes D1 and D3 conduct in series while diodes D2 and D4 are reverse biased and the current flows through the load. During the negative half cycle of the supply, diodes D2 and D4 conduct in series, but diodes D1 and D3 switch "OFF" as they are now reverse biased. The current flowing through the load is the same direction as before.

Circuit Diagram:



Pin diagram

Fig: DC Regulated power supply

Procedure:

1. Connections are made as shown in the diagram.
2. The value of R_2 is calculated using the design equation for the given voltages.
3. Set the value in DRB and note the corresponding values at the output.

LINE REGULATION:

1. R_2 values are fixed at a constant value & connect the load resistance (DRB) across the output terminal.
2. Keep the load resistance R_l = 1K in DRB.
3. Vary the input voltage from 0 to 15 V and note the corresponding output voltage.
4. Draw the graph betweenV_{in} and V_o.

LOAD REGULATION:

1. Keep the input voltage as constant V_{in}=15V.
2. Connect the ammeter in series with R_l.
3. Vary the values of R_l(100Ω to 1K) and note the corresponding ammeter reading (I_L) & the output voltage (V_o).
4. Draw the graph between I_L and V_o.

Tabular Column:

Input voltage (AC Volts)	Transformer Output Voltage (AC Volts)	RPS Output Voltage (DC Volts)

Result:

Thus the line and load regulation was studied using IC7805.

Review Questions:

1. What are the types of power supplies?
2. What is the efficiency of SMPS?
3. What is the function of IC regulator?
4. How can you get negative supply voltage from RPS?
5. What is working voltage DC of the filter capacitor?

Exp. No:3(b)

DESIGN OF V/I and I/V CONVERTERS

Aim:

To design and construct a voltage to current and current to voltage converter.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	RPS	+/-15V , 5V	1 each
2.	Operational Amplifier	IC 741	2
3.	Resistors	560Ω,1KΩ	2,7
4.	Trim Pot	10KΩ	1
5.	Transistor	CL100	1
6.	Ammeter	0 – 30mA	1
7.	Bread Board & Connecting	-	Sufficient

VOLTAGE TO CURRENT CONVERTER

Voltage to current converter is also known as transconductance amplifier. The inverting input voltage (V_i= I R) is given. The input voltage is converted into an output current of V/R. The same current flows through the signal source and load.

Circuit Diagram:

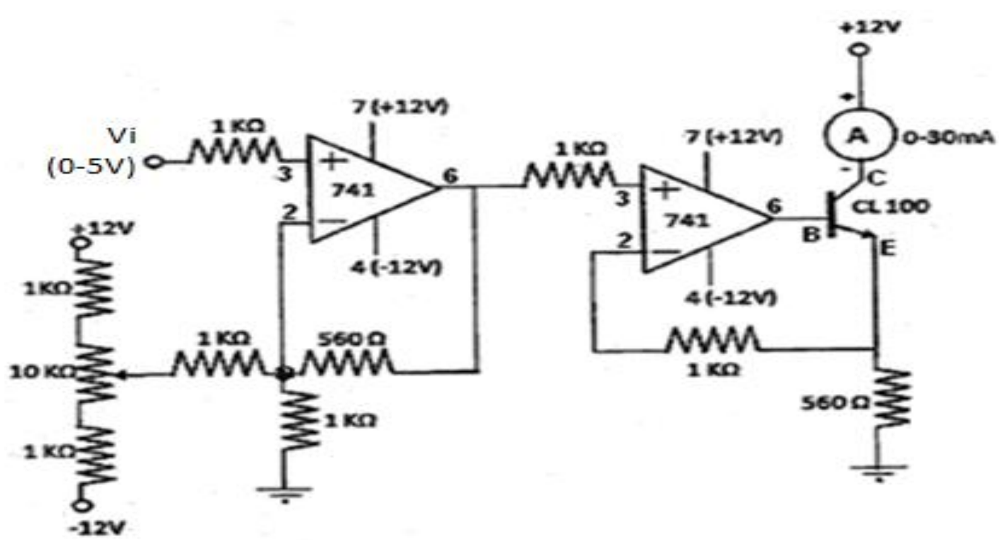


Fig: Voltage to Current Converter

Procedure:

1. Give the connections as per the circuit diagram.
2. The values of R and $E_{ref}$are calculated using the design formula and set the proper values in DRB and POT respectively.
3. Set the minimum value in power supply and note the corresponding ammeter reading.

Tabular Column:

S.No.	Input Voltage (Volts)	Output Current (mA)

CURRENT TO VOLTAGE CONVERTER

Theory:

In electronics, a transimpedance amplifier is an amplifier that converts current to voltage. Its input ideally has zero impedance, and the input signal is a current. Its output may have low impedance, may be matched to a driven transmission line; the output signal is measured as a voltage. Because the output is a voltage and the input is a current, the gain, or ratio of output to input, is expressed in units of ohms. Inverting amplifier configuration of an op-amp becomes a trans impedance amplifier when R_{in} is 0 ohms.

Circuit Diagram:

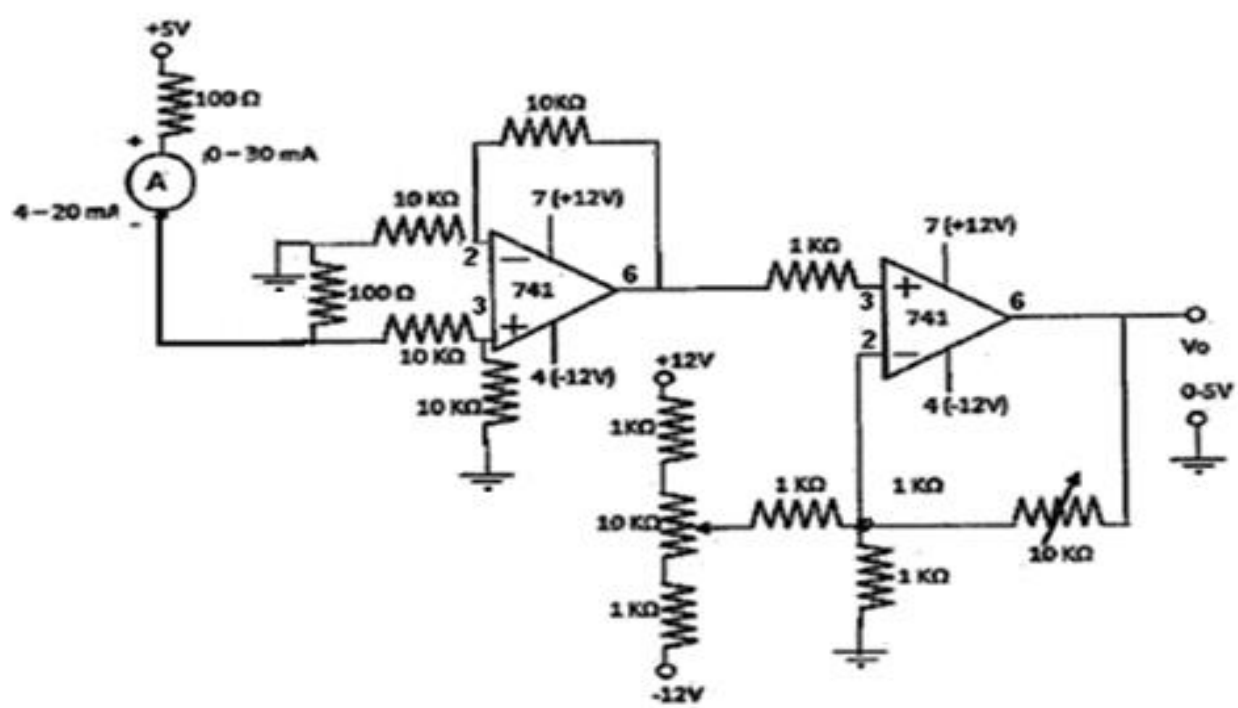


Fig: Current to Voltage Converter

Procedure:

1. Give the connections as per the circuit diagram.
2. Vary the input current (4-20 mA) in steps of 1.5 mA.
3. Observe the output voltage and tabulate.
4. Plot the graph between input current and output voltage.

Tabular Column:

S.No.	Input Current (mA)	Output Voltage (Volts)

Result:

Thus theI to V&V to I converter is designed and verified.

Review questions:

1. What is the other name of I/V &V/I converter?
2. What are the applications of I/V&V/I converters?
3. Draw the simplified circuit of I/V&V/I converter.
4. What is the function of 10k trim pot in I/V&V/I circuit?
5. How will you change the range of I/V&V/I converters?

Exp. No:4

DESIGN OF LINEARIZING CIRCUIT AND COLD JUNCTION COMPENSATION CIRCUIT FOR THERMOCOUPLE

Aim:

To design and construct a linearizing circuit and cold junction compensation circuit for thermocouple.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	RPS	+/-15V	1
1.	Operational Amplifier	IC 741	1
2.	Thermocouple	AD590	1
3.	Resistors	1KΩ	3
4.	Trim Pot	10KΩ	1
5.	Capacitors	1µF	2
6.	Thermometer & Heating element	-	1 each
7.	Bread Board & Connecting	-	Sufficient

Theory:

When temperature at ambient are to be measured with a thermocouple, it is inconvenient to use a fixed reference junction. Therefore the compensating circuit must be employed in the measuring system. An arrangement for automatic compensation is shown below. A temperature sensitive bridge is included in the thermocouple circuit, such that variations in ambient temperature are compensated by the changes in resistance.

Procedure:

1. Connections are made as per the circuit diagram.
2. Design a signal conditioning circuit for the given thermocouple to get the appropriate desired output.
3. Measure the room temperature with thermometer, thermocouple and note down the corresponding readings.
4. Increase the temperature by using soldering iron and measure the output voltage for different temperatures.

Circuit Diagram:

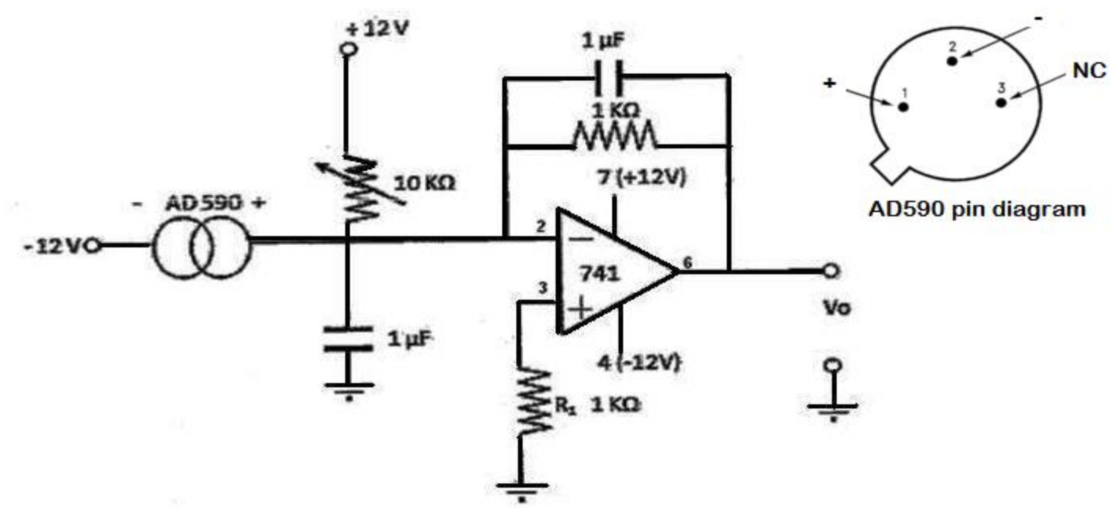


Fig: AD590 Based Cold Junction compensation circuit

Tabular Column:

S.No.	Temperature (°C)	Output Voltage (Volts)

Result:

Thus the cold junction compensation circuit was designed and implemented for the given specification. And also plot the graph of temperature Vs O/p voltage.

Review questions:

1. What is Peltier effect?
2. What are the different types of thermocouples?
3. What is Thomson effect?
4. What is the working principle of thermocouple?
5. What is the need of cold junction compensation?

Exp. No:5(a)

DESIGN OF SIGNAL CONDITIONING CIRCUIT FOR STRAIN GAUGE

Aim:

To design and construct a signal conditioning circuit for strain gauge.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	RPS	+/-15V, 5V	1 each
1.	Operational Amplifier	IC 741	2
2.	Strain Gauge (Resistor)	DRB	1
3.	Resistors	1KΩ, 10 KΩ, 47 KΩ	4,4,1
4.	Digital Multimeter	-	1
5.	Bread Board & Connecting	-	Sufficient

Theory:

Signal conditioning circuits normally employ amplifiers, temperature compensation devices etc.

Strain Gauge: Strain gauge is a bridge network which has four arms. Each arm has a resistor. The principle of strain gauge is given by the following formula:

$$\boldsymbol{R = \frac{\rho\, L}{A}}$$

Where R is the resistance, ρ is the specific resistance or resistivity in ohm-m. L is length in mm and A is area in m^2 .Thus the resistance change according to the stress applied along the horizontal or vertical columns. There are tensile forces acting along vertical and compressive forces along horizontal direction. Initially the bridge will be in a balanced position. Hence no output is obtained. Whenever there is a change in strain values the corresponding change in voltage is measured.

Procedure:

1. Connections are made as per the circuit diagram.
2. Design a signal conditioning circuit for the strain gauge to get the appropriate desired output.
3. Balance the bridge initially so that no output voltage occurs.
4. Gradually increase the strain gauge resistance.
5. Note down voltage value corresponding to the increase in strain.
6. Check the output voltage at each stage of amplification.
7. Observe the final output voltage and tabulate.

Circuit Diagram:

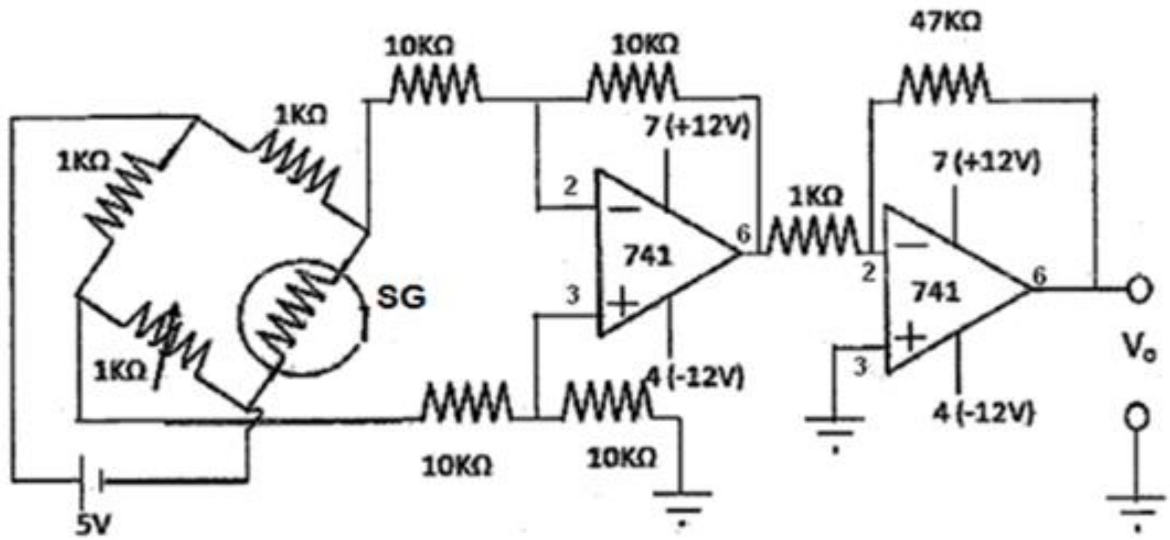


Fig: Signal Conditioning Circuit for Strain Gauge

Tabulation:

S.No.	Resistance (Ω)	Output Voltage (Volts)

Result:

Thus a signal conditioning circuit for strain gauge circuit using operational amplifier was designed and implemented..

Review Questions:

1. What is dummy strain gauge?
2. What is Rossete?
3. What is the need of signal conditioning circuit for strain gauges?
4. What is gauge factor?
5. What is the working principle of strain gauge?

Exp. No:5(b)

DESIGN OF SIGNAL CONDITIONING CIRCUITS FOR RTD

Aim:

To design and construct a signal conditioning circuit for resistance temperature detector .

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	RPS	+/-15V, 5V	1 each
1.	Operational Amplifier	IC 741	2
2.	RTD (Resistor)	DRB	1
3.	Resistors	1KΩ, 10 KΩ, 47 KΩ	4,4,1
4.	Digital Multimeter	-	1
5.	Thermometer & Water bath	-	1 each
6.	Bread Board & Connecting	-	Sufficient

Theory:

Cold junction compensation: Signal conditioning circuits normally employ amplifiers, temperature compensation devices etc.

Resistance Temperature Detector: RTD has a positive temperature coefficient. The principle of RTD is as there is a change in the temperature, the resistance changes, and this change in resistance is measured. As RTD has a positive temperature coefficient i.e as temperature increases, resistance increases, the resistance at any temperature t can be calculated using the formula.

$$\mathbf{R_T = R_0[\,1 + \alpha\,(t - t_0)]}$$

Where,

R_T is resistance at T^0c

R_0 is resistance at 0^0c , room temperature.

α - Temperature coefficient of the material 0.04.

Thus the value of resistance can be calculated.

Circuit Diagram:

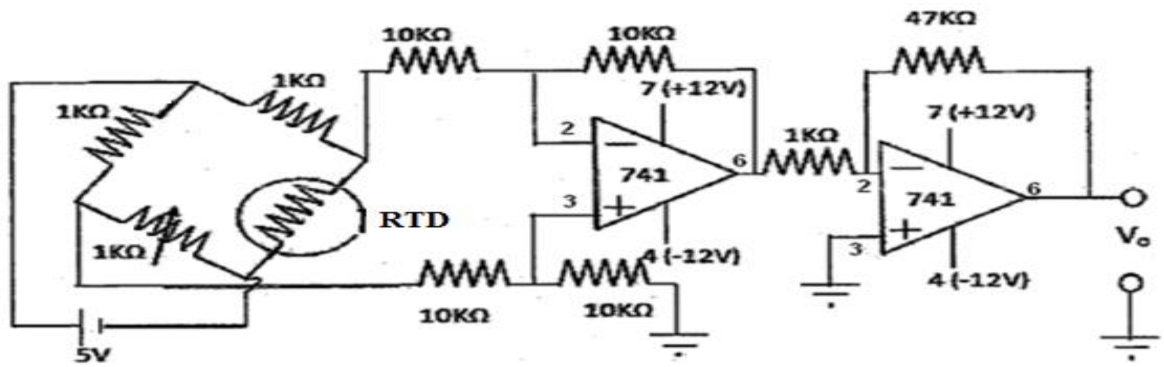


Fig: Signal Conditioning Circuit for Resistance Temperature Detector

Procedure:

1. Connections are made as per the circuit diagram.
2. Design a signal conditioning circuit for the RTD to get the appropriate desired output.
3. Balance the bridge initially so that no output voltage occurs.
4. Increase the temperature of the RTD by using water bath. Note down the change in resistance of RTD and output voltage.
5. Plot the graph between RTD resistance and output voltage.

Tabulation: Resistance of RTD at ambient conditions =

S.No.	Temperature (°C)	Resistance (Ω)	Output Voltage (Volts)

Result:

Thus a signal conditioning circuit for an RTD was designed as per the given specifications and implemented.

Review Questions:

1. What is 3 wire RTD?
2. What is 4 wire RTD?
3. What do you mean by resistance compensation in RTD?
4. What is the working principle of RTD?
5. What is positive temperature coefficient?

Exp. No:6(a)

DESIGN OF ORIFICE PLATE

Aim:

To determine the discharge coefficient (C_d) of Orifice plate for various flow rates.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	Orifice plate setup	Flat-plate, sharp-edge	1
2.	Mercury manometer	-	1
3.	Stopwatch	-	1

Theory:

An Orifice plate is a device which measures the rate of fluid flow. It uses the same principle as a nozzle, namely Bernoulli's principle which says that there is a relationship between the pressure of the fluid and the velocity of the fluid. When the velocity increases, the pressure decreases and vice versa.

An orifice plate is basically a thin plate with a hole in the middle. It is usually placed in a pipe in which fluid flows. As fluid flows through the pipe, it has a certain velocity and a certain pressure. When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole; the point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called vena contracta point. As it does so, the velocity and the pressure changes. Beyond the vena contracta, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena contracta, the volumetric and mass flow rates can be obtained from equation. It states that in a steady, ideal flow of an incompressible fluid, the total energy at any point of the fluid is constant. The total energy consists of pressure energy, kinetic energy and potential energy or datum energy. Mathematically Bernoulli's theorem is written as

$$\frac{p}{w} + \frac{v^2}{2g} + z = Constant$$

Coefficient of discharge (C_d): It is defined as the ratio of the actual discharge from an Orifice to the theoretical discharge from the Orifice. Mathematically

Coefficient of discharge $= \frac{Q_{Act}}{Q_{The}}$

Q_{Act} = Volume / time taken for collecting in to the tank. (m^3/ sec)

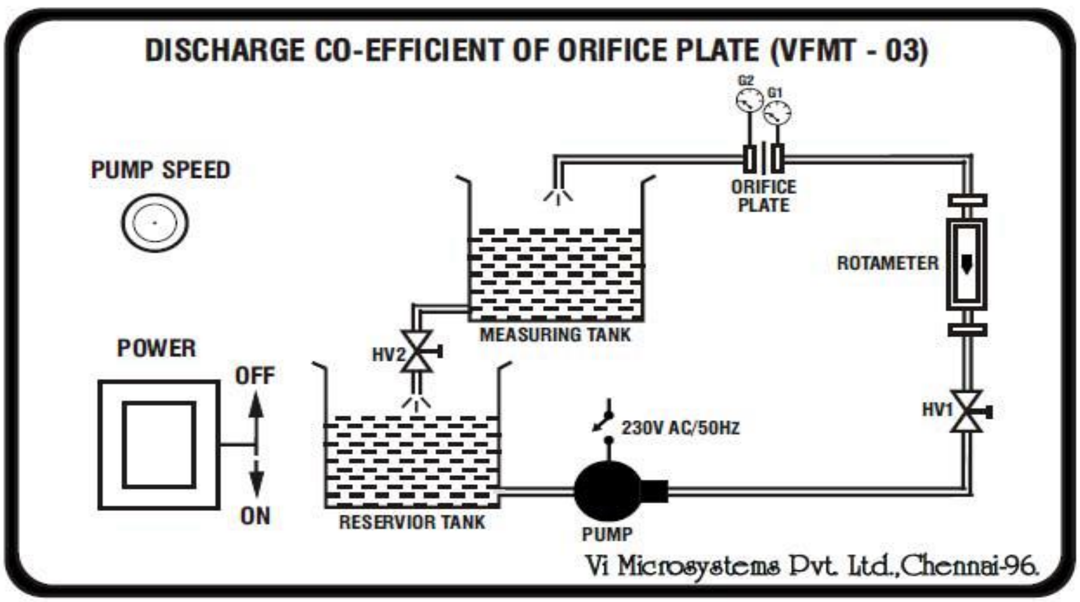
$$Q_{The} = \frac{a_1 * a_2\sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}} \cdot (m^3/sec)$$

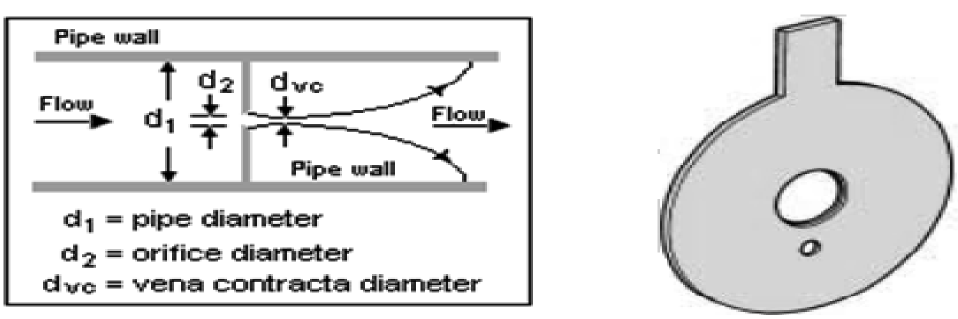
C_d = Coefficient of discharge,
a_1 = cross sectional area of inlet (π $d_1^2/4$) = x $10^{-6}m^2$,
a_2 = cross sectional area of outlet (π d $_2^2/4$) = x $10^{-6}m^2$,
d_1= diameter of inlet section in meter,
d_2= diameter of throat section in meter = 0.6 x d_1

$$h = \frac{h_1 - h_2}{100} * 12.6$$

$h_1 - h_2$= difference of mercury level in the manometer.
g = acceleration due to gravity = 9.81 m/sec^2

General Diagram:





Orifice Plate

Fig: Discharge coefficient (C_d) of Orifice plate

Precaution:

1. The arrangement of orifice plate is closed type.
2. Water is circulated through the Orifice meter from reservoir to collecting tank by means of a monoblock pump.
3. The collecting tank of the Orifice meter is connected to a mercury manometer.

Procedure:

1. The pump is primed and started.
2. Keeping the gate valve fully open the experiment is started.
3. Pressure gauge reading is set by adjusting the gate valve and the time taken for 100 cm of water (Rotameter reading) are noted.
4. The gate valve is gradually closed; for each valve setting the readings are noted and the values are tabulated.

Tabular column:

S.No.	Pressure Gauge reading (mm.wc)	Rotameter reading (LPH)	Q_{Act} (m^3/sec) X 10^{-5}	Q_{The} (m^3/sec) X 10^{-5}	Discharge coefficient C_d

Model Calculation:

Result:

Thus the orifice platedesigned for the given specificationfor determines the discharge coefficient (C_d) of Orifice plate for various flow rates.

Review Questions:

1. What are the different types of orifice plates?
2. What is vena contracta?
3. What are the advantages and disadvantages of orifice plates?
4. Name some other flow sensors.
5. For slurry type fluids which type of orifice plate is suitable?

Exp. No:6(b)

DESIGN OF ROTAMETER

Aim:

To design the rotameter for measuring the flow rate.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	Pump and reservoir	-	1
2.	Pipeline with rotameter	-	1
3.	Collecting tank	-	1
4.	Stopwatch	-	1

Theory:

The rotameter operation is based on the variable area principle: fluid flow raises a float in a tapered tube, increasing the area for passage of the fluid. The greater the flow, the higher the float is raised. The height of the float is directly proportional to the flow rate. With liquids, the float is raised by a combination of the buoyancy of the liquid and the velocity head of the fluid. With gases, buoyancy is negligible, and the float responds to the velocity head alone.The float moves up or down in the tube in proportion to the fluid flow rate and the annular area between the float and the tube wall. The float reaches a stable position in the tube when the upward force exerted by the flowing fluid equals the downward gravitational force exerted by the weight of the float. A change in flow rate upsets this balance of forces. The float then moves up or down, changing the annular area until it again reaches a position where the forces are in equilibrium. To satisfy the force equation, the rotameter float assumes a distinct position for every constant flow rate. However, it is important to note that because the float position is gravity dependent, rotameters must be vertically oriented and mounted. Rotameter consists of the vertical tube with tapered tube in which float assumes vertical position corresponding to each flow rate through the tube for the given flow rate. Float remains stationary since the vertical forces of differential pressure, gravity, viscosity and buoyancy are balanced. Downward force is constant, since the pressure drop across the float is constant.

Process Setup:

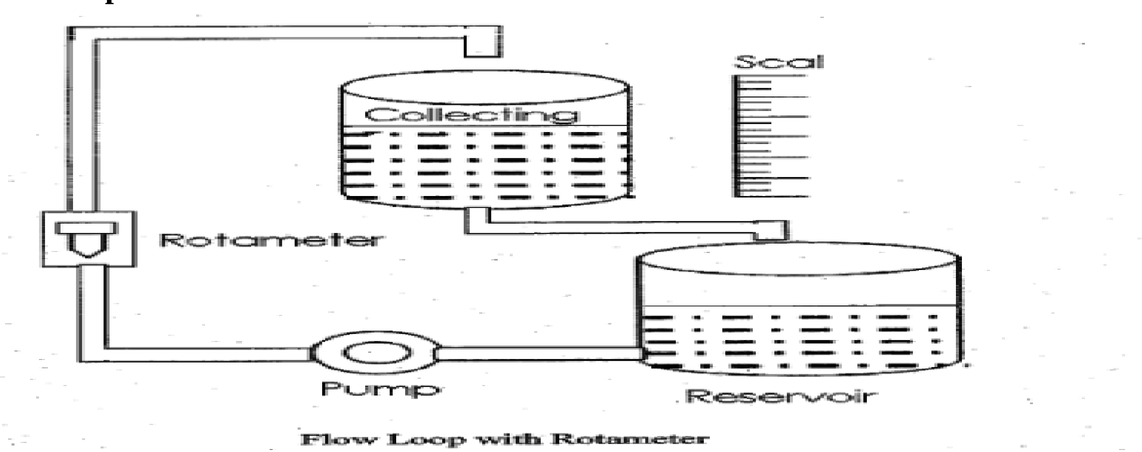


Fig: Flow loop with Rotameter

Procedure:

1. Switch ON the motor.
2. Adjust the rotameter to read the required flow rate.
3. Start the timer.
4. After 5 minutes, note down the head in the tank.
5. Drain the tank.
6. Repeat the procedure & calculate C_d in each case.

Tabular Column:

S. No.	Flow (LPH)	Time (sec)	Head 'h' of water (mm)	Q_{Act} (m^3/sec)	Q_{The} (m^3/sec)	Discharge coefficient C_d	% Error

Formulae used:

$Q_{Act} = A^2\ h / t\ (m^3/sec)$

Q_{The} = flow rate (lph) x 10^{-3} / 3600 (m^3/sec)

$C_d = Q_{Act} / Q_{The}$

% Error = $(Q_{The} – Q_{Act}) / Q_{The}$

Model Calculation:

Result:

Thus the Rotameter designed for the given specification for measuring flow rate.

Review Questions:

1. Why rotameter is called so?
2. What is discharge coefficient?
3. What is the shape of glass tube in Rotameter?
4. What is the need for mechanical casing in rotameter?
5. What is the other name of rotameter?

Exp. No:7

DESSIGN OF CONTROL VALVE

Aim:

To study the actuator characteristics and control valve characteristics of on – off and equal percentage control valve.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	Control valve trainer setup	-	1
2.	Air Compressor	(0 – 100)psi	1

Theory:

In most of the industrial process control systems control valve is the final control element.. The control valve consists of two major components, viz. Actuator and Valve. The actuator is made up of flexible diaphragm; spring and spring tension adjustments, plate, stem and lock nut, housing. The valve is made up of body, plug, stem, and pressure tight connection.

The function of a control value is to vary the flow of fluid through the value by means of a change of pressure to the valve top. The relation between the flow through the valve and the valve stem position (or lift) is called the valve characteristic. There are three main types of valve characteristics. The types of valve characteristics can be defined in terms of the sensitivity of the valve, which is simply the fraction change in flow to the fractional change in stem position for fixed upstream and downstream pressures. Mathematically

Sensitivity = dm / dx

In terms of valve characteristics, valve can be classified into three types:

1. Linear, 2. Increasing sensitivity, 3.Decreasing sensitivity.

For the **linear type valve** characteristics, the sensitivity is constant and the characteristic curve is a straight line (e.g. linear valve). For increasing sensitivity type, the sensitivity increases with flow. (e.g.Equal percentage or Logarithmic valve). In practice, the ideal characteristics for linear and equal percentage valves are only approximated by commercially available valves. These discrepancies cause no difficulty because the inherent characteristics are changed considerably when the valve is installed in a line having resistance to flow, a situation that usually prevails in practice.

Equal percentage control valve:

Flow changes by a constant percentage of its instantaneous value for each unit of valve lift.

Quick opening control valve:

Flow increases rapidly with initial travel reaching near its maximum at a low lift.

Characteristic of control valve:

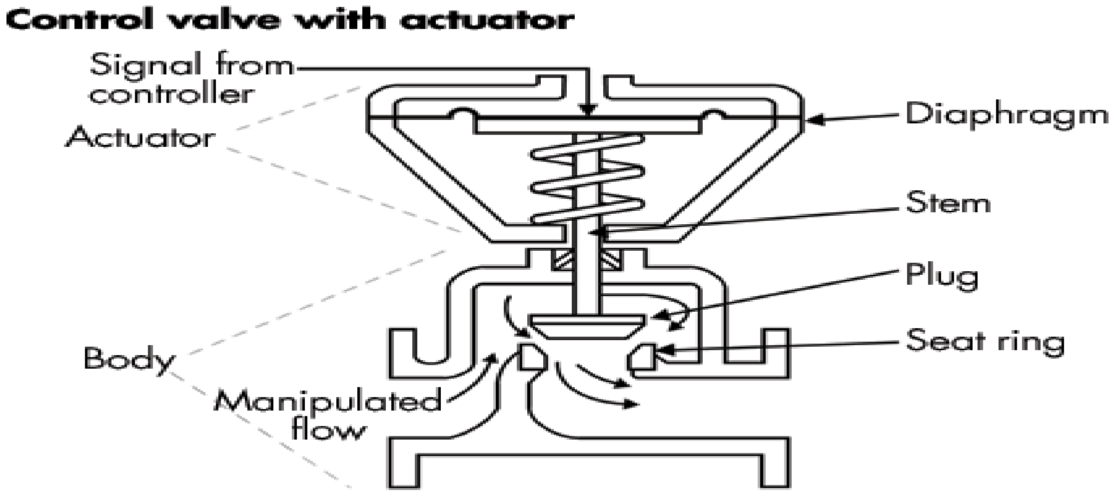


Fig: Control valve with Actuator

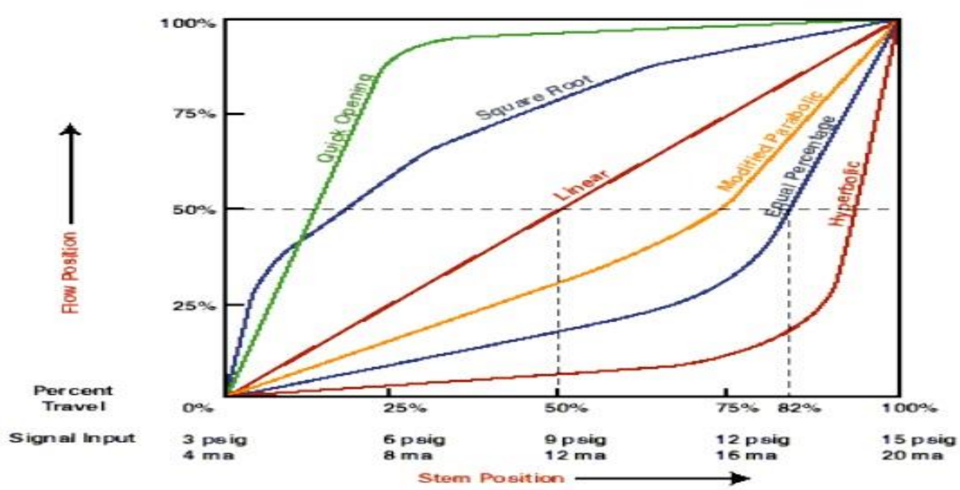


Fig : Control valve characteristics

Precautions:

1. Check the inlet pressure to the air regulator.
2. Don't operate the motor, pump without load
3. Release the air pressure before conducting the experiment.

Procedure:

1. Open the appropriate hand valve for ON/OFF control valve and close all other hand valves.
2. Vary the pressure using the knob provided in the air regulator.
3. Note down the pressure in gauge and corresponding stem movement and flow rate.
4. Reduce the output pressure to zero using the air regulator knob.

5. Release the air in the control valve using the hand valve.
6. Select another control valve and repeat the same procedure.
7. Draw the graph between input pressures to the control valve and stem movement.
8. Draw the graph between input pressures to the control valve and flow rate.
9. Find out the sensitivity of the control valve.

Table 1: ON-OFF control valve (quick opening valve)

S. No.	Input pressure (psi)	Stem movement (mm)	Flow Rate (LPH)	C_V=Q

Formula used:

C_V=Q Where, Q-Flow rate in LPH; P-Input pressure in psi;
G- Specific gravity of water.

Table 2: Equal percentage control valve

S. No.	Input pressure (psi)	Stem movement (mm)	Flow Rate (LPH)	C_V=Q

Model Calculation:

Result:

Thus the actuator characteristicsofthe control valves are designed.

Review Questions:

1. What is under sizing of control valve?
2. What is over sizing of control valve?
3. What is the need for monographs in control valve?
4. What is cavitation?
5. What is flashing?

Exp. No:8(a)

DESIGN OF PID CONTROLLER USING OPERATIONAL AMPLIFIER

Aim:

To design and construct a PID controller using operational amplifier.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	RPS	+/-15V , 5V	1 each
2.	Function Generator	1MHz	1
3.	CRO	30 MHz	1
4.	Operational Amplifier	IC 741	3
5.	Resistors	470Ω,1KΩ,10KΩ	1,4,7
6.	Capacitors	0.1µF	2
7.	Bread Board & Connecting	-	Sufficient

Theory:

Two position control results in a continuously oscillating response. These oscillations will affect the performance of final control element. This can be avoided by replacing two position controller by continuous mode controllers such as proportional, Proportional + Integral and Proportional + derivative. The proportional controller produces an output signal that is proportional to error e. this may be expressed as

$$\mathbf{P = K_c\, e + P_s}$$

Where P = Output signal from controller,
K_c = Gain or sensitivity, e = Error = Set point – measured value, P_s = Constant.

Proportional band (P_b) is defined as the error response based as a percentage of the range of measured variable to move the valve from fully open to fully close. The relation between proportional band in % and $K_c = 100/ [Pb (\%)]$

Proportional Integral control mode is described by the relation

$\boldsymbol{P = K_c\, e + \int \frac{K_c}{\tau_I}\, e\, dt + P_s}$ Where τ_I = Integral time.

The Proportional Integral Derivative control mode is given by the expression

$\boldsymbol{P = K_c\, e + K_c \tau_D \frac{de}{dt} \int \frac{K_c}{\tau_I}\, e\, dt + P_s}$ Where τ_D = Derivative time.

Procedure:

1. Connections are made as per the circuit diagram.
2. Give a square wave input of 4V peak to peak at 1KHz using function generator.
3. The output is observed in a digital storage oscilloscope (DSO).
4. Draw the graph between Magnitude and Frequency of the output voltage.

Formula used:

$$V_{out} = \frac{R_2}{R_1}V_e + \frac{R_2}{R_1}\frac{1}{R_I C_I}\int V\, edt + \frac{R_2}{R_1}R_D C_D \frac{dV_e\, dt}{dt} + V_{out(0)}$$

$$G_p = \frac{R_2}{R_1}\ ;\ G_D = R_D C_D\ ;\ G_I = \frac{1}{R_I C_I}$$

Circuit Diagram:

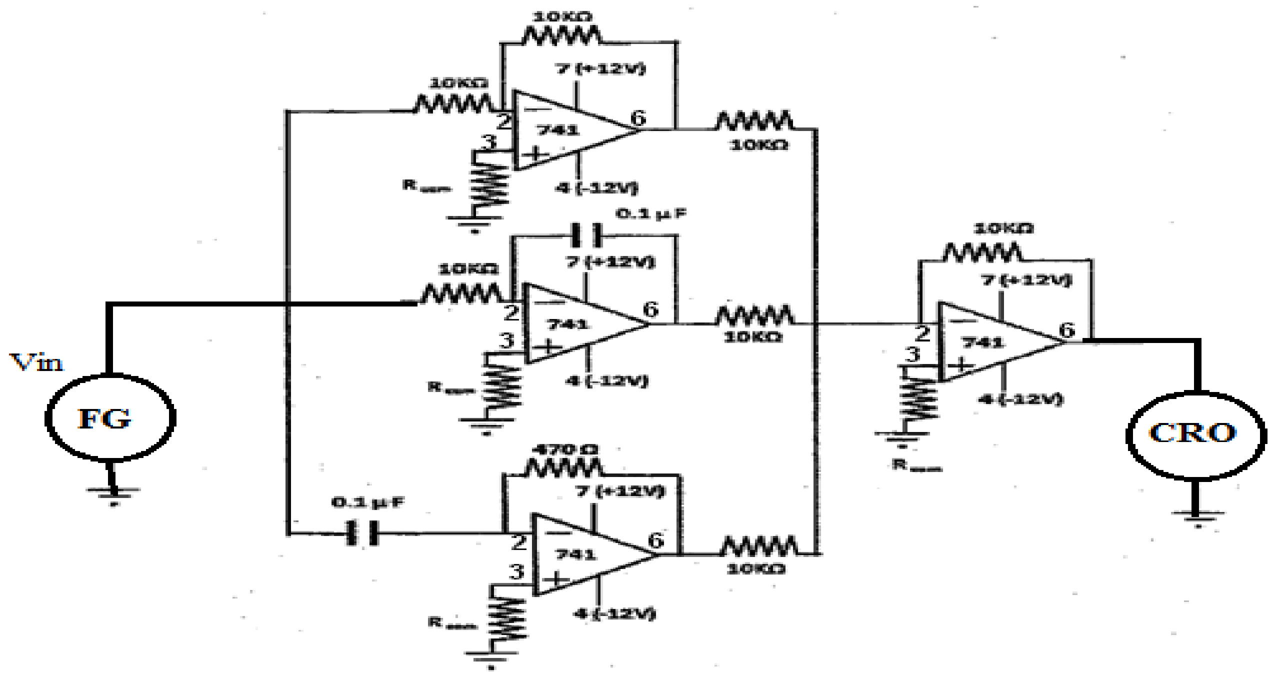


Fig: PID CONTROLLER USING OPERATIONAL AMPLIFIER

Tabulation:

Controller	PB or K_c	τ_i	τ_d	Amplitude (V)	Time period (Sec)	Frequency (Hz)
P						
I						
D						
P I D						

Result:

Thus the response of PID controller using operational amplifieris studied.

Review Questions:

1. What are the two different forms of discrete PID controllers?
2. Compare PI, PD, PID controllers.
3. Why D mode cannot be used alone?
4. What is tuning of controllers?
5. What is proportional band?

Exp. No:8(b)

DESIGN OF PID CONTROLLER USING MICROPROCESSOR

Aim:

To study the action of proportional + integral + derivative (PID) controller.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	PID Controller Trainer kit	-	1
2.	Digital Storage Oscilloscope	100MHz	1

Theory:

Two-position control applied to a process results in a continuous oscillation in the variable to be controlled. This drawback was overcome by a continuous control action which could maintain a continuous balance of the i/p and o/p. A mode of control which could accomplish this is known as proportional, proportional + integral, proportional + integral + derivative control.

The proportional controller produces an output signal that is proportional to the error e. This action may be expressed as

$$\mathbf{P = K_c\, e + P_s}$$

Where,

P = output signal from controller
K_c = gain or sensitivity
e = error = set point – measured valve
P_s= a constant

The term proportional band is commonly used among process control in place of the term gain. Proportional band (PB) is defined as the error (expressed as a percentage of the range of measured variable) required to move the valve from fully open to fully closed. The relation between proportional band (PB) in percentage and K_c is $K_c = 100 / [\ PB\ (\ \%\ )]$.

The proportional – Integral control mode is described by the relation

$\boldsymbol{P = K_c\, e + \int \frac{K_c}{\tau_I}\, e\, dt + P_s}$ where, τ_I = integral time

The proportional – Integral - Derivative control mode is given by the expression

$\boldsymbol{P = K_c\, e + K_c \tau_D \frac{de}{dt} \int \frac{K_c}{\tau_I}\, e\, dt + P_s}$ where τ_D = Derivative time.

Circuit Diagram:

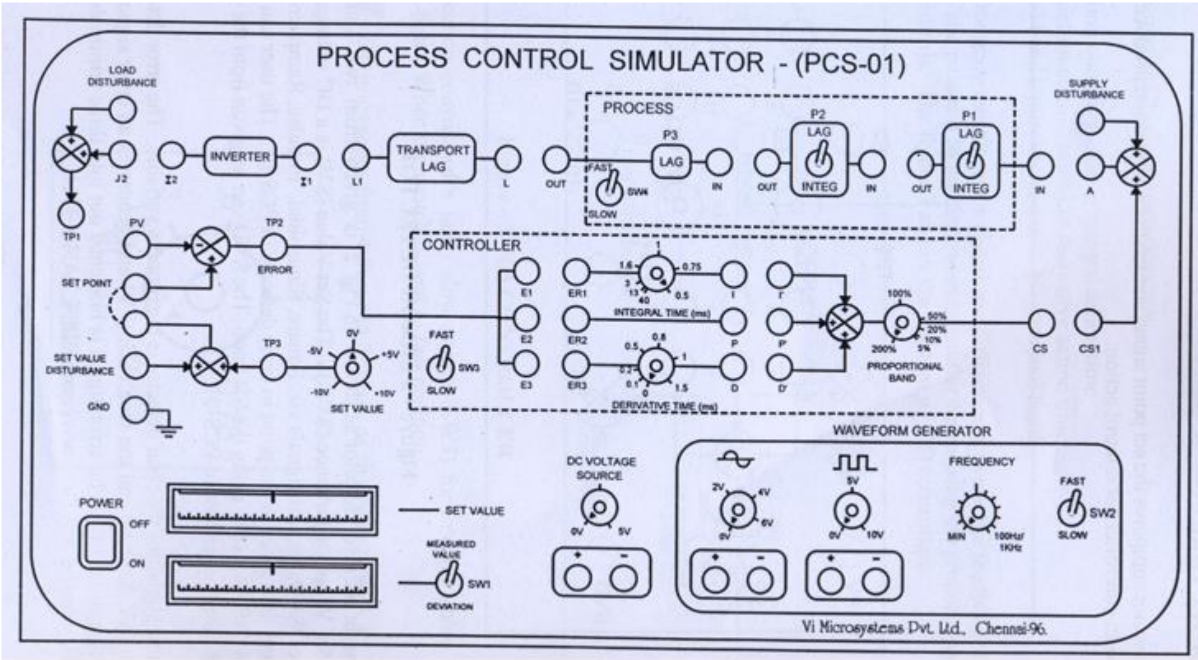


Fig:PID Trainer kit

Procedure:

P Controller

1. Connections are made as per the connection diagram given.
2. Set the process fast/slow switch (SW4) in fast position.
3. Keep the set value pot at zero.
4. Apply a square wave signal of 10 V_{pp} at around 50 Hz.
5. Observe the output from the oscilloscope.
6. Repeat all the above steps for 50% and 40% PB.

PI Controller

1. Connections are made as per the connection diagram given.
2. Set the process fast/slow switch (SW4) in fast position.
3. Keep the set value pot at zero.
4. Apply a square wave signal of 10 V_{pp} at around 50 Hz.
5. Adjust the proportional band control until the system settles within 2 to 3 overshoots.
6. Connect the integral section.
7. Slowly reduce the integral time until the deviation falls zero.
8. Observe and plot the response.

PID Controller

1. Connections are made as per the connection diagram given.
2. Set the process fast/slow switch (SW4) and controller fast/slow switch (SW3) in fast position.
3. Apply a square wave signal of to $2V_{pp}$ at around 50 Hz.
4. Now patch I and I’ and adjust the integral time until the steady state deviation is zero.
5. Note down the number of overshoots before the system settles.
6. Then connect D and D’ and slowly increase the derivative time and note down its effect.
7. Observe and plot the response.

Tabular column: PID Controller

Controller	Amplitude	Time period	Frequency
P controller			
PI controller			
PD controller			
PID controller			

Result:

Thus the response of PID controller using microprocessorstudied.

Review Questions:

1. What are the two different forms of discrete PID controllers?
2. Compare PI, PD, PID controllers.
3. Why D mode cannot be used alone?
4. What is tuning of controllers?
5. What is proportional band?

Exp. No:9 DESIGN OF MULTIRANGE DP TRANSMITTER

Aim:

To design a multirange Differential Pressure Transmitter.

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	Collecting tank	-	1
2.	DPT setup	-	1
3.	Pump and reservoir	-	1

Theory:

The differential pressure detector method of liquid level measurement uses a differential pressure detector connected to the bottom the tank being monitored. The high pressure, caused by the fluid in the tank, is compared to a lower reference pressure (usually atmosphere).The tank is open to the atmosphere; therefore, it is necessary to use only the high pressure connector on the differential pressure transmitter. With the lower pressure side being open to the atmosphere the differential pressure is the hydrostatic head of the liquid in the tank Most of the tanks are totally enclosed to prevent vapor or steam from escaping, or to allow pressurizing the contents of the tank. In this case both the high pressure and the low pressure sides of the differential pressure transmitter must be connected.

Circuit Diagram:

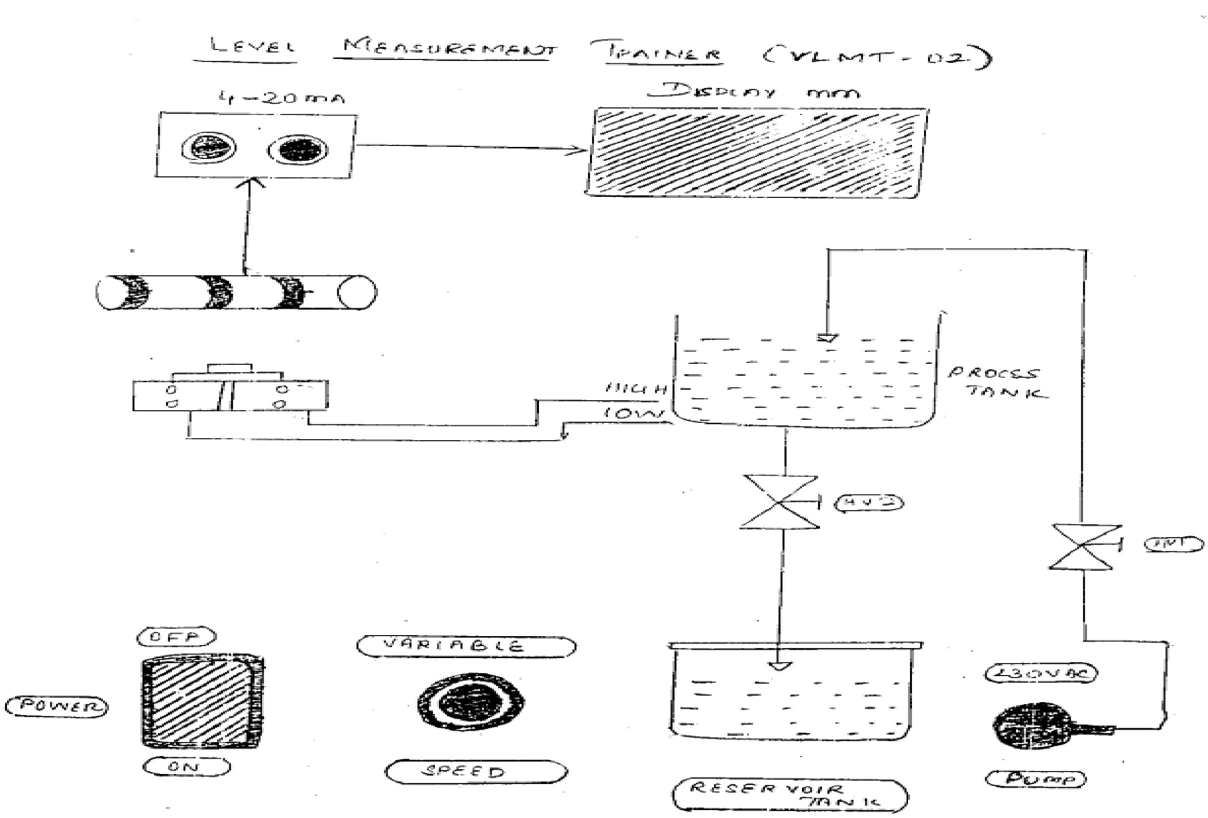


Fig:DPT Trainer Kit Setup

PROCEDURE:

1. Weight the empty container and calibrate the zero level to 4mA.
2. Fill the container with the water and calibrate the full level to 20mA.
3. Now perform the experiment in ascending order insteps of 5cms.
4. Repeat the same procedure for the descending order and tabulate the reading.
5. A graph is plotted between the liquid level and its corresponding current output.

TABULATION:

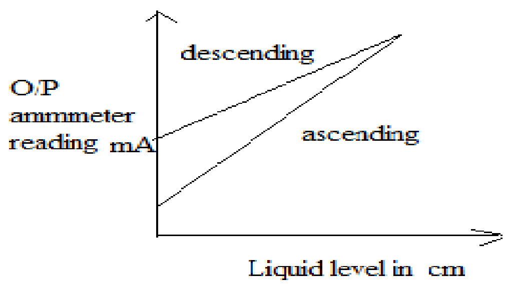
Table: 1 Ascending Liquid Level

S.No	Liquid level (cm)	DPT output(mA)

Table: 2 Descending Liquid Level

S.No	Liquid level (cm)	DPT output(mA)

Model Graph:



Result:

Thus the response of a multirange Differential Pressure Transmitterstudied.

Review Questions:

1. What is the principle of DPT?
2. How does DPT measures the liquid level?
3. What is the use of current loop?
4. Why (4-20)mA current loop is mostly preferred?
5. Define differential pressure
6. Name few sensors used for differential pressure measurement.
7. Define (4-20)mA current loop.

Exp. No:10

PIPING AND INSTRUMENTATION DIAGRAM

Aim:

To draw the P & I Diagram for the flow, level, pressure and Temperature process.

Theory:

An important means for engineering communication in the process industry is the so called Process & Instrumentation (P&I) diagram. Figure 1.5 shows the P&I diagram of a typical industrial heat exchanger. Heat exchanger is a process unit in which steam is used to heat up a liquid material. The material (called feedstock) is pumped at a specific flow rate into the pipes passing through the heat exchanger chamber where heat is transferred from steam to the material in the pipe. It is usually desired to regulate the temperature of the outlet flow irrespective of the change in the demand (flow rate) of the feedstock or change in the inlet temperature of the feedstock. The regulation of the outlet temperature is achieved by automatic control of the steam flow rate to the heat exchanger. The P&I diagram utilizes certain standard symbols to represent the process units, the instrumentation, and the process flow.

A Process & Instrumentation diagram consists of:

1- A pictorial representation of the major pieces of equipment required with major lines of flow to and from each piece.

2- All other equipment items with design temperatures, pressures, flow, etc..

3- All interconnecting piping with size, material and fabrication specifications indicated.

4- All major instrument devices.

P&I Diagram of a Heat Exchanger

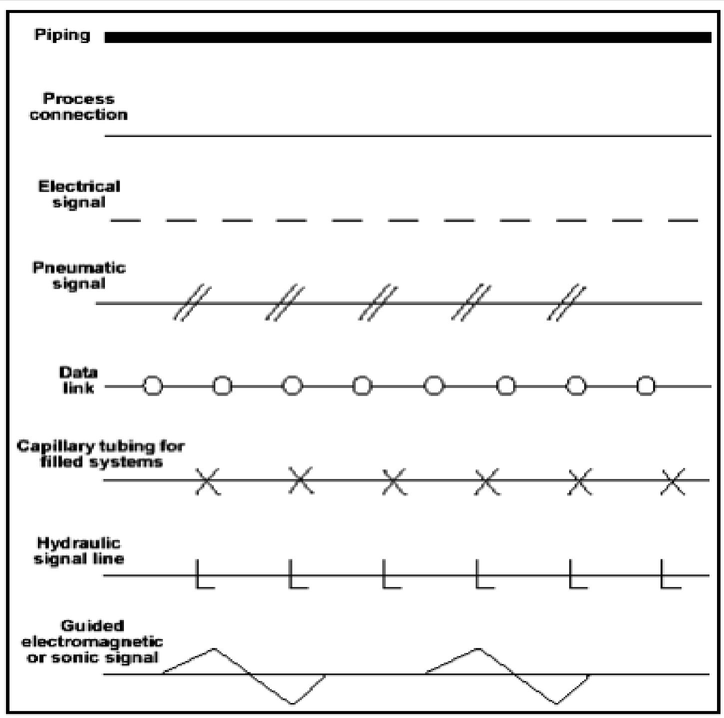
A partial list of the symbols and abbreviations are given in the table. A comprehensive coverage may be found in the ISA standard. Instruments are shown on the P&I diagram by circles, usually called “balloons”. The balloons contain alphanumeric which reflect the function of the instrument and its tag number. For example, TT102 means Temperature Transmitter number 2 in the process unit (or area) number 1. The number 102 is called tag number. Each Temperature Transmitter (TT) must have a unique tag number in the plant. Tag numbering may be different from one user to the other. P&I diagrams provide a valuable reference for proper project installation. The instrument engineer uses it as a source formany documents which must be prepared.

Another type of diagrams is known as ***Process flow Sheet.*** Process flow sheets consist also of a pictorial representation of the major pieces of equipment required with major lines of flow to and from each piece. However, additional information often given includes operating conditions at various stages of the process (flows, pressures, temperatures, viscosity, etc.), material balance, equipment size and configuration and, in some cases, utility requirements. On the other hand, instrumentation on process flow sheets may or may not be essentially complete.

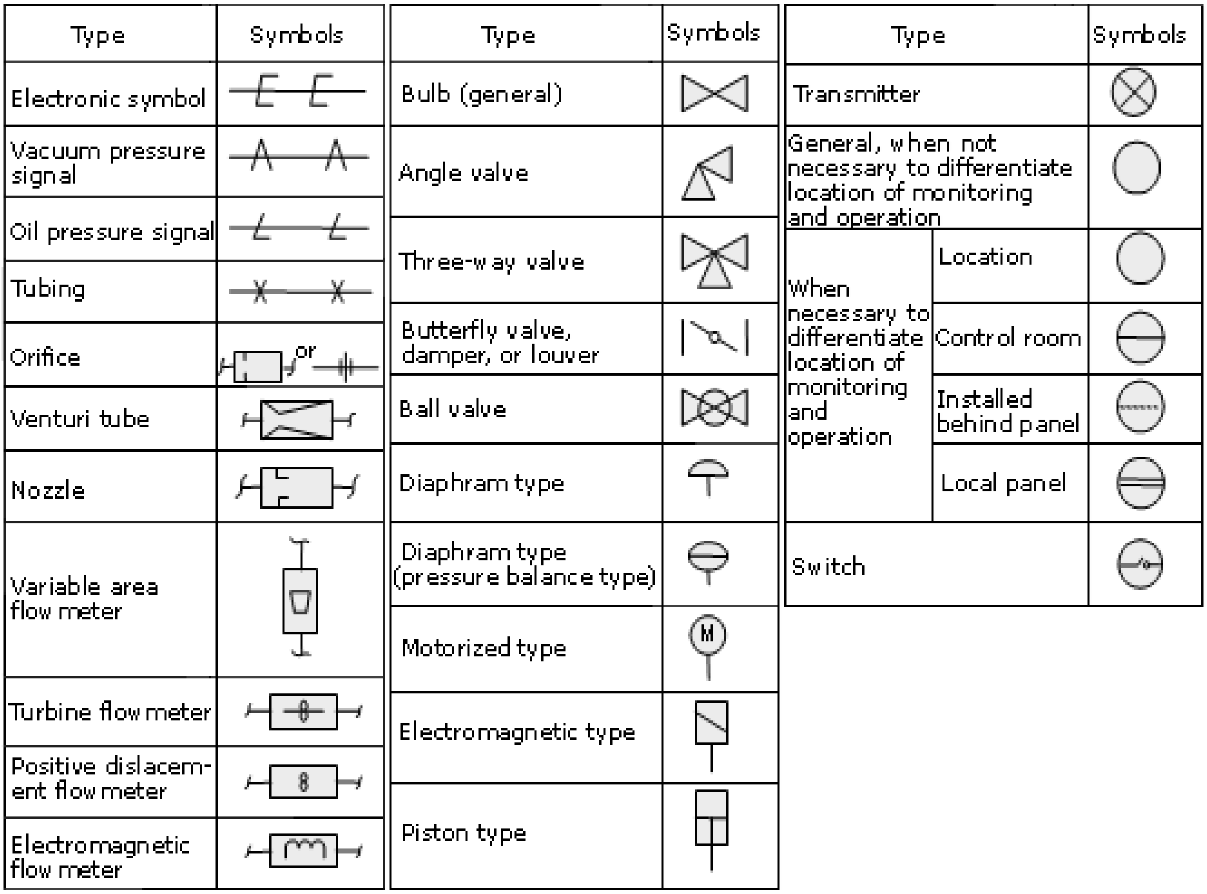
A third type of diagrams is called ***Loop Wiring Diagrams.*** Electrical loop wiring diagrams are electrical schematic drawings which are prepared for individual (or typical) electrical loops. The simplest loop is one that contains only a transmitter and a receiver.

Other loops may contain many items such as; transmitters. Recorders, controllers, alarm units, control valves, transducers, integrators, and perhaps other items. Loop wiring Diagrams are intended to show the location of the instruments, their identification numbers and termination of interconnecting wiring. Cable routing, wire size intermediate terminal points and other pertinent information are necessarily shown in other drawings. However, knowledge of these diagrams is not required to understand the material of this book. Understanding the basic P&I examples shown in this book can easily be achieved following the heat exchanger example. A to verify and understand the following instruments list of the heat exchanger P&I diagram.

P&I diagram:



Piping and Connection Symbols



Type	Symbols
Electronic symbol	
Vacuum pressure signal	
Oil pressure signal	
Tubing	
Orifice	or
Venturi tube	
Nozzle	
Variable area flow meter	
Turbine flow meter	
Positive dislacem-ent flow meter	
Electromagnetic flow meter	

Type	Symbols
Bulb (general)	
Angle valve	
Three-way valve	
Butterfly valve, damper, or louver	
Ball valve	
Diaphram type	
Diaphram type (pressure balance type)	
Motorized type	M
Electromagnetic type	
Piston type	

Type		Symbols
Transmitter		
General, when not necessary to differentiate location of monitoring and operation		
When necessary to differentiate location of monitoring and operation	Location	
	Control room	
	Installed behind panel	
	Local panel	
Switch		

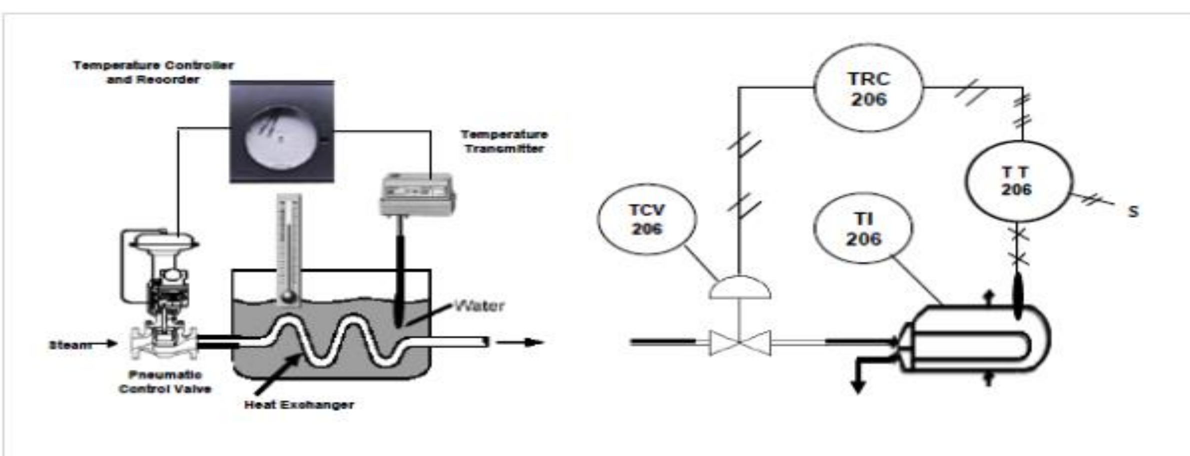


Fig: P & I Diagram Example

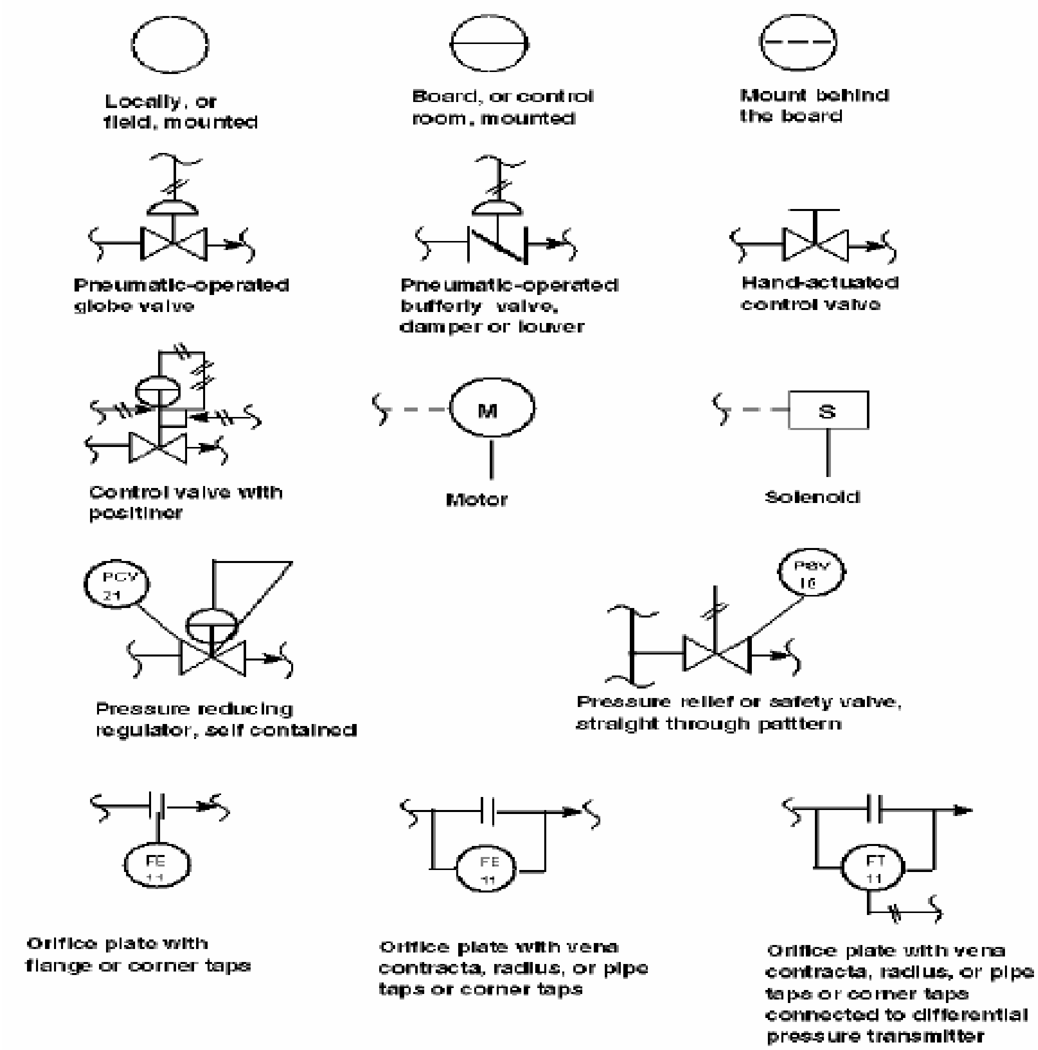


Fig: P & I Diagram Example

HEAT EXCHANGER

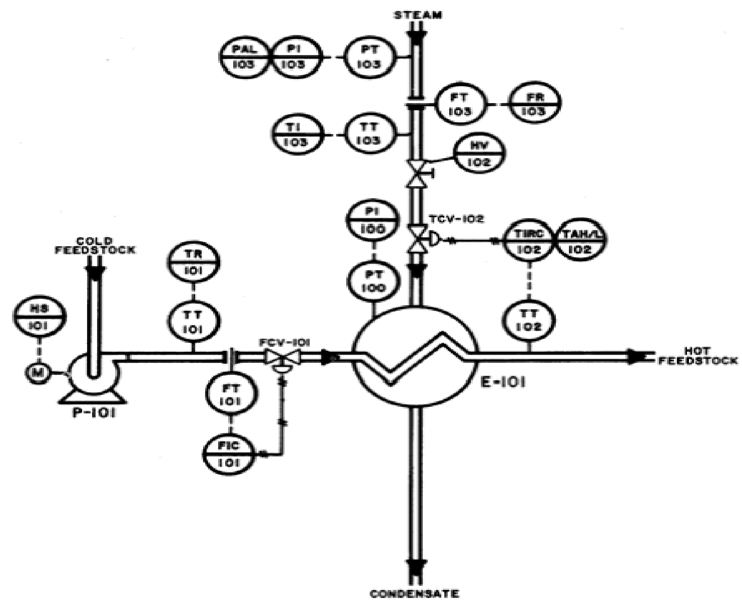


Fig: P & I Diagram Example

Instrument Description:

FIC-101 Flow Indicator and Controller.0 to 50 m^3/Hr, (normal reading 30 T/Hr).
This instrument controls the flow of cold feedstock entering the tube side of the heat exchanger by positioning a valve on the cold feedstock flow path.
FR-103 Flow Recorder, 0 to 10 Ton/Hr, (2.14 T/Hr).
This instrument records the steam flow rate.
HS-101 Hand Switch, ON/OFF (ON).

This switch turns on/off cold feedstock pump P-101. When the switch is in the ON condition, the pump is running. When the switch is in the OFF condition, the pump is not running.

HV-102 Hand Valve, OPEN/CLOSED, (OPEN).

This switch opens/closes the steam block valve through which steam is routed from the header to the shell side of the heat exchanger.
When the switch is in the OPEN condition the block valve is open. When the switch is in the CLOSED condition, the block valve is closed.
PAL-103 Pressure Alarm Low, (Normal).
This alarm fires should the steam header pressure be less than 6 kg/cm.sqr.
PI-100 Pressure Indicator, 0 to 15 kg/cm.sqr , (3.18 Kg/cm2).
This instrument displays the steam pressure at the shell side of the heat exchanger.
PI-103 Pressure Indicator, 0 to 15 kg/cm.sqr, (10.55 Kg/cm2).

This instrument displays the steam header pressure. TAH/L-102 Temperature Alarm High/Low, (Normal). This alarm fires should the temperature of the feedstock at the exchanger outlet exceed 85 °C or be less than 71°C. TI-103 Temperature Indicator, 0 to 200°C, (186 °C). This instrument displays the temperature of the steam entering the shell side of the heat exchanger.TIRC-102 Temperature Indicator, Recorder, and Controller, 0 to 200°C, (80 °C).This instrument controls the temperature of the feedstock at the exchanger outlet by positioning the valve that regulates the steam flow to the exchanger. TR-101 Temperature Recorder, 0 to 200°C, (38 °C). This instrument displays the temperature of the feedstock entering the exchanger.

Measured or initiating variable	**Symbols**
Process signal lines	
Instrument air supply	
Instrument electric power supply	
Un defined signal	
Pneumatic signal	
Electric signal	
Hydraulic signal	
Filled thermal element capillary tube	
Guided EM signal	
Fiber optic cable guided same signal	
Unguided EM signal	
Unguided sonic signal	
Alternative radio communication link	
System with software link	
Field is locally mounted	
Signal connector	
Central or mail control room	
Central or main control room and not Normally accessible to an operator	
Secondary or local control room.	

Result:

Thus the design of P& I Diagram for the flow, level, pressure and Temperature process studied.

Exp. No:11

PROGRAMMABLE LOGIC CONTROLLER – CASE STUDY

Aim:

To Study about Programmable Logic Controller basic theory , programming , communication, I/O modules, selection and application.

THEORY

What does 'PLC' mean?

A PLC (Programmable Logic Controllers) is an industrial computer used to monitor inputs, and depending upon their state make decisions based on its program or logic, to control (turn on/off) its outputs to automate a machine or a process.

NEMA defines a PROGRAMMABLE LOGIC CONTROLLER as:

"A digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions such as logic sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machines or processes".

Traditional PLC Applications

*****In automated system, PLC controller is usually the central part of a process control system.
*To run more complex processes it is possible to connect more PLC controllers to a central computer.

Disadvantages of PLC control

- ❖ Too much work required in connecting wires.
- ❖ Difficulty with changes or replacements.
- ❖ Difficulty in finding errors; requiring skillful work force.
- ❖ When a problem occurs, hold-up time is indefinite, usually long.

Advantages of PLC control

- ❖ Rugged and designed to withstand vibrations, temperature, humidity, and noise.
- ❖ Have interfacing for inputs and outputs already inside the controller.
- ❖ Easily programmed and have an easily understood programming language.

PLC HISTORY

PLC development began in 1968 in response to a request from an US car manufacturer (GE). The first PLCs were installed in industry in 1969. Communications abilities began to appear in approximately 1973. They could also be used in the 70's to send and receive varying voltages to allow them to enter the analog world.

The <u>80's</u> saw an attempt to standardize communications with manufacturing automation protocol (MAP), reduce the size of the PLC, and making them software programmable through symbolic programming on personal computers instead of dedicated programming terminals or handheld programmers.

The <u>90's</u> have seen a gradual reduction in the introduction of new protocols, and the modernization of the physical layers of some of the more popular protocols that survived the 1980's.

The latest standard “IEC 1131-3” has tried to merge PLC programming languages under one international standard. We now have PLCs that are programmable in function block diagrams, instruction lists, C and structured text all at the same time.

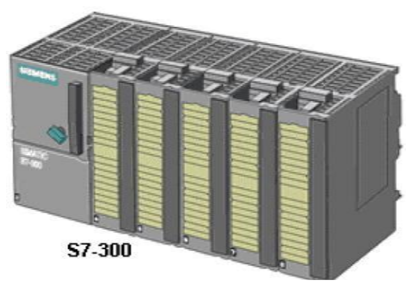
PLC HARDWARE

Hardware Components of a PLC System

Processor unit (CPU), Memory, Input/output, Power supply unit, Programming device, and other devices.

Central Processing Unit (CPU)

CPU – Microprocessor based, may allow arithmetic operations, logic operators, block memory moves, computer interface, local area network, functions, etc.
CPU makes a great number of check-ups of the PLC controller itself so eventual errors would be discovered early.



System Busses

The internal paths along which the digital signals flow within the PLC are called busses.
The system has four busses:
– The CPU uses the data bus for sending data between the different elements,
– The address bus to send the addresses of locations for accessing stored data,
– The control bus for signals relating to internal control actions,
– The system bus is used for communications between the I/O ports and the I/O unit.

Memory

System (ROM) to give permanent storage for the operating system and the fixed data used by the CPU. RAM for data. This is where information is stored on the status of input and output devices and the values of timers and counters and other internal devices. EPROM for ROM’s that can be programmed and then the program made permanent.

I/O Sections

Inputs monitor field devices, such as switches and sensors.
Outputs control other devices, such as motors, pumps, solenoid valves, and lights.

Power Supply

Most PLC controllers work either at 24 VDC or 220 VAC. Some PLC controllers have electrical supply as a separate module, while small and medium series already contain the supply module.

Programming Device

The programming device is used to enter the required program into the memory of the processor. The program is developed in the programming device and then transferred to the memory unit of the PLC.

PLC OPERATION

Input Relays

These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc. Typically they are not relays but rather they are transistors.

Internal Utility Relays

These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays. There are also some special relays that are dedicated to performing only one task.

Counters

These do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down. Since they are simulated they are limited in their counting speed. Some manufacturers also include high speed counters that are hardware based.

Timers

These also do not physically exist. They come in many varieties and increments. The most common type is an on-delay type. Others include off-delay and both retentive and non-retentive types. Increments vary from 1ms through 1s.

Output Relays

These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights, etc. They can be transistors, relays, or triacs depending upon the model chosen.

Data Storage

Typically there are registers assigned to simply store data. Usually used as temporary storage for math or data manipulation. They can also typically be used to store data when power is removed from the PLC.

PLC COMMUNICATION

Cables

Twisted-pair cabling, often routed through steel conduit. Coaxial cable enables higher data rates to be transmitted and does not require the shielding of steel conduit. Fiber-optic cabling has the advantage of resistance to noise, small size and flexibility.

Parallel communication

Parallel communication is when all the constituent bits of a word are simultaneously transmitted along parallel cables. This allows data to be transmitted over short distances at high speeds. Might be used when connecting laboratory instruments to the system.

Parallel standards

The standard interface most commonly used for parallel communication is IEEE-488, and now termed as General Purpose Instrument Bus (GPIB). Parallel data communications can take place between listeners,talkers, and controllers. There are 24 lines: 8 data (bidirectional), 5 status & control, 3 handshaking, and 8 ground lines.

Serial communication

Serial communication is when data is transmitted one bit at a time. A data word has to be separated into its constituent bits for transmission and then reassembled into the word when received.

Serial communication is used for transmitting data over long distances. Might be used for the connection between a computer and a PLC.

Serial standards

RS-232 communications is the most popular method of plc to external device communications. RS 232 is a communication interface included under SCADA applications. Other standards such as RS422 and RS423 are similar to RS232 although they permit higher transmission rates and longer cable distances.

There are 2 types of RS-232 devices:

DTE – Data Terminal Equipment and a common example is a computer.

DCE – Data Communications Equipment and a common example is a modem. PLC may be either a DTE or DCE device.

ASCII

ASCII is a human-readable to computer-readable translation code (each letter/number is translated to 1's and 0's). It's a 7-bit code, so we can translate 128 characters (2^7 is 128).

Protocols

It is necessary to exercise control of the flow of data between two devices so what constitutes the message, and how the communication is to be initiated and terminated, is defined. This is termed the protocol. One device needs to indicate to the other to start or stop sending data.

Interconnecting several devices can present problems because of compatibility problems.

In order to facilitate communications between different devices the International Standard Organization (ISO) in 1979 devised a model to be used for standardization for Open System Interconnection (OSI).

PLC INPUT UNITS

Example of input lines can be connection of external input device. Sensor outputs can be different depending on a sensor itself and also on a particular application.

In practice we use a system of connecting several inputs (or outputs) to one return line. These common lines are usually marked "COMM" on the PLC controller housing.

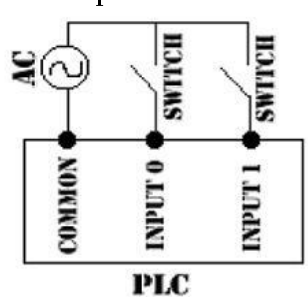
DC Inputs

DC input modules allow to connect either PNP (sourcing) or NPN (sinking) transistor type devices to them. When we are using a sensor have to worry about its output configuration. If we are using a regular switch (toggle or pushbutton) we typically don't have to worry about whether we wire it as NPN or PNP.

AC Inputs

An ac voltage is non-polarized. Most commonly, the AC voltage is being switched through a limit switch or other switch type. AC input modules are less common than DC input modules, because today's sensors typically have transistor outputs. If application is using a sensor it probably is operating on a DC voltage.

Typical connection of an AC device to PLC input module



Typically an AC input takes longer than a DC input for the PLC to see. In most cases it doesn't matter to the programmer because an AC input device is typically a mechanical switch and mechanical devices are slow. It's quite common for a PLC to require that the input be on for 25 ms (or more) before it's seen. This delay is required because of the filtering which is needed by the PLC internal circuit.

PLC OUTPUTS

PLC Output units can be: Relay, Transistor, orTriac. .Check the specifications of load before connecting it to the PLC output. Make sure that the maximum current it will consume is within the specifications of the PLC output.

Relay Outputs

One of the most common types of outputs available is the relay output. Existence of relays as outputs makes it easier to connect with external devices. A relay is non-polarized and typically it can switch either AC or DC.

Transistor Outputs

Transistor type outputs can only switch a dc current. The PLC applies a small current to the transistor base and the transistor output "closes". When it's closed, the device connected to the PLC output will be turned on.

A transistor typically cannot switch as large a load as a relay. If the load current you need to switch exceeds the specification of the output, you can connect the plc output to an external relay, then connect the relay to the large load.Typically a PLC will have either NPN or PNP transistor type outputs. Some of the common types available are BJT and MOSFET. A BJT type often has less switching capacity than a MOSFET type. The BJT also has a slightly faster switching time. A transistor is fast, switches a small current, has a long lifetime and works with dc only. A relay is slow, can switch a large current, has a shorter lifetime and works with ac or dc.

Triac Output

Triac output can be used to control AC loads only. Triac output is faster in operation and has longer life than relay output. Inductive loads have a tendency to deliver a "back current" when they turn on. This back current is like a voltage spike coming through the system. This could be dangerous to output relays. Typically a diode, varistor, or other "snubber" circuit should be used to protect the PLC output from any damage

PLC SELECTION CRITERIA

PLC selection criteria consist of:
* System (task) requirements.
* Application requirements.
* What input/output capacity is required?
* What type of inputs/outputs are required?
* What size of memory is required?
* What speed is required of the CPU?
* Electrical requirements.
* Speed of operation.
* Communication requirements.
* Software.
* Operator interface.
* Physical environments.

System requirements

* The starting point in determining any solution must be to understand what is to be achieved.

* The program design starts with breaking down the task into a number of simple understandable elements, each of which can be easily
described.

Application requirements

* Input and output device requirements. After determining the operation of the system, the next step is to determine what input and
output devices the system requires.
* List the function required and identifies a specific type of device.
* The need for special operations in addition to discrete (On/Off) logic.
* List the advanced functions required beside simple discrete logic.

Electrical Requirements

The electrical requirements for inputs, outputs, and system power; When determining the electrical requirements of a system, consider three items:

- Incoming power (power for the control system);
- Input device voltage; and
- Output voltage and current.

Speed of Operation

How fast the control system must operate (speed of operation).
When determining speed of operation, consider these points:
– How fast does the process occur or machine operate?
– Are there “time critical” operations or events that must be detected?
– In what time frame must the fastest action occur (input device detection to output device activation)?
– Does the control system need to count pulses from an encoder or flow-meter and respond quickly?

Communication

If the application requires sharing data outside the process, i.e. communication. Communication involves sharing application data or status with another electronic device, such as a computer or a monitor in an operator’s station. Communication can take place locally through a twisted-pair wire, or remotely via telephone or radio modem.

Operator Interface

If the system needs operator control or interaction. In order to convey information about machine or process status, or to allow an operator to input data, many applications require operator interfaces. Traditional operator interfaces include pushbuttons, pilot lights and LED numeric display. Electronic operator interface devices display messages about machine status in descriptive text, display part count and track alarms. Also, they can be used for data input.

Physical Environment

The physical environment in which the control system will be located. Consider the environment where the control system will be located. In harsh environments, house the control system in an appropriate IP-rated enclosure. Remember to consider accessibility for maintenance, troubleshooting or reprogramming.

VENDOR SELECTION

The range of PLC suppliers is vast and many offer a number of alternative product ranges with any number of modules, boasting special features.
Our choice must meet the application requirements, provide extra capacity for future development and provide a cost-effective solution.

Price is the most commonly stated reason for making a choice, but the true price of a PLC to meet the requirements of a particular application is often much the same over a wide range of supplier equipment.

The final choice of supplier for our PLC will depend upon functionality, support available, customer preferences, user knowledge and price.

These are the issues that must be addressed:

– *Functionality*: We have to match the application requirements with the features of each of the contending suppliers' equipment to identify the one that best meets our requirements.

– *Support*: Before any purchase is made the following points should be confirmed with any manufacturer:

*Training;

*Technical support (on site and over the phone);

*Application support to configure and design a system;

*Rapid exchange/repair of failed equipment;

*Guaranteed support for any products for at least 10 years from purchase.

Exp. No:12

STUDY OF A MULTI-CHANNEL DATA ACQUISITION SYSTEM

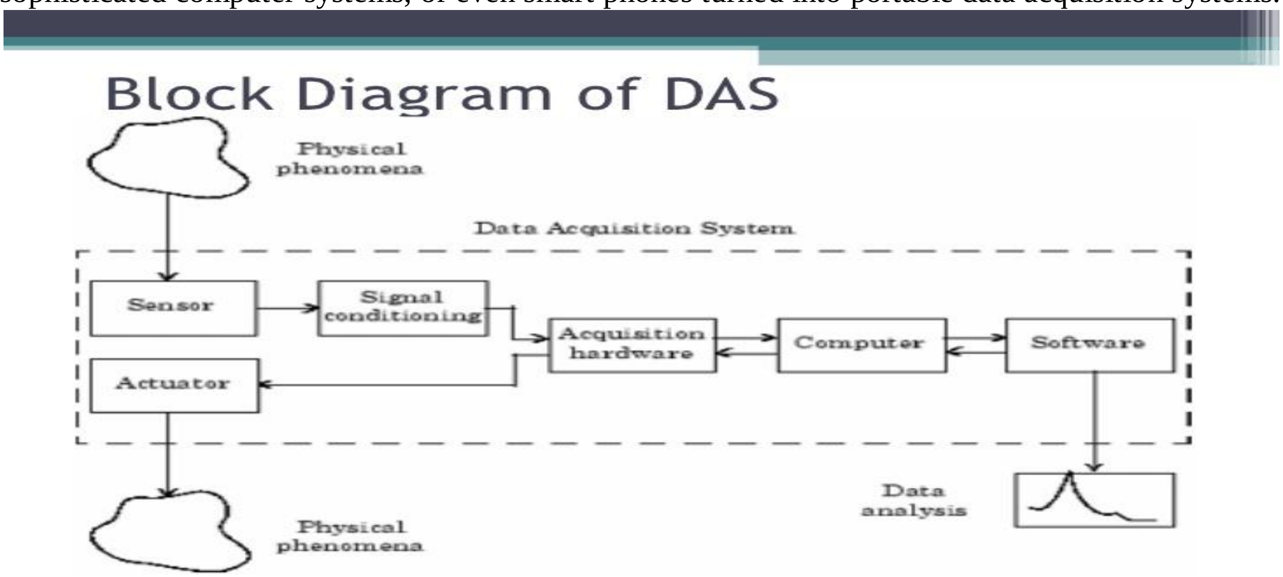
Aim:

To study about a multi-channel data acquisition system.

THEORY

Data acquisition systems, as the name implies, are products and/or processes used to collect information to document or analyze some phenomenon. In the simplest form, a technician logging the temperature of an oven on a piece of paper is performing data acquisition.

As technology has progressed, this type of process has been simplified and made more accurate, versatile, and reliable through electronic equipment. Equipment ranges from simple recorders to sophisticated computer systems, or even smart phones turned into portable data acquisition systems.



Data acquisition products serve as a focal point in a system, tying together a wide variety of products, such as sensors that indicate temperature, flow, level, or pressure

Analog-to-digital converter (ADC)

An electronic device that converts analog signals to an equivalent digital form. The analog-to-digital converter is the heart of most data acquisition systems.

Digital-to-Analog Converter (D/A)

An electronic component found in many data acquistion devices that produce an analog output signal.

Digital Input/Output (DIO)

Refers to a type of data acquistion signal. Digital I/O are discrete signals which are either one of two states. These states may be on/off, high/low, 1/0, etc. Digital I/O are also referred to as binary I/O.

Differential Input

Refers to the way a signal is wired to a data acquisition device. Differential inputs have a unique high and unique low connection for each channel. Data acquisition devices have either single-ended or differential inputs, many devices support both configurations.

General Purpose Interface Bus (GPIB)

Synonymous with HPIB (for Hewlett-Packard), the standard bus used for controlling electronic instruments with a computer. Also called IEEE 488 in reference to defining ANSI/IEEE standards.

Resolution

The smallest signal increment that can be detected by a data acquisition system. Resolution can be expressed in bits, in proportions, or in percent of full scale. For example, a system has 12-bit resolution, one part in 4,096 resolution, and 0.0244 percent of full scale.

RS232

A standard for serial communications found in many data acquistion systems. RS232 is the most common serial communication, however, it is somewhat limited in that it only supports communication to one device connected to the bus at a time and it only supports transmission distances up to 50 feet.

RS485

A standard for serial communications found in many data acquistion systems. RS485 is not as popular as RS232, however, it is more flexible in that it supports communication to more than one device on the bus at a time and supports transmission distances of approximately 5,000 feet.

Sample Rate

The speed at which a data acquisition system collects data. The speed is normally expressed in samples per second. For multi-channel data acquisition devices the sample rate is typically given as the speed of the analog-to-digital converter(A/D). To obtain individual channel sample rate, you need to divide the speed of the A/D by the number of channels being sampled.

Single-ended Input (SE)

Refers to the way a signal is wired to a data acquisition device. In single-ended wiring, each analog input has a unique high connection but all channels share a common ground connection. Data acquisition devices have either single-ended or differential inputs.

NI 9219 - 24-Bit Universal Analog Input DATA AQUISITION SYSTEM

The NI 9219 is a four-channel universal C Series module designed for multipurpose testing in any NI CompactDAQ or CompactRIO chassis. With the NI 9219, you can measure several signals from sensors such as strain gages, RTDs, thermocouples, load cells, and other powered sensors. The channels are individually selectable, so you can perform a different measurement type on each of the four channels. Measurement ranges differ for each type of measurement and include up to ±60 V for voltage and ±25 mA for current.

Key Features

High-accuracy, high-performance analog measurements for any CompactRIO embedded system, R Series expansion chassis, or NI CompactDAQ chassis Screw terminals, BNC, D-Sub, spring terminals, strain relief, high voltage, cable, solder cup backshell, and other connectivity options

Available channel-to-earth ground double-isolation barrier for safety, noise immunity, and high common-mode voltage range CompactRIO Extreme Industrial Certifications and Ratings Built-in signal conditioning for direct connection to sensors and industrial devices

Figure 4-1 shows the analog input circuitry of NI 6232/6233 devices.

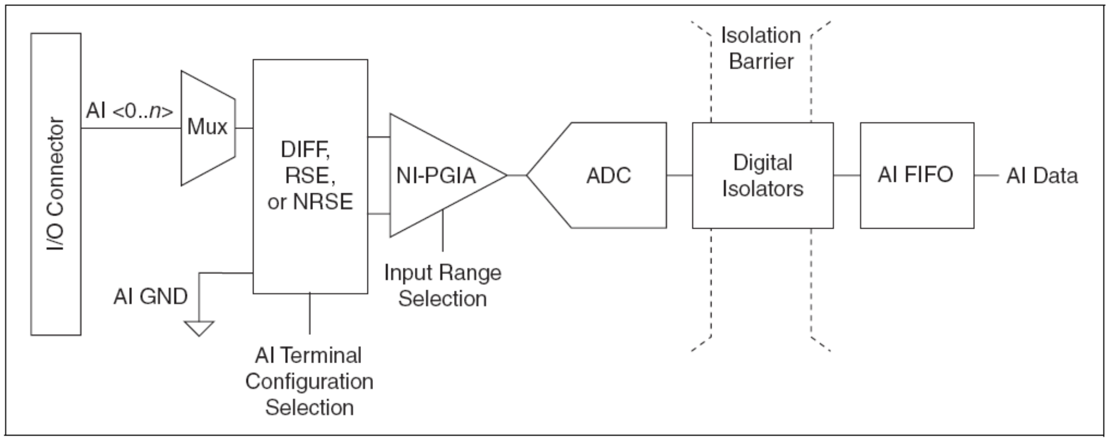


Figure 4-1. NI 6232/6233 Analog Input Circuitry

I/O Connector

Connect analog input signals to the M Series device through the I/O connector. The proper way to connect analog input signals depends on the analog input ground-reference settings, described in the Analog InputGround-Reference Settings section.

MUX

Each M Series device has one analog-to-digital converter (ADC). Themultiplexers (MUX) route one AI channel at a time to the ADC through theNI-PGIA

Ground-Reference Settings

The analog input ground-reference settings circuitry selects between differential and referenced single-ended modes. Each AI channel can use a different mode.

Instrumentation Amplifier (NI-PGIA)

The NI programmable gain instrumentation amplifier (PGIA) is a measurement and instrument class amplifier that minimizes settling times for all input ranges. The NI-PGIA can amplify or attenuate an AI signal to

ensure that you use the maximum resolution of the ADC. M Series devices use the NI-PGIA to deliver high accuracy even when sampling multiple channels with small input ranges at fast rates. M Series devices can sample channels in any order at the maximum conversion rate, and you can individually program each channel in a sample with a different input range.

A/D Converter

The analog-to-digital converter (ADC) digitizes the AI signal by converting the analog voltage into a digital number.

Isolation Barrier and Digital Isolators The digital isolators across the isolation barrier provide a ground breakbetween the isolated analog front end and the earth/chassis/buildingground.

AI FIFO

M Series devices can perform both single and multiple A/D conversions of a fixed or infinite number of samples. A large first-in-first-out (FIFO) buffer holds data during AI acquisitions to ensure that no data is lost. M Series devices can handle multiple A/D conversion operations with DMA, interrupts, or programmed I/O.

RESULT

Thus the study and Design preocedure for DAQ system is performed.

Exp. No:13 **DESIGN OF FIRST ORDER ACTIVE FILTERS**

Aim:

To design a first order active low pass filter (LPF) & high pass filter (HPF) using operational amplifier

Apparatus Required:

S. No.	Components / Equipments	Specifications	Quantity
1.	IC Power Supply	+/-15V dc	1
2.	Function Generator	1Hz - 1Mhz	1
3.	Cathode Ray Oscilloscope	30MHz	1
4.	Operational Amplifier	IC 741	1
5.	Resistors	1.59KΩ, 10 KΩ, 5.86	2,1,1
6.	Capacitors	0.1µf	2
7.	Bread Board & Connecting	-	Sufficient nos.

Theory:

An improved filter response can be obtained by using a second order active filter. A second order filter consist of two RC pairs has a roll-off rate of –40dB/decade. The transfer function of a Low pass filter

$$\text{DC gain} = \left(1 + \frac{R_2}{R_1}\right)$$

Gain for an Active High Pass Filter

$$\text{Voltage Gain, } (A_v) = \frac{V_{out}}{V_{in}} = \frac{A_F\left(\frac{f}{fc}\right)}{\sqrt{1+\left(\frac{f}{fc}\right)^2}}$$

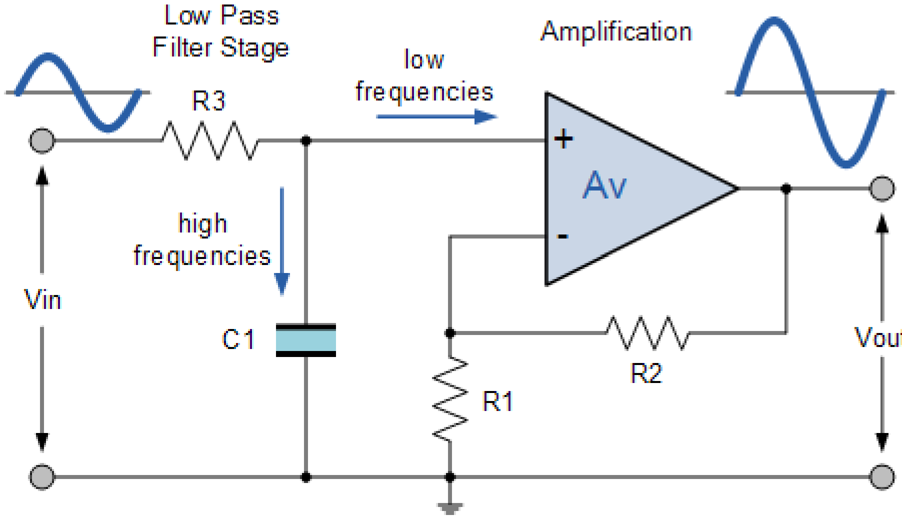
- Where:
- A_F = the Pass band Gain of the filter, (1 + R2/R1)
- f = the Frequency of the Input Signal in Hertz, (Hz)
- fc = the Cut-off Frequency in Hertz, (Hz)

Design:

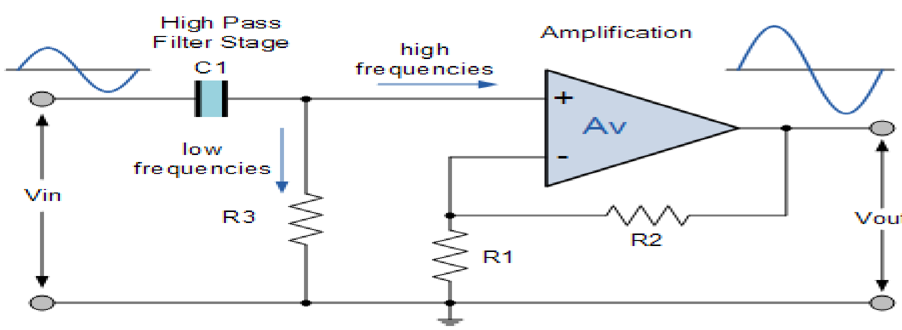
F_c = 1 KHz, Assume C = 0.1 µF, R = 1.6 KΩ

Let R_f = 5.86 KΩ , R_i = 10 KΩ; Gain =A_o = [1+5.86/10] = [1+0.586]=1.586.

First Order Active Low Pass Filter



First Order Active High Pass Filter



Procedure:

1. Connect the low pass filter circuit as shown in the circuit diagram.
2. The value of R is calculated using the design formula and set the proper values in DRB.
3. Set an input voltage of 1V in AFO and obtain the gain for different frequencies.
4. Plot a graph between the gain and frequency and check whether it satisfies the characteristic curve.
5. Repeat the above for HPF.

Table 1: Low Pass Filter: **V_{in} = Volts**

S.No	Frequency (Hz)	Output Voltage (Volts)	Gain = 20log(V_o / V_{in}) (dB)

Table 2: High Pass Filter:V_{in} = Volts

S.No	Frequency (Hz)	Output Voltage (Volts)	Gain = 20log(V_o / V_{in}) (dB)

Results:

Thus the first order Active low pass filter & high pass filter was designed and the cut-off frequency was calculated from thegraph.

Review Questions:

1. What are the different types of filters?
2. What is cut-off frequency?
3. Draw the first order passive filter.
4. What are the applications of filters?
5. When we will we go for band pass filter?