Varuvan Vadivelan Institute of Technology

Dharmapuri – 636 703

LAB MANUAL

Regulation : 2013

Branch : *B.E.* - EEE

Year & Semester : III Year / V Semester

EE6511-CONTROL AND INSTRUMENTATION LABORATORY

REGULATION - 2013

SYLLABUS

EE6511 CONTROL AND INSTRUMENTATION LABORATORY

OBJECTIVES:

To provide knowledge on analysis and design of control system along with basics of instrumentation

LIST OF EXPERIMENTS:

CONTROL SYSTEMS:

1. P, PI and PID controllers
2. Stability Analysis
3. Modeling of Systems – Machines, Sensors and Transducers
4. Design of Lag, Lead and Lag-Lead Compensators
5. Position Control Systems
6. Synchro -Transmitter- Receiver and Characteristics
7. Simulation of Control Systems by Mathematical development tools.

INSTRUMENTATION:

8. Bridge Networks –AC and DC Bridges
9. Dynamics of Sensors/Transducers
    a. Temperature
    b. Pressure
    c. Displacement
    d. Optical
    e. Strain
    f. Flow
10. Power and Energy Measurement
11. Signal Conditioning
    a. Instrumentation Amplifier
    b. Analog – Digital and Digital –Analog converters (ADC and DACs)
12. Process Simulation.

TOTAL: 45 PERIODS

INDEX

EX.NO	DATE	NAME OF THE EXPERIMENT	MARKS	STAFF SIGN
1		Wheatstone bridge		
2		Kelvin's Double Bridge		
3		Anderson's bridge		
4		Maxwell's inductance bridge		
5		Schering Bridge		
6		Study of Displacement Transducer - LVDT		
7		Measurement of pressure using Transducer		
8		Calibration of Single Phase Energy Meter		
9		Signal conditioning of Instrumentation Amplifier		
10		Signal conditioning of Analog to Digital Converter (ADC)		
11		Signal conditioning of Digital to Analog Converter (DAC)		
12		DC Position Control System		
13		AC Position Control System		
14		Digital Simulation of Linear Systems		
15		Stability Analysis of Linear system		
16		Study The Effect Of P, PI, PID Controllers Using Mat Lab		
17		Design and implementation of compensators		

INTRODUCTION:

Engineering is concerned with understanding and controlling the materials and forces of nature for the benefit of humankind. Control system engineers are concerned with understanding and controlling segments of their environment, often called systems, to provide useful economic products for society. The twin goals of understanding and controlling are complementary because effective systems control requires that the systems be understood and modeled. Furthermore, control engineering must often consider the control of poorly understood systems such as chemical process systems. The present challenge to control engineers is the modeling and control of modern, complex, interrelated systems such as traffic control systems, chemical processes, and robotic systems. Simultaneously, the fortunate engineer has the opportunity to control many useful and interesting industrial automation systems. Perhaps the most characteristic quality of control engineering is the opportunity to control machines and industrial and economic processes for the benefit of society. Control engineering is based on the foundations of feedback theory and linear system analysis, and it integrates the concepts of network theory and communication theory. Therefore control engineering is not limited to any engineering discipline but is equally applicable to aeronautical, chemical, mechanical, environmental, civil, and electrical engineering. For example, a control system often includes electrical, mechanical, and chemical components. Furthermore, as the understanding of the dynamics of business, social and political systems increases, the ability to control these systems will also increase.

SYSTEM:

The number of element and components are connected in a sequence to form a group that group is said to be a system.

CONTROL SYSTEM:

The output quantity is controlled by varying the input quantity this system is said to be a control system.

Exp No: 1

Date:

WHEATSTONE BRIDGE

AIM:

To determine the value of unknown resistance using Wheatstone bridge

APPARATUS REQUIRED:

Sl. No	Name of the Apparatus	Qty
1	Wheatstone Bridge Trainer kit	1
2	Unknown Resistor	1
3	CRO	1
4	Connecting Wires	1
5	Digital Multimeter	1

THEORY:

Wheatstone bridge trainer consists of basic bridge circuit with a built in 1 kHz oscillator and an isolation transformer. The arm AC and AD consists of a 1Kohm resistor. Arms BD consists of variable resistor. The unknown resistor (Rx) whose value is to be determined is connected across the terminal BC .The resistor R2 is varied suitably to obtain the bridge balance condition. The DMM is used to determine the balanced output voltage of the bridge circuit.

FORMULA:

$R_x = R_1 . R_3 / R_2 \ \Omega$

Where,

Rx= unknown resistance in Ω.

R1= standard variable arm resistance in Ω.

R2 & R3 = Fixed ratio arms resistance in Ω.

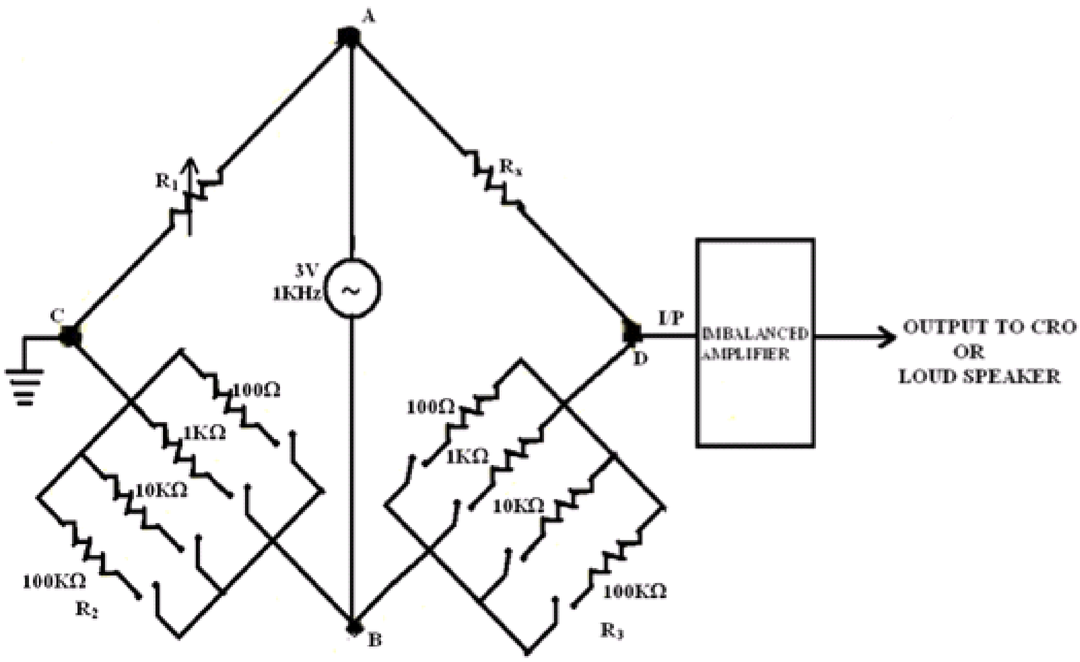
PRECAUTIONS:

1. Before switch ON the power supply points should be in minimum position.
2. Before switch ON the unknown resistance set the multi meter in correct position.
3. The resistance across the variable pot R1 is to be measured using multi meter disconnecting terminal across it.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Switch ON the trainer and check the power supply to be +15V.
3. Connect the unknown resistor in the arm marked Rx.
4. Observe the sine wave at the secondary of the isolation transformer on an oscilloscope.
5. Select some values of R2 and R3.
6. Connect the oscilloscope between the ground and the output point.
7. Vary R1 from the minimum position in a clockwise direction. If the selection of R2 & R3 is correct the balance or null point can be observed on CRO. [(i.e.) amplitude of the Output comes to a minimum for particular value of R1 & then again increases by varying R1 in the same clockwise direction].If that is not case, select another value of R2 or R3.
8. After balancing, measure the standard variable pot R1 using multimeter.
9. Calculate the values of unknown resistance using formula.

CIRCUIT DIAGRAM: (Wheatstone bridge)



TABULATION:

Sl. No	R1 Ω	R2 Ω	R3 Ω	Rx Ω (Actual)	Rx Ω (Observed)	Percentage Error
1						
2						
3						
4						

RESULT :

Thus evaluate the value of unknown resistance by using Wheatstone bridge circuit.

Exp No: 2

Date:

KELVIN'S DOUBLE BRIDGE

AIM:

To measure the low resistance using Kelvin's Double bridge

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Kelvin's Double Bridge Trainer kit	1
2	Unknown Resistor	1
3	CRO	1
4	Connecting Wires	1
5	Galvanometer	1

THEORY:

Kelvin's double bridge is a modification of wheatstone's bridge and provides more accuracy in measurement of low resistances. It incorporates two sets of ratio arms and the use of four terminal resistors for the low resistance arms, as shown in figure. Rx is the resistance under test and S is the resistor of the same higher current rating than one under test. Two resistances Rx and S are connected in series with a short link of as low value of resistance r as possible. P, Q, p, q are four known non inductive resistances, one pair of each (P and p, Q and q) are variable. A sensitive galvanometer G is connected across dividing points PQ and pq. The ratio PQ is kept the same as pq these ratios have been varied until the galvanometer reads zero.

FORMULA USED:

Rx = (P/Q)S (Ω)

Where,

P= Resistance of left arm of the bridge.

Q= Resistance of right arm of the bridge.

S= Variable potentiometer to balance the bridge.

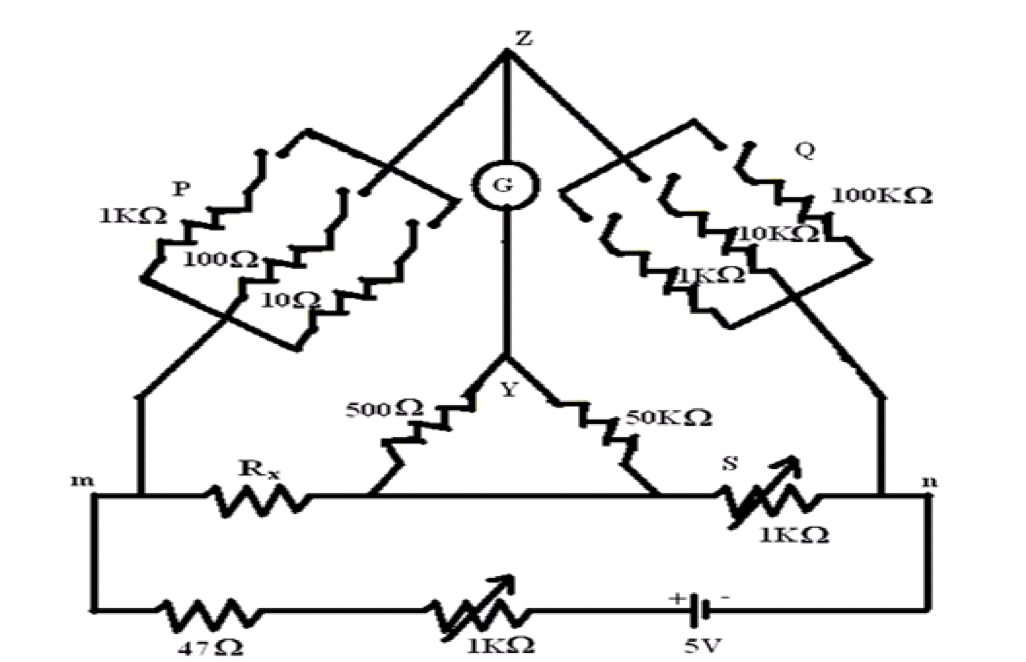
PRECAUTIONS:

1. Connect externally a galvanometer across the terminals a and b.
2. Connect the unknown resistance Rx as marked on the trainer.
3. The ratio of P & Q selected depends upon balancing the bridge using trial & error method
4. The resistance across the variable pot S is measured only after switch OFF the Power Supply in the kit & by disconnecting the connections across S.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. Trainer power supply is switched ON.
3. Energize the trainer by switching ON & check the power supply to be +5V
4. The galvanometer deflection shows the imbalance condition of the nature of the bridge.
5. The potentiometer S is varied in steps for proper balance of the bridge & the value of S is Noted at balanced condition.
6. The value of unknown resistance is calculated by using the formula & the value of P, Q, S are no.

CIRCUIT DIAGRAM: (Kelvin's Double Bridge)



TABULATION:

SL. NO	P Ω	Q Ω	S Ω	Rx = (P/Q)S Ω
1				
2				
3				
4				

RESULT:

Thus verify the value of unknown resistance by using kelvine's double bridge circuit.

Exp No: 3

Date:

ANDERSON'S BRIDGE

AIM:

To find the value of unknown inductance using an Anderson's bridge

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Anderson's Bridge Trainer kit	1
2	Unknown Resistor	1
3	CRO	1
4	Connecting Wires	1
5	Digital Multimeter	1

FORMULA USED:

Lx= C (R3 / R4) [R (R4 + R2) + (R2 R4)]

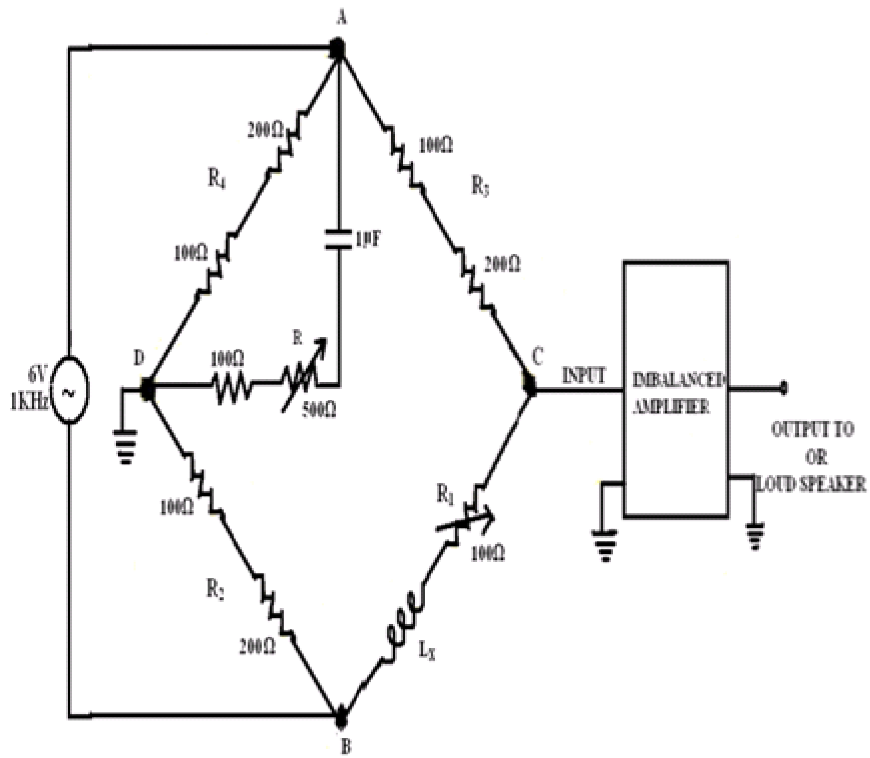
PRECAUTIONS:

1. Before switch ON the power supply points should be in minimum position.
2. Before switch ON the unknown inductance set the multimeter in correct position.

PROCEDURE:

1. Patch the connections as shown in circuit diagram.
2. Connect the unknown resistance
3. Now vary resistance R to some value till resistance at Lx (unknown) point and switch on the power supply, you hear sound.
4. Now vary R and R1 one after one to hear least sound possible or no sound at all.
5. By using CRO for balancing the bridge, while balancing first adjust R pot in clockwise direction then the waveform amplitude decreases & then increases, later adjust R1 then amplitude decreases & then increases, stop varying the pot R1 & measure the resistance R1 & R.
6. Remove the patching and note down the reading according to the table given below and valuate the value of unknown inductance by given formula.
7. Repeat the experiment for different values of inductance.

CIRCUIT DIAGRAM: (Anderson's Bridge)



TABULATION:

SL. NO	R2 Ω	R3 Ω	R4 Ω	R Ω	R1 Ω	INDUCTANCE - L(mH)	
						Actual	Observed
1							
2							
3							
4							

RESULT:

Thus calculate the value of unknown inductance by using an Anderson's bridge

Exp No: 4

Date:

MAXWELL'S INDUCTANCE BRIDGE

AIM

To find the value of unknown inductance using a maxwell's inductance bridge

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Maxwell's Inductance Bridge Trainer kit	1
2	Unknown Inductance	1
3	CRO	1
4	Connecting Wires	1
5	Digital Multimeter	1

THEORY:

In this bridge, an inductance is measured by comparison with a standard variable capacitance. The connection at the balanced condition is given in the circuit diagram.

Let L_1 = Unknown Inductance.

R_1 = effective resistance of Inductor L1.

R_2, R_3 and R_4 = Known non-inductive resistances.

C_4 = Variable standard Capacitor.

FORMULA USED:

$Lx = R_1R_3C$

$Q = \omega L1/R_1$

$Rx = R_1R_3/R_2$

Note:

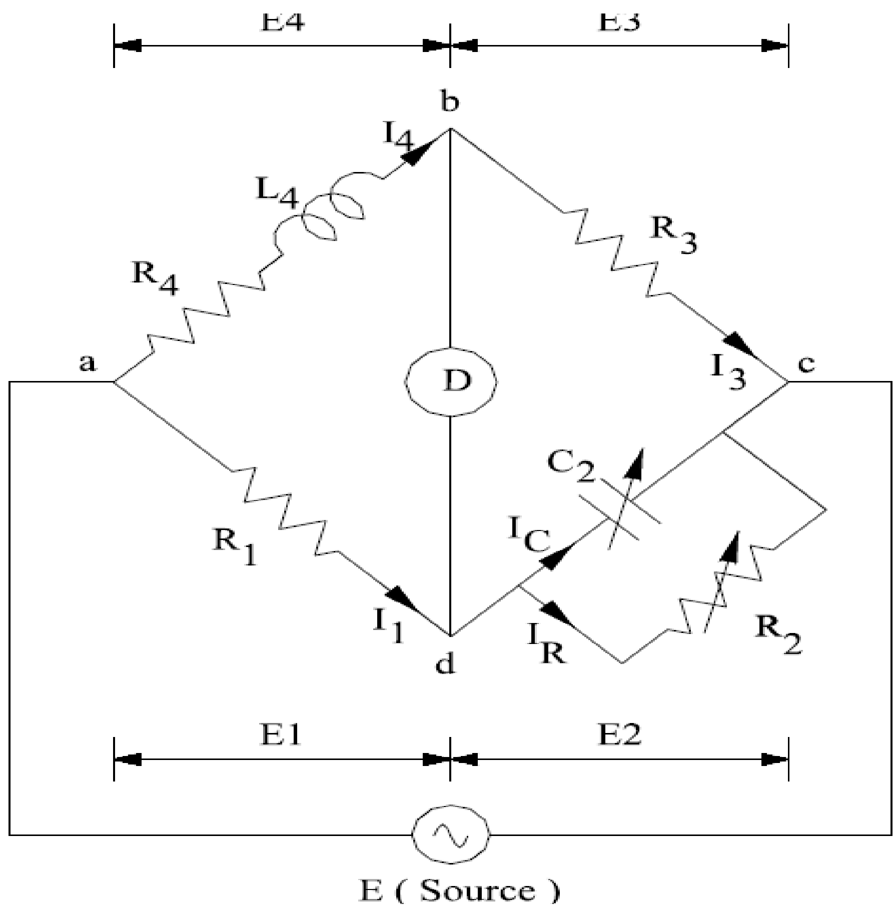
In this bridge resistance R1 is for maximum variation of output and resistance R2 and R is minute

PROCEDURE:

1. Connections are made as per the connection diagram shown above
2. Connect the unknown inductance at the Lx (Unknown) point.
3. Connect the CRO across P and Q.
4. Switch ON the unit.
5. Choose R3, such that you can obtain a maximum variation of output.
6. Now set R2 to maximum position.
7. Vary the potentiometer R1 such that the amplitude of sine wave will is decreases and that one point it will obtain a minimum of zero amplitude and then it will start increasing at that point stop the tuning and switch OFF the unit.
8. Remove the patching at R1 and find the resistance using multimeter and note down the reading according to the table given below and calculate the value of unknown inductance.
9. One can verify the balancing condition by connecting the bridge output (P & Q) to the input (P & Q) of audio power amplifier and you can hear a minimum noise or no noise.

If you vary the potentiometer R1 you can hear a maximum noise.

CIRCUIT DIAGRAM: (Maxwell's Inductance Bridge)



TABULATION:

Sl.No	R1 Ω	R3 Ω	Inductance Lx mH	
			Actual	Observed
1				
2				
3				
4				

RESULT:

Thus the value of unknown inductance was found using by a maxwell's inductance bridge circuit.

Exp No: 5

Date:

SCHERING BRIDGE

AIM

To measure the value of unknown capacitance using Schering's bridge & dissipation factor.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Schering Bridge Trainer kit	1
2	Decade Capacitance Box	1
3	CRO	1
4	Connecting Wires	1
5	Digital Multimeter	1

THEORY:

In this bridge the arm BC consists of a parallel combination of resistor & a Capacitor and the arm AC contains capacitor. The arm BD consists of a set of resistors varying from 1Ω to 1 MΩ. In the arm AD the unknown capacitance is connected. The bridge consists of a built in power supply, 1 kHz oscillator and a detector.

BALANCE EQUATIONS:

Let C_1=Capacitor whose capacitance is to be measured.

R_1= a series resistance representing the loss in the capacitor C_1.

C_2= a standard capacitor.

R_3= a non-inductive resistance.

C_4= a variable capacitor.

R_4= a variable non-inductive resistance in parallel with variable capacitor C_4.

At balance,

$Z_1Z_4=Z_2Z_3$

FORMULA USED:

$Cx = (R_4/R_3)C_2D_1 = \omega C_4R_4$

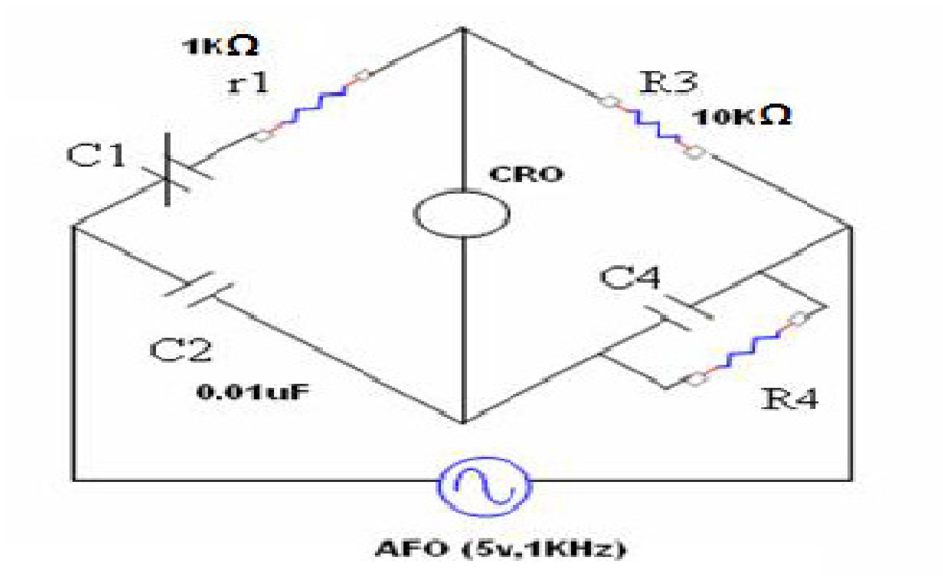
$C_4 = Cx$

$R_4 = Rx$

PROCEDURE:

1. Switch on the trainer board and connect the unknown in the arm marked Cx.
2. Observe the sine wave at the output of oscillator and patch the circuit by using the wiring diagram.
3. Observe the sine wave at secondary of isolation transformer on CRO. Select some value of R_3.
4. Connect the CRO between ground and the output point of imbalance amplifier.
5. Vary R_4 (500Ω potentiometer) from minimum position in the clockwise direction.
6. If the selection of R_3 is correct, the balance point (DC line) can be observed on CRO. (That is at balance the output waveform comes to a minimum voltage for a particular value of R_4 and then increases by varying R_3 in the same clockwise direction). If that is not the case, select another value of R_4.
7. Capacitor C_2 is also varied for fine balance adjustment. The balance of the bridge can be observed by using loud speaker.
8. Tabulate the readings and calculate the unknown capacitance and dissipation factor.

CIRCUIT DIAGRAM: **(Schering Bridge)**



TABULATION:

Sl.No	C2 μF	R3 Ω	R4 Ω	Capacitance Cx μF		Dissipation Factor (D)
				True Value	Measured Value	
1						
2						
3						
4						

RESULT:

Thus the value of unknown capacitance and dissipation factor are found using Schering's bridge.

Exp No: 6

Date:

STUDY OF DISPLACEMENT TRANSDUCER - LVDT

AIM:

To study the displacement transducer using LVDT and to obtain its characteristics

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	LVDT Trainer kit	1
2	Connecting Wires	1
3	Digital Multimeter	1
4	Screw gauge	1

FORMULA USED:

%ERROR = [(Displayed Displacement – Actual Displacement)/ Actual Displacement] x100

PRECAUTIONS:

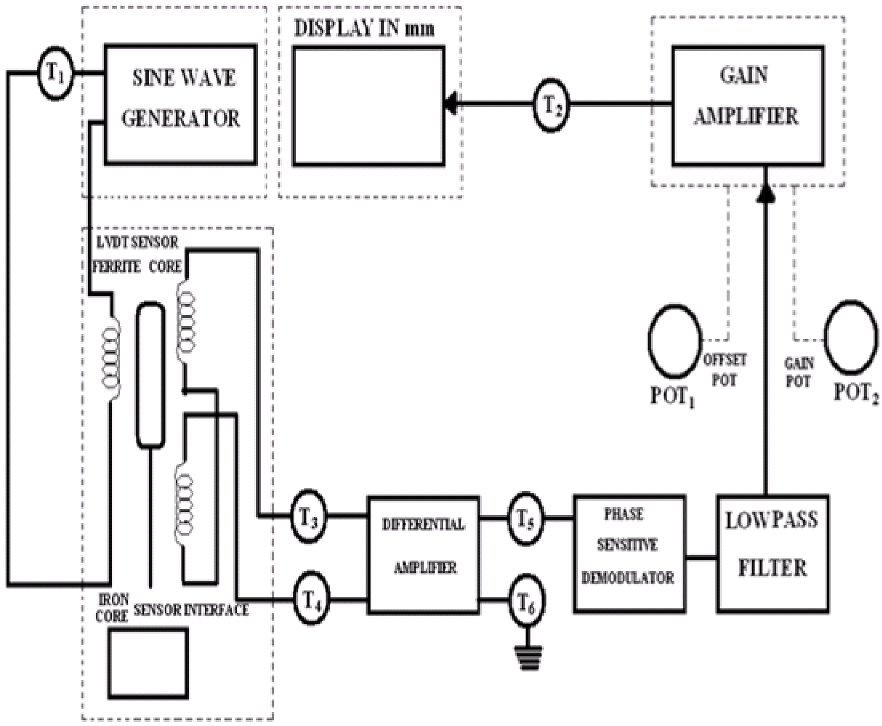
1. While taking reading on scale parallel error has to be avoided.
2. Smooth gradual movement of the core to be ensured.

PROCEDURE:

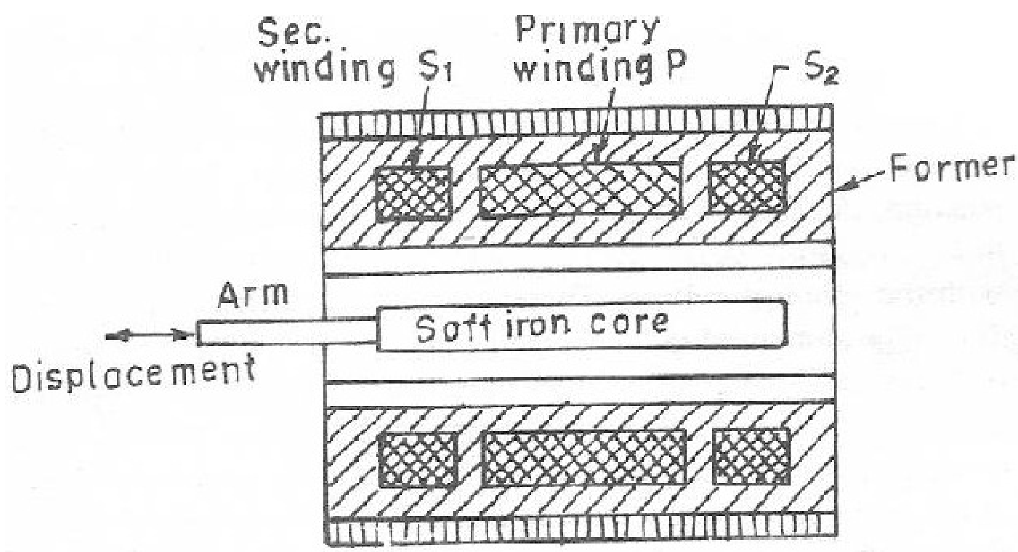
1. Switch on the power supply to the LVDT module.
2. Connect the CRO at T1 to check the input sine wave signal. Adjust the frequency to kHz.
3. Place the LVDT at the null position (10mm) and adjust the offset to display zero on the DVM(actual displacement).calibrated in displacement of the core. Gradually move the core of the LVDT in the positive direction (20mm) and Note the reading on the display (mm).It should be around 10mm, if it not adjust the gain to display 10mm.
4. Repeat step 4 in the opposite direction.
5. Tabulate the readings of actual displacement and displayed on the DVM. The LVDT core may be moved through a distance of 20mm.

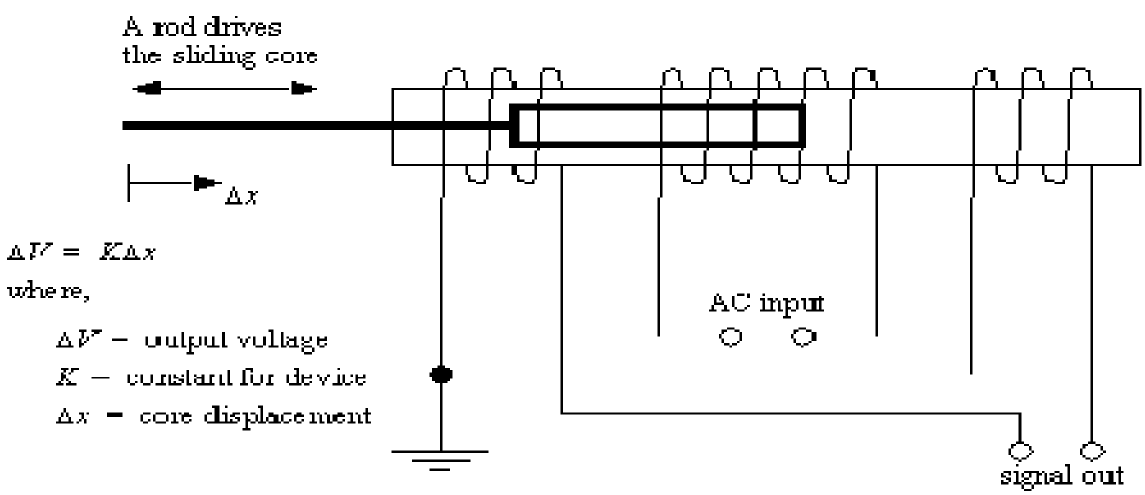
CIRCUIT DIAGRAM:

Study Of Displacement Transducer - LVDT



GENERAL DIAGRAM

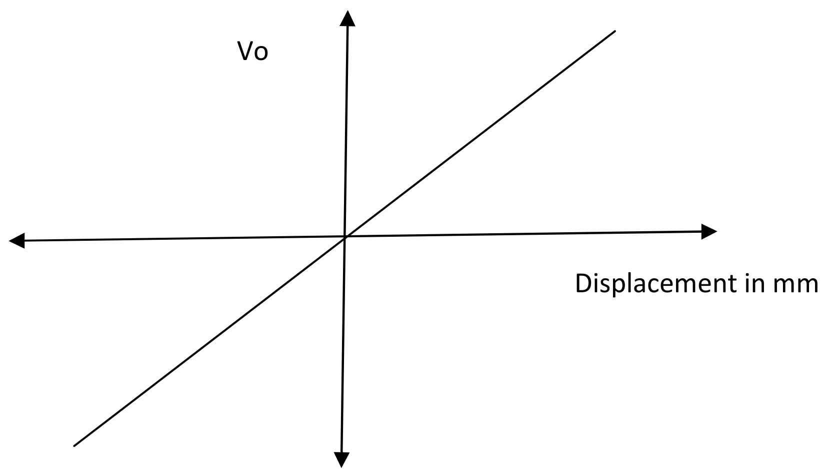




TABULATION:

ACTUAL DISPLACEMENT D_a(mm)	OUTPUT VOLTAGE V_o *volts*	DISPLAYED DISPLACEMENT D_d (mm)	% ERROR
1			
2			
3			
4			

MODEL GRAPH:



RESULT:

Thus the displacement and characteristics of transducer are studied using LVDT.

Exp No : 7

Date:

MEASUREMENT OF PRESSURE USING TRANSDUCER- BOURDON TUBE

AIM:

To measure the pressure using pressure transducer with respect to signal conditioned output voltage.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Pressure Trainer kit	1
2	Connecting Wires	1
3	Digital Multimeter	1

FORMULA USED:

Percentage Error = [(Gauge Pressure-Displaced Pressure)/Di splaced Pressure] * 100

PROCEDURE

1. Install the sensor setup and interface the 9 pin D connector with ITB-16-CE kit

2. Connect the multimeter in Volt mode across T5 and GND for the signal conditioned voltage measurement. 3. Switch "ON" the module.

4. Initially, open the air release valve and exhaust the tank inlet air and nullify the signal conditioned output voltage by using zero adjustment POT.

5. Now, close the opened air release valve and apply the pressure of 50 Psig to the cylinder and adjust the display to 50 Psig by using gain adjustment POT.

6. After the gain calibration, open the air release valve and exhaust the tank inlet air.

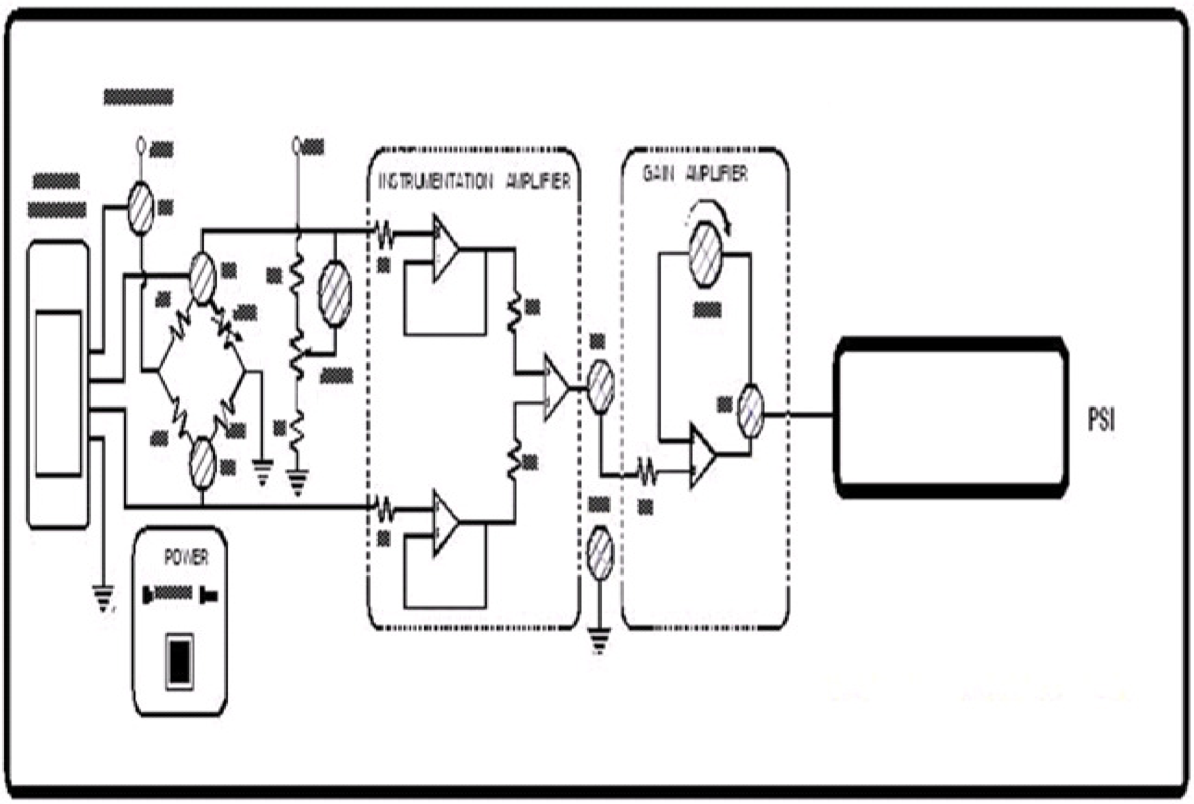
7. Again, close the opened air release valve. By pressing the pump piston, the pump sucks the air from atmosphere and supply it to the cylinder. Then, the pressure will be developed in the cylinder and measure the signal conditioned output voltage (V) across T5 and GND.

8. Gradually increase the pressure the pump piston and note down the signal conditioned output voltage (V) for corresponding gauge pressure.

9. Tabulate the readings and plot a graph between gauge pressure and signal conditioned output voltage (V).

CIRCUIT DIAGRAM :

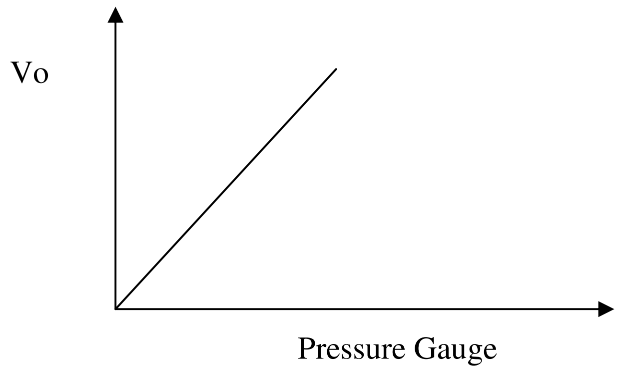
(Measurement Of Pressure Using Transducer- Bourdon Tube)



TABULATION:

Gauge Pressure (Psig)	Signal conditioned output voltage *Volts*	Displayed Pressure (Psig)	% Error

MODEL GRAPH:



RESULT:

Thus the pressure with respect to signal conditioned output voltage using pressure transducer is measured.

Exp No: 8

Date:

CALIBRATION OF SINGLE PHASE ENERGY METER

AIM:

To calibrate the given energy meter using a standard wattmeter and to obtain percentage error

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Energy Meter (Single Phase)	1
2	Wattmeter,300V,10A,UPF	1
3	Voltmeter(0-300v)MI	1
4	Ammeter(0-10A)MI	1
5	Lamp Load	1

THEORY:

The energy meter is an integrated type instrument where the speed of rotation of aluminium disc is directly proportional to the amount of power consumed by the load and the no of revs/min is proportional to the amount of energy consumed by the load. In energy meter the angular displacement offered by the driving system is connected to the gearing arrangement to provide the rotation of energy meter visually.

The ratings associated with an energy meter are

1. Voltage Rating
2. Current Rating
3. Frequency Rating
4. Meter Constants.

Based on the amount of energy consumption, the driving system provides rotational torque for the moving system which in turn activates the energy registering system for reading the real energy consumption. The energy meter is operated based on induction principle in which the eddy current produced by the induction of eddy emf in the portion of the aluminium disc which creates the driving torque by the interaction of 2 eddy current fluxes.

PROCEDURE:

1. Connections are given as per the circuit diagram.
2. The DPST switch is closed to give the supply to the circuit.
3. The load is switched on.
4. Note down the ammeter, voltmeter & wattmeter reading .Also note down the time taken for 5 revolutions for the initial load.
5. The number of revolutions can be noted down by adapting the following procedure. when the red indication mark on the aluminium disc of the meter passes, start to count the number of revolutions made by the disc by using a stop watch and note it down. Repeat the above steps (4) for different load currents by varying the load for the fixed number of revolutions.

FORMULA USED:

% Error = [(True Value – Measured value) / True Value] * 100

Power = V*I

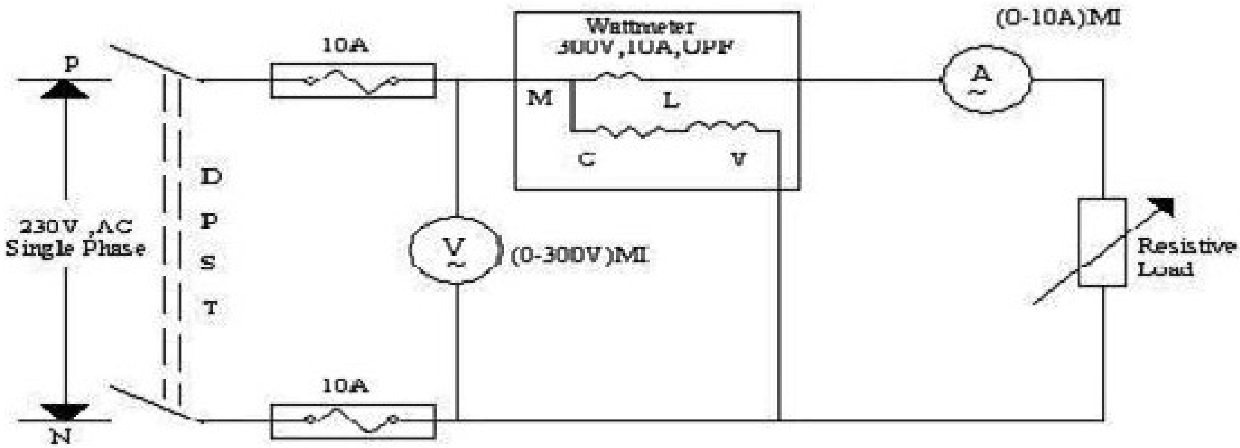
True Value = No.of.Revolution / Energy meter Constant

Measured Value = Wattmeter Reading * Time

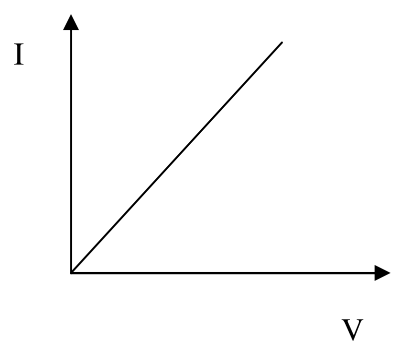
Measured Value = VI*COSθ/3600

CIRCUIT DIAGRAM :

(Calibration Of Single Phase Energy Meter)



Model Graph:



TABULATION:

Voltmeter Reading volts	Ammeter Reading amps	Wattmeter Reading watts	Time Period sec	No.of Revolution	Energy Meter Reading		% Error
					Measured	True	

RESULT:

Thus the energy is calculated by using single phase energy meter.

Exp No: 9

Date:

DESIGN OF INSTRUMENTATION AMPLIFIER

AIM:

To design and study the instrumentation amplifier and its characteristics.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	Op-Amp(IC 741)	1
2	Resistor 1k ohm	6
3	DRB	1
4	Bread Board	1
5	Connecting Wires	1

THEORY:

In industrial and consumer applications, the physical quantities such as temperature, pressure, humidity, light intensity, water flow etc is measured with the help of transducers. The output of transducer has to be amplified using instrumentation so that it can drive the indicator or display system.

The important features of an instrumentation amplifier are

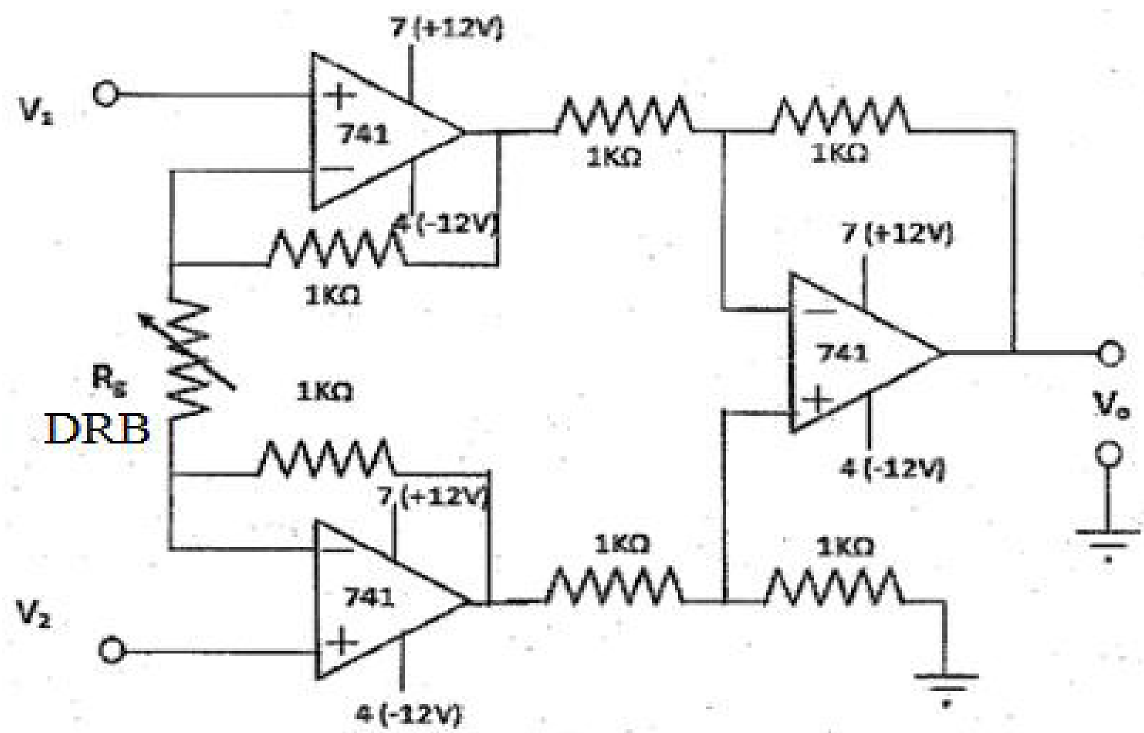
1) high Accuracy
2) High CMRR
3) High Gain Stability with low temperature coefficient
4) Low dc offset
5) Low output impedance.

The circuit diagram shows a simplified differential instrumentation amplifier. A variable resistor (DRB) is connected in one arm, which is assumed as a transducer in the experiment and it is changed manually. The voltage follower circuit and a differential OP-AMP circuit are connected as shown.

PROCEDURE:

1. Give the connections as per the circuit diagram.
2. Switch on the RPS
3. Set Rg, V1 and V2 to particular values
4. Repeat Step 3 for different values of Rg, V1 and V2
5. Calculate the theoretical output voltage using the given formula and compare with practical value.

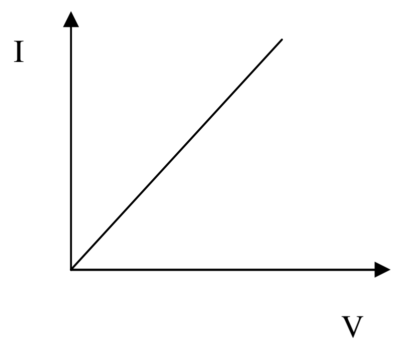
CIRCUIT DIAGRAM : (Instrumentation Amplifier)



TABULATION :

S.No	V1 volts	V2 volts	V_d= (V1-V2) volts	Vo Actual volts	Vo Observed volts	Gain A= V_{out} / V_d
1						
2						
3						
4						

Model Graph:



RESULT:

Thus the characteristic of instrumentation amplifier is studied.

Exp No: 10

Date:

ANALOG TO DIGITAL CONVERTER

AIM:

To design, setup and test the analog to digital converter using ADC.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	ADC Trainer Kit	1
2	Multimeter	1

THEORY:

Analog to Digital converters can be designed with or without the use of DAC as part of their circuitry.

The commonly used types of ADC's incorporating DAC are:

a) Successive Approximation type.

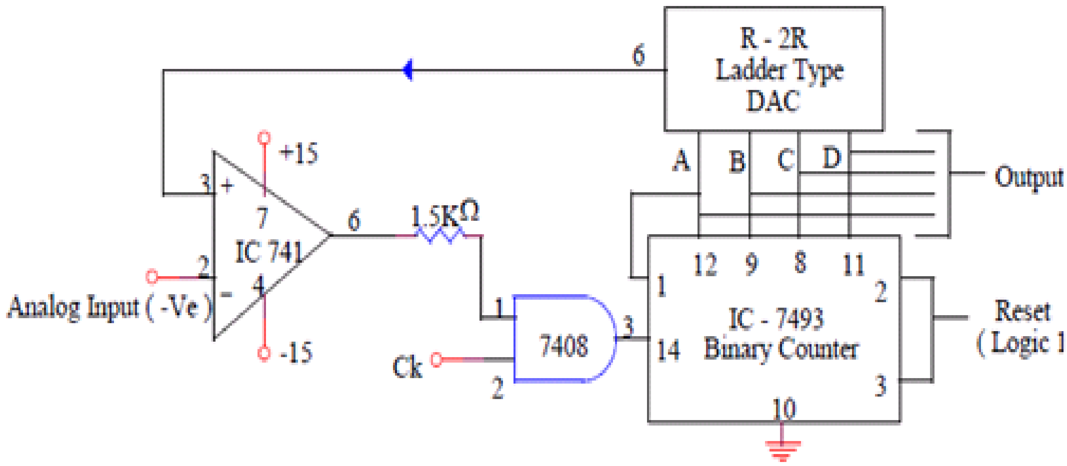
b) Counting or Ramp type.

The block diagram of a counting type ADC using a DAC is shown in the figure. When the clock pulses are applied, the contents of the register/counter are modified by the control circuit. The binary output of the counter/register is converted into an analog voltage V_P by the DAC. The V_P is then compared with the analog input voltage V_{in} .This process continues until $V_P>=V_{in}$. After which the contents of the register /counter are not changed. Thus the output of the register /counter is the required digital output.

PROCEDURE:

1. By making use of the R-2R ladder DAC circuit set up the circuit as shown in the figure.
2. Apply various input voltages in the range of 0 to 10V at the analog input terminal.
3. Apply clock pulses and observe the stable digital output at Q_D,Q_C,Q_B and Q_A for each analog input voltage

CIRCUIT DIAGRAM: Analog To Digital Converter(Adc)



TABULATION:

S.No	Analog I/P	Digital O/P
1		
2		
3		
4		

RESULT:

Thus the analog to digital converter is studied and verified.

Exp No: 11

Date:

DIGITAL –ANALOG CONVERTER

AIM:

To design, setup and test the analog to digital converter using DAC.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	DAC Trainer Kit	1
2	Multimeter	1

FORMULA USED:

4 BIT WEIGHTED RESISTOR DAC:

Output voltage Vo = Io Rf (Rf =R)

Vo = Vo (Rf/R) (d12 +d22 +……. + dn2)

R-2R LADDER NETWORK DAC:

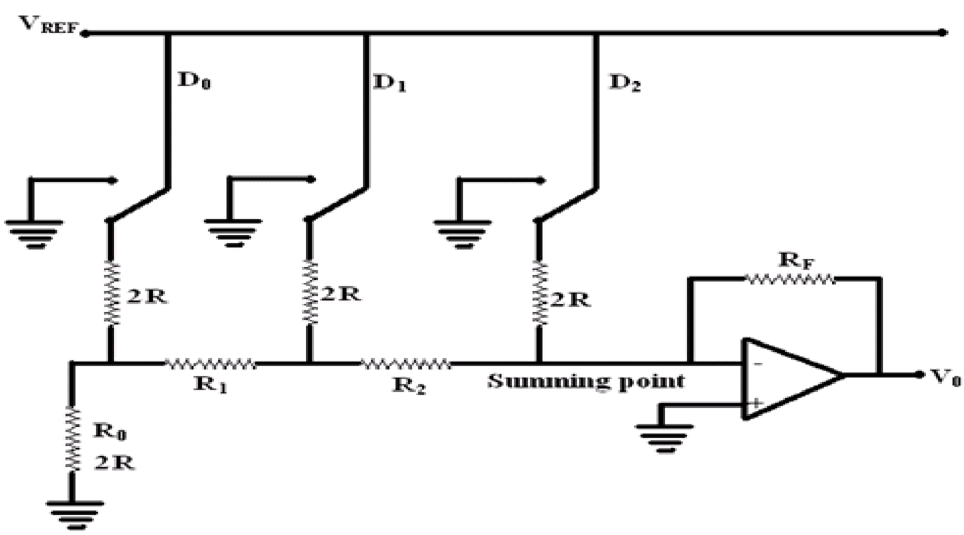
Vo = Io Rf

Vo = (V/2) (Rf/R) (d12 +d22 +……..+ dn2)

PROCEDURE:

1. The power supply is switched ON.
2. The jumpers J9 through J16 should be in s/w(right) position.
3. The switches SW1 through SW8 are placed appropriately to represent the desired input.
4. The output voltage can be observed by using a CRO/multimeter at the terminal pin 2.

CIRCUIT DIAGRAM: (Digital To Analog Converter)



TABULATION:

Sl.No	Digital Input			HEX Value	Va Output volts
	B2	B1	B0		
1					
2					
3					
4					
5					
6					
7					
8					

RESULT:

Thus the digital to analog converter is studied and verified.

Exp No : 12

Date:

DC POSITION CONTROL SYSTEM

AIM:

To control the position of loading system using DC servo motor.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	DC Servomotor control Kit	1
2	Connecting Wires	1

THEORY:

DC Servo Motor Position Control Trainer has consist of various stages. They are Position set control (Tx), Position feedback control (Rx), buffer amplifiers, summing amplifiers, error detector and power driver circuits. All these stages are assembled in a separate PCB board. Apart from these, dc servo potentiometers and a dc servomotor are mounted in the separate assembly. By Jones plug these two assemblies are connected.

The servo potentiometers are different from conventional potentiometers by angle of rotation. The Normal potentiometers are rotating up to 270ohm. But the servo potentiometers are can be rotate up to 360ohm. For example, 1Kohm servo potentiometer give its value from o to 1Kohm for one complete rotation (360ohm).

All the circuits involved in this trainer are constructed by operational amplifiers. For some stages quad operational amplifier is used. Mainly IC LM 324 and IC LM 310 are used. For the power driver circuit the power transistors like 2N 3055 and 2N 2955 are employed with suitable heat sinks.

Servo Potentiometers:

A 1 Kohm servo potentiometer is used in this stage. A + 5 V power supply is connected to this potentiometer. The feed point of this potentiometer is connected to the buffer amplifiers. A same value of another servo potentiometer is provided for position feedback control circuit. This potentiometer is mechanically mounted with DC servomotor through a proper gear arrangement. When two feed point voltages are equal, there is no moving in the motor. If the positions set control voltages are higher than feedback point, the motor will be run in one direction and for lesser voltage it will run in another direction. Buffer amplifier for transmitter and receiver and summing amplifier are constructed in one quad operational amplifier. The error detector is constructed in a single Op-Amp IC LM 310. And another quad operational amplifier constructs other buffer stages.

PROCEDURE:

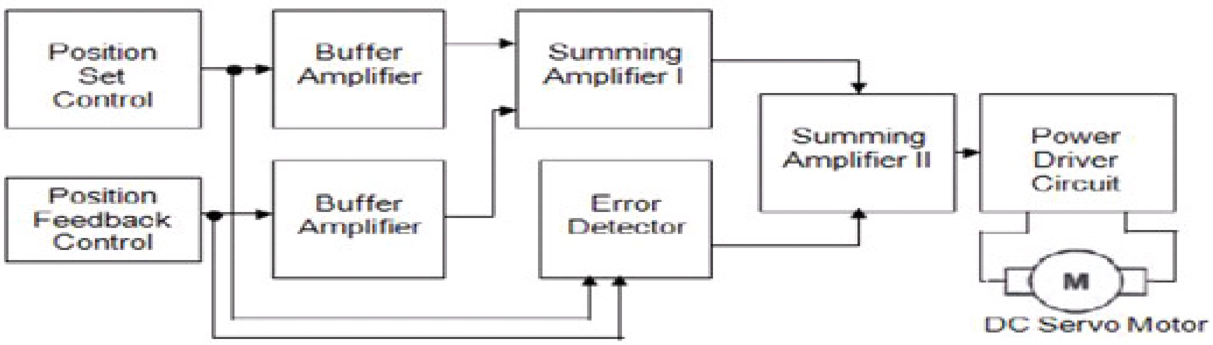
1. Connect the trainer kit with motor setup through 9 pin D connector.
2. Switch ON the trainer kit.
3. Set the angle in the transmitter by adjusting the position set control as Θ_s.
4. Now, the motor will start to rotate and stop at a particular angle which is tabulated as Θ_m.
5. Tabulate Θ_m for different set angle Θ_s.
6. Calculate % error using the formulae and plot the graph Θ_s vs Θ_m and Θ_s vs % error.

FORMULA USED:

Error in degree $= \Theta_s - \Theta_m$

Error in percentage $= ((\Theta_s - \Theta_m) / \Theta_s) * 100$

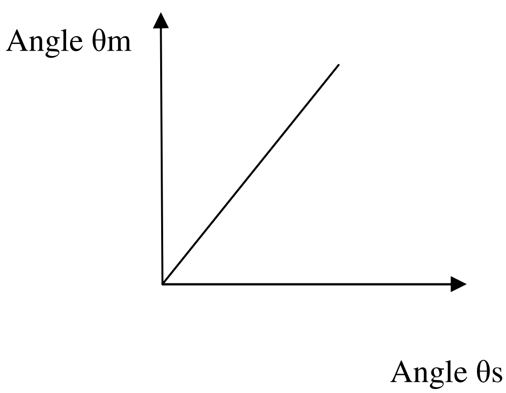
BLOCK DIAGRAM: (Dc Position Control System)



TABULATION:

S.No	Set Angle in degress (set Θ_s)	Measured Angle in degress (set Θ_m)	Error in degrees($\Theta_s - \Theta_m$)	Error in % [($\Theta_s - \Theta_m$) / Θ_s] x 100
1				
2				
3				
4				
5				

Model Graph :



RESULT:

Thus the position of loading system is controlled by using DC servo motor.

Exp No : 13

Date:

AC POSITION CONTROL SYSTEM

AIM:

To control the position of loading system using AC servo motor.

APPARATUS REQUIRED:

Sl.No	Name of the Apparatus	Qty
1	AC Servomotor control Kit	1
2	Connecting Wires	1

THEORY:

AC SERVOMOTOR POSITION CONTROL:

It is attempted to position the shaft of a AC Synchronous Motor's (Receiver) shaft at any angle in the range of 10^0 to 350o as set by the Transmitter's angular position transducer potentiometer), in the range of 10^0 to 350o. This trainer is intended to study angular position between two mechanical components (potentiometers), a Transmitter Pot and Receiver pot. The relation between these two parameters must be studied.

Any servo system has three blocks namely Command, Control and Monitor.

(a) The command is responsible for determining what angular position is desired.. This is corresponds to a Transmitter's angular position (Set Point- Sp) set by a potentiometer.

(b) The Control (servo) is an action, in accordance with the command issued and a control is initiated (Control Variable -Cv) which causes a change in the Motor's angular position. This corresponds to the receiver's angular position using a mechanically ganged potentiometer.

(c) Monitor is to identify whether the intended controlled action is executed properly or not. This is similar to feedback. This corresponds to Process Variable Pv. All the three actions together form a closed loop system.

PROCEDURE:

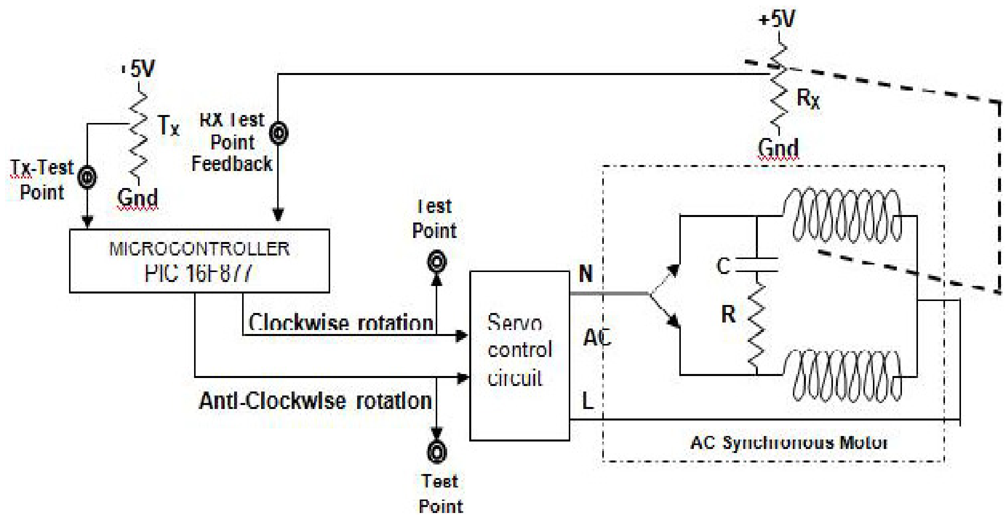
1. Connect the trainer kit with motor setup through 9 pin D connector.
2. Switch ON the trainer kit.
3. Set the angle in the transmitter by adjusting the position set control as Θ_s.
4. Now, the motor will start to rotate and stop at a particular angle which is tabulated as Θ_m.
5. Tabulate Θ_m for different set angle Θ_s.
6. Calculate % error using the formulae and plot the graph Θ_s vs Θ_m and Θ_s vs % error.

FORMULA USED:

Error in degree $= \Theta_s - \Theta_m$

Error in percentage $= ((\Theta_s - \Theta_m) / \Theta_s) * 100$

BLOCK DIAGRAM: (AC Position Control System)

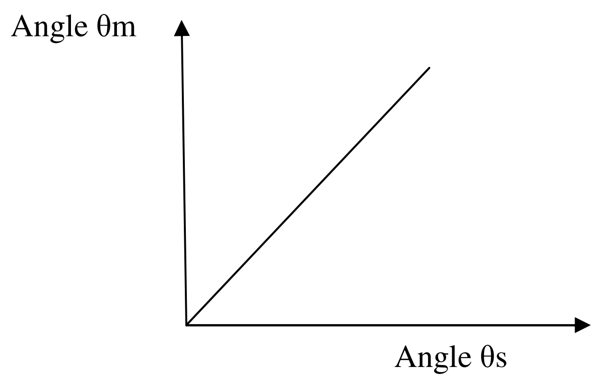


Department of Electrical and Electronics Engineering
Varuvan Vadivelan Institute of Technology, Dharmapuri – 636 703

TABULATION:

S.No	Set Angle in degress (set Θ_s)	Measured Angle in degress (set Θ_m)	Error in degrees($\Theta_s - \Theta_m$)	Error in % [($\Theta_s - \Theta_m$) /Θ_s] x 100
1				
2				
3				
4				

Model Graph :



RESULT:

Thus the position of loading system is controlled by using AC servo motor.

Exp No : 14

Date:

STABILITY ANALYSIS OF LINEAR SYSTEM

AIM:

To digitally simulate the time response characteristics of higher-order MIMO linear systems using state – variable formulation

EQUIPMENTS REQUIRED:

PC system with mat lab

THEORY:

INTRODUCTION TO MATLAB & SIMULINK

MATLAB® is a **high-performance language for technical computing**. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

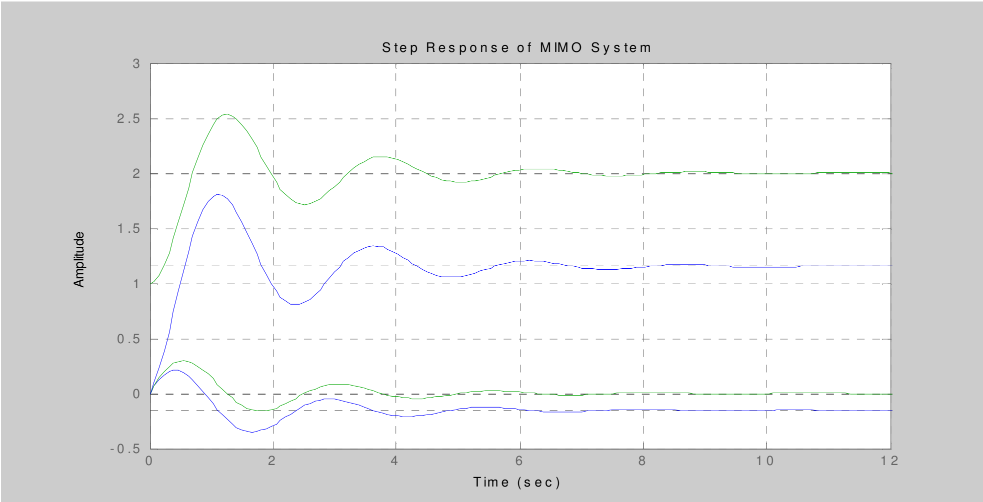
- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or FORTRAN.

The name **MATLAB** stands for **matrix laboratory**. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

MATLAB PROGRAM:

```
Open new m file and type the given program
% State Space Analysis of MIMO System
%-----X^ = Ax+Bu; y =Cx+Du -------%
A=[-1 -1; 6.5 0];   %----State Matrix-----%
B=[1 1;1 0];   %----Input Matrix------%
C=[1 0;0 1];   %----Output Matrix ------%
D=[0 0;0 1];   %----Transistion Matrix---%
step(A,B,C,D,1)
hold
step(A,B,C,D,2)
title('Step Response of MIMO System')
grid
[num1,den1]=ss2tf(A,B,C,D,1)
[num2,den2]=ss2tf(A,B,C,D,2)
n1=num1(1,:)
n2=num1(2,:)
n3=num2(1,:)
n4=num2(2,:)
d1=den1(1,:)
d2=den2(1,:)
tf1=tf(n1,d1)
tf2=tf(n2,d1)
tf3=tf(n3,d2)
tf4=tf(n4,d2)
```



MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

Starting MATLAB

Instructions for starting MATLAB® depend on your platform. For a list of supported platforms, see the system requirements in the installation documentation, or the Products section of the MathWorks . Starting MATLAB on Windows Platforms To start MATLAB on a Microsoft Windows platform, select the Start -> Programs -> MATLAB 7.0 -> MATLAB 7.0, or double-click the MATLAB shortcut icon on your Windows desktop. The shortcut was automatically created by the installer.

Transfer function of the given 4 systems

Transfer function:

```
     s - 1
-------------
s^2 + s + 6.5
```

Transfer function:

```
    s + 7.5
-------------
s^2 + s + 6.5
```

Transfer function:

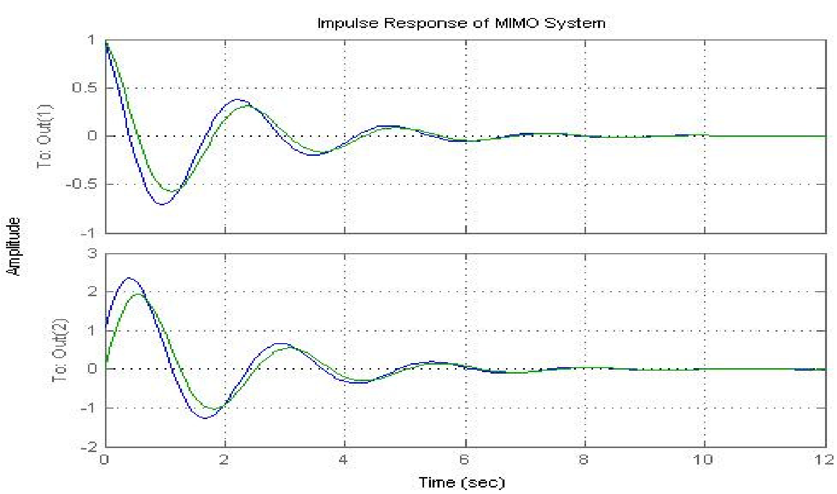
```
s + 3.553e-015
--------------
 s^2 + s + 6.5
```

Transfer function:

```
 s^2 + s + 13
-------------
s^2 + s + 6.5
```

FOR IMPULSE RESPONSE

```
response MIMO system
% State Space Analysis of MIMO System
%-----X^ = Ax+Bu; y =Cx+Du -------%
A=[-1 -1; 6.5 0];%----State Matrix-----%
B=[1 1;1 0];%----Input Mtrix------%
C=[1 0;0 1];%----Output Matrix ------%
D=[0 0;0 1];%----Transistion Matrix---%
impulse(A,B,C,D,1)
hold
impulse(A,B,C,D,2)
title('Impulse Response of MIMO System')
grid
[num1,den1]=ss2tf(A,B,C,D,1)
[num2,den2]=ss2tf(A,B,C,D,2)
n1=num1(1,:)
n2=num1(2,:)
n3=num2(1,:)
n4=num2(2,:)
d1=den1(1,:)
d2=den2(1,:)
tf1=tf(n1,d1)
tf2=tf(n2,d1)
tf3=tf(n3,d2)
tf4=tf(n4,d2)
```



RESULT:

Thus the time response characteristics of higher-order MIMO linear systems using state – variable formulation is simulated.

Ex.NO :15
Date:

Stability Analysis of Linear Systems

AIM:

To analyze the stability of linear systems using Bode, Root locus, Nyquist plots

EQUIPMENTS REQUIRED:

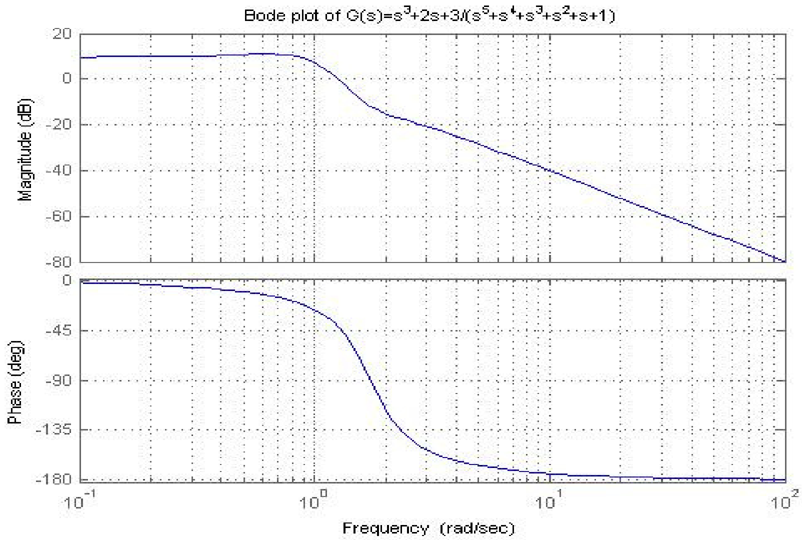
PC system with mat lab

PROGRAM:

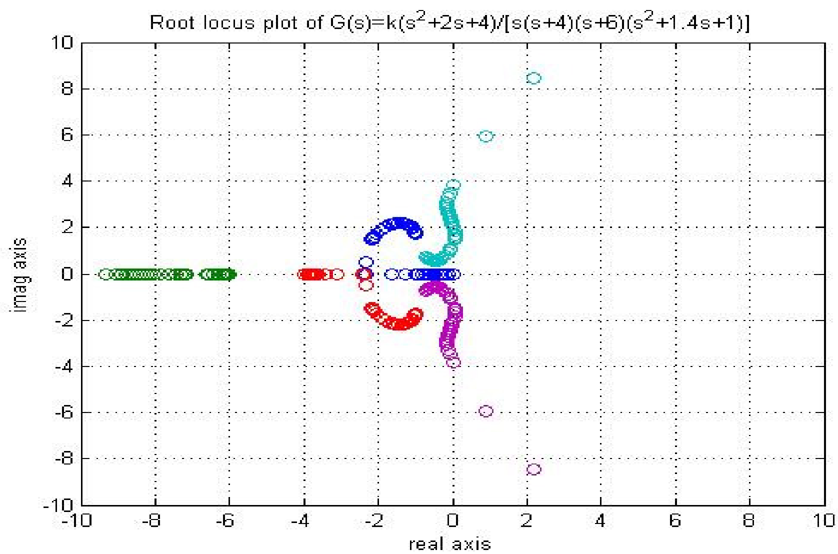
STABILITY ANALYSIS
Program For Nyquist Plot.

```
%---Given System G(s)=1/(s^2+0.8s+1)-----%
%--------Nyquist plot-----------%
num=[0 0 1];
den=[1 0.8 1];
nyquist(num,den);
axis(v)
grid
title('Nyquist plot of G(s)=1/(s^2+0.8s+1)')
xlabel('Real axis')
ylabel('Imag axis')
hold on
```

BODE PLOT



ROOT LOCUS



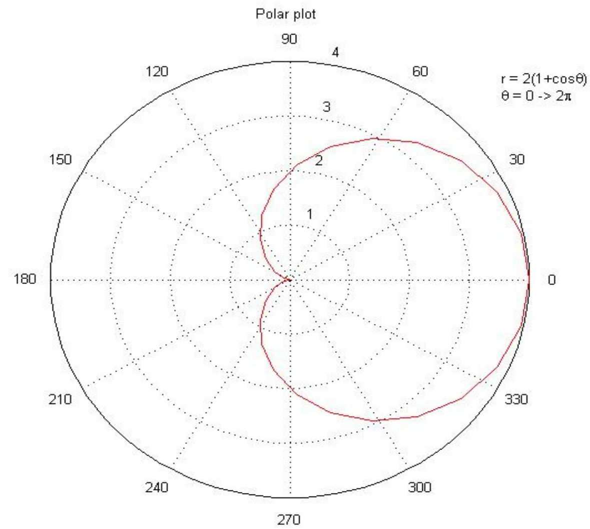
PROGRAM FOR ROOT LOCUS

```
%---conditionally stable system--%
%---Given System G(s)=k(s^2+2s+4)/[s(s+4)(s+6)(s^2+1.4s+1)-----%
clc;
close all;
clear all;
%--------Root Locus----------%
numz=[0 0 0 1 2 4];
denp=[1 11.4 39 43.6 24 0];
r=rlocus(numz,denp);
plot(r,'o');
axis(v)
grid
title('Root locus plot of
G(s)=k(s^2+2s+4)/[s(s+4)(s+6)(s^2+1.4s+1)]')
xlabel('real axis')
ylabel('imag axis')
hold
```

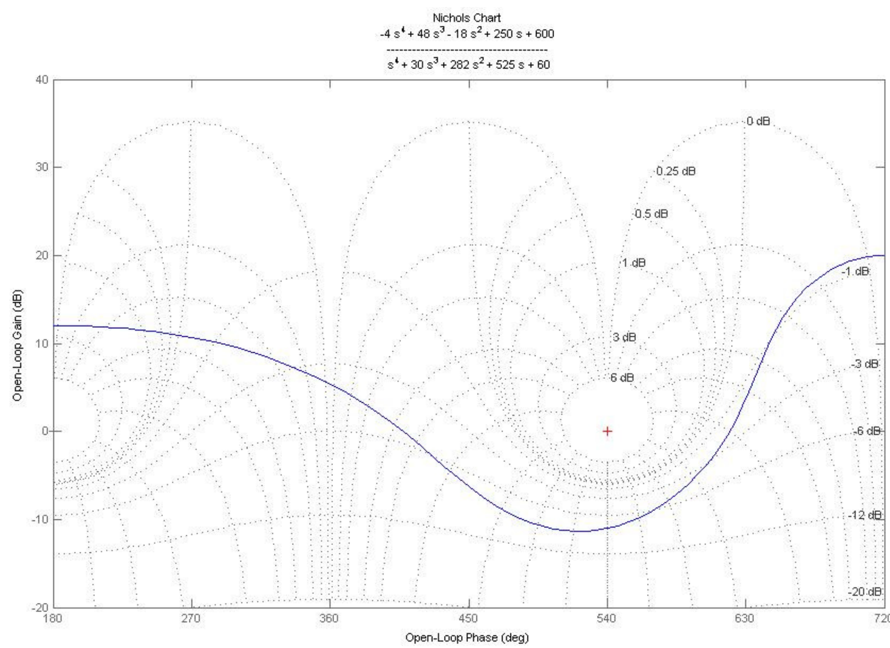
PROGRAM FOR BODE PLOT

```
%---Given System=s^3+2s+3/(s^5+s^4+s^3+s^2+s+1)---%
%--------Bode Plot ----------%
numg=[1 0 2 3];
deng=[1 1 1 1 1 1 ];
'G(s)'
u=tf(numg,deng);
bode(u)
grid
hold
title('Bode plot of G(s)=s^3+2s+3/(s^5+s^4+s^3+s^2+s+1)')
[Gm,Pm,Wcg,Wcp] = margin(u)
Gm_dB = 20*log10(Gm)
```

POLAR PLOT



NICHOLS CHAR



Program For Polar Plot

```
format compact
set (gcf,'Toolbar','none','Name','Polar Plot', ...
    'Number Title','off','Position',[10,350,350,300]);
theta = 2*pi*linspace(0,1,30);
r = 2*(1 + cos(theta));
Polar (theta,r,'r-')
Set (gca,'Position',[0.1 0.1 0.75 0.75]);
Title ('\bf\itA Polar
Plot','Color','k','VerticalAlignment','bottom')
textstr (1)={'r = 2(1+cos\theta)'};
textstr(2)={'\theta = 0 -> 2\pi'};
text(5*cos(pi/4),5*sin(pi/4), ...
    strcat(textstr))
title('Polar plot ')
    hold
```

Program for Nichols Chart

```
%Plot the Nichols response of the system
num = [-4 48 -18 250 600];
den = [1 30 282 525 60];
H = tf(num,den)
nichols(H); ngrid
```

RESULT:

Thus the stability of linear systems using Bode, Root locus, Nyquist plots is analysed.

EX.NO :16

Date:

STUDY THE EFFECT OF P, PI, PID CONTROLLERS USING MAT LAB

AIM:

To Study the effect of P, PI, PID controllers using Mat lab**.**

THEORY

1 Choice of the Controller type

In so far were described proportional, integrative and derivative modes of the controllers and a rational behind their use was explained. However, excerpt for a few tips, an attention was not given to a question when to use different types of controllers. The rest of this section will give some answers on that particular topic.

1.1 On-off Controller

On-off controller is the simplest controller and it has some important advantages. It is economical, simple to design and it does not require any parameter tuning. If oscillations will hamper the operation of the system and if controller parameter tuning is to be avoided, on-off controller is a good solution. In addition, if actuators work in only two modes (on and off), then it is almost always only controller that can be used with such actuators. That is a reason why on-off controllers are often used in home appliances (refrigerators, washers etc.) and in process industry when control quality requirements are not high (temperature control in buildings etc.). Additional advantage of on-off controllers is that they in general do not require any maintenance.

1.2 P Controller

When P controller is used, large gain is needed to improve steady state error. Stable system do not have a problems when large gain is used. Such systems are systems with one energy storage (1st order capacitive systems). If constant steady state error can be accepted with such processes, than P controller can be used. Small steady state errors can be accepted if sensor will give measured value with error or if importance of measured value is not too great anyway. Example of such system is liquid level control in tanks when exact approximate level of liquid suffice for the proper plant operation. Also, in cascade control sometime it is not important if there is an error inside inner loop, so P controller can a good solution in such cases.

Derivative mode is not required if the process itself is fast or if the control system as whole does not have to be fast in response. Processes of 1st order react immediately on the reference signal change, so it is not necessary to predict error (introduce D mode) or compensate for the steady state error (introduce I mode) if it is possible to achieve satisfactory steady state error using only P controller.

1.3 PD controller

It is well known that thermal processes with good thermal insulation act almost as integrators. Since insulation is good and thermal losses are small, the most significant art of the energy that is led to the system is used temperature rise. Those processes allow 18 for large gains so that integral mode in the controller is not needed. These processes can be described as different connections of thermal energy storages. Thermal energy is shifted from one storage into another. In general, with such processes there is present a process dynamics with large inertia. Since dynamics is slow, derivative mode is required for control of such processes. Integral mode would only already slow dynamics make more slowly. The other reason for using PPD controllers in such systems are that is possible to measure temperature with low level of noise in the measured signal.

PD controller is often used in control of moving objects such are flying and underwater vehicles, ships, rockets etc. One of the reason is in stabilizing effect of PD controller on sudden changes in heading variable y(t). Often a "rate gyro" for velocity measurement is used as sensor of heading change of moving object.

1.3 PI controller

PI controllers are the most often type used today in industry. A control without D mode is used when:

a) fast response of the system is not required
b) large disturbances and noise are present during operation of the process
c) there is only one energy storage in process (capacitive or inductive)
d) there are large transport delays in the system

If there are large transport delays present in the controlled process, error prediction is required. However, D mode cannot be used for prediction because every information is delayed till the moment when a change in controlled variable is recorded. In such cases it is better to predict the output signal using mathematical model of the process in broader sense (process + actuator). The controller structures that can be used are, for example, Otto-Smith predictor (controller), PIP controller or so called Internal Model Controller (IMC).

An interesting feature of IMC is that when the model of the process is precise

(A = AM and B = BM), then a feedback signal eM = y – yM is equal to disturbance:

$$e_M = y - y_M = \frac{B}{A} u_{IMC} + d - \frac{B_M}{A_M} u_{IMC} = d \,,$$

It follows that a control signal is not influenced by the reference signal and control systems behaves as open loop. A usual problems with stability that arrise when closed loop systems are used are then avoided. Control system with IMC controller will be stable and if IMC and process are stable. With the exact model of process IMC is actually a feed forward controller and can designed as such, but, unlike feed forward controllers, it can compensate for unmeasured disturbances because feedback signal is equal to disturbance, which allows suitable tuning of the reference value of the controller.

If model of the process is not exact5 (AM =□A, BM □=B), then feedback signal eM will contain not only disturbance d but a modeling error, $\left[\left(\frac{B}{A}-\frac{B_M}{A_M}\right)u_{IMC}\right]$ also. Thus, a feedback will have its usual role, and stability problem can arise. This requires for parameters6 to be tuned again so the stability is not lost.

1.4 PID controller

Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot are for the most part PID type controllers.

1.5 Topology of PID controllers

Problem of topology (structure) of controller arises when:

- designing control system (defining structure and controller parameters)
- tuning parameters of the given controller

There are a number of different PID controller structures. Different manufacturers design controllers in different manner. However, two topologies are the most often case:

- parallel (non-interactive)
- serial (interactive)

Parallel structure is most often in textbooks, so it is often called "ideal" or "textbook type". This non-interactive structure because proportional, integral and derivative mode are independent on each other. Parallel structure is still very rare in the market. The reason for that is mostly historical. First controllers were pneumatic and it was very difficult to build parallel structure using pneumatic components. Due to certain conservatism in process industry most of the controller used there are still in serial structure, although it is relatively simple to realize parallel structure controller using electronics. In other areas, where tradition is not so strong, parallel structure can be found more often.

1.5.1 Parallel PID topology

A parallel connection of proportional, derivative and integral element is called parallel or non-interactive structure of PID controller. Parallel structure is shown in Fig.

It can be seen that P, I and D channels react on the error signal and that they are unbundled. This is basic structure of PID controller most often found in textbooks. There are other non-interactive structures.

CIRCUIT DIAGRAM (EFFECT OF P, PI, PID CONTROLLERS)

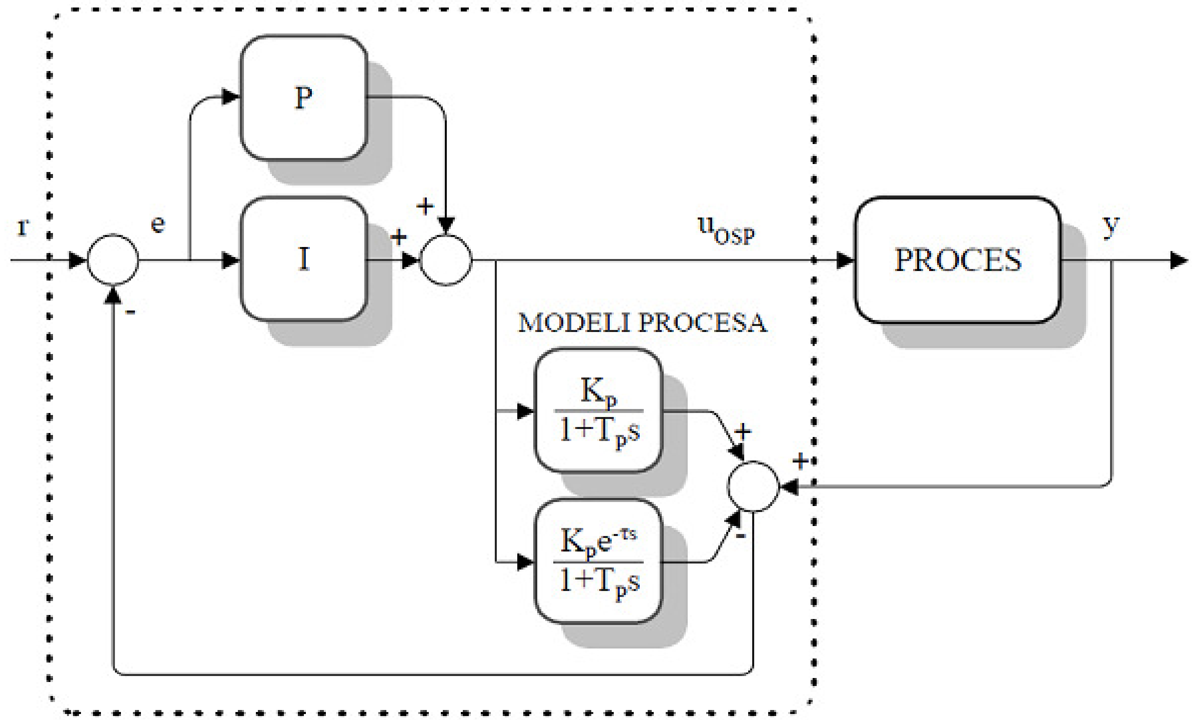


Fig. Otto-Smith controller for systems with transport delay

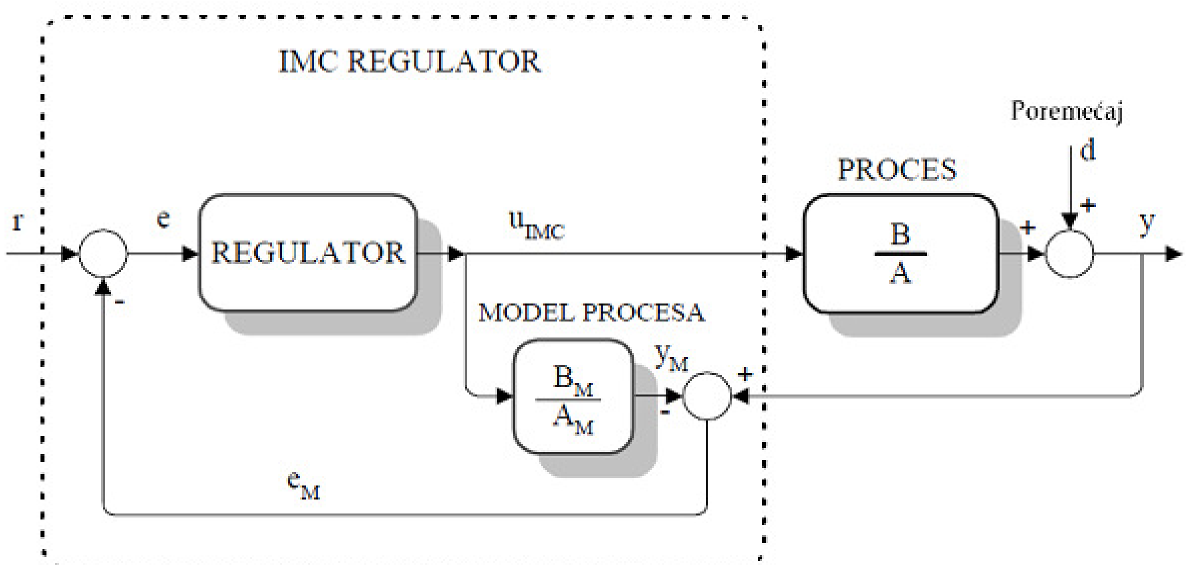


Fig. Structure of IMC

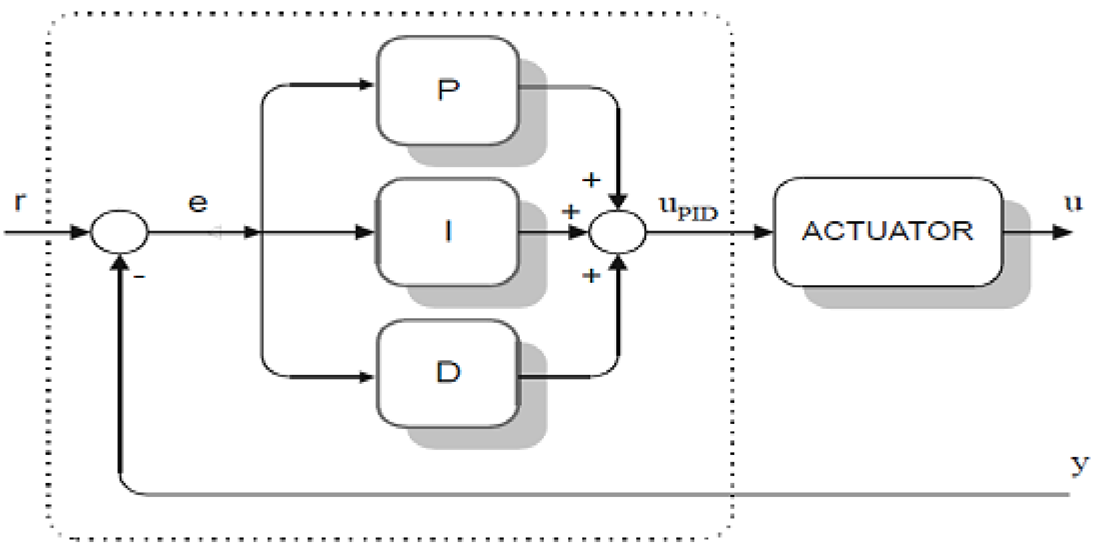


Fig. : Parallel structure of PID controller

RESULT:

Thus the effect of P, PI, PID controllers using Mat lab are studied.

EX.NO :17

Date:

DESIGN AND IMPLEMENTATION OF COMPENSATORS

AIM:

To study the compensation of the second order process by using lead – Lag Compensator

EQUIPMENT REQUIRED:

1. LEAD – Lag network system kit
2. Capacitors – 0.1µF
3. Decade Resistance Box
4. CRO

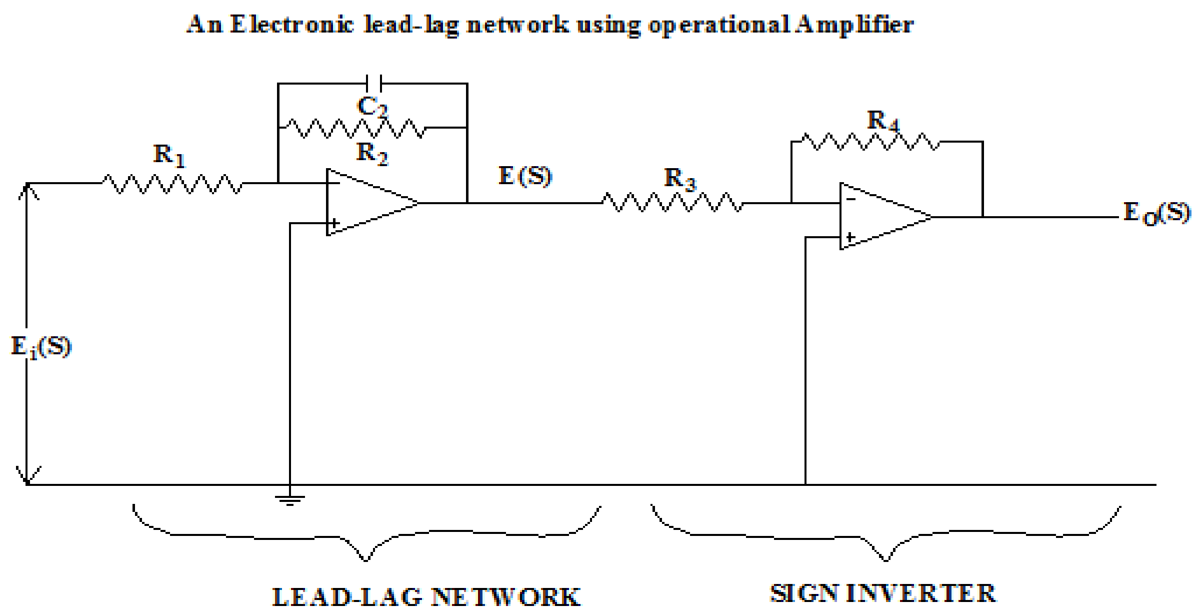
DESIGN:

1. Lead – Lag network using operational amplifier:
2. An electronic lead –lag network using operational Amplifier is shown in Fig.

PROCEDURE:

3. Switch ON the power to the instrument.
4. Connect the individual blocks using patch chords bypassing the compensating network and gain as shown in fig. 4.2.
5. Give a sinusoidal input as the set value to the error detector.
6. Measure the amplitude and frequency of the input signal.
7. Measure the amplitude and phase difference of the output signal with respect to the input signal using DSO.
8. Using the technique explained previously, calculate the values of R1, R2, C2, and C1 to compensate for the phase shift of the output signal.
9. Connects the components at the points provided.
10. Now include the compensation block in the forward path before the process using patch chords as shown in fig.4.2.
11. Observe the compensated wave form through DSO.

CIRCUIT DIAGRAM: (Lead-Lag Compensators)



TABULATION: (Lead-Lag Compensators)

Si No	**Amplitude (V)**	**Frequency (Hz)**	**Phase Shift**	**R1 (Ohms)**	**C1 (F)**	**R2** (Ohms)	**C2 (F)**

The transfer function for this circuit can be obtained as follows:

Let

$Z_1 = R_1 \parallel C_1$

$Z_2 = R_2 \parallel C_2$

The second op-amp acts as a sign inverter with a variable gain to compensate for the magnitude. The transfer function of the entire system is given by G(jω).

$$G(s) = \frac{R_4 R_2 (1 + R_1 C_1 s)}{R_3 R_1 (1 + R_2 C_2 s)}$$

We have

$$|G(j\omega)| = \frac{R_2 R_4 \sqrt{(1 + T_1^2 \omega^2)}}{R_1 R_3 \sqrt{(1 + T_2^2 \omega^2)}}$$

Where

$T_1 = R_1 C_1$

$T_2 = R_2 C_2$ and

Thus the steady state output is

$$Y_{ss}(t) = \frac{R_2 R_4 \sqrt{(1 + T_1^2 \omega^2)}}{R_1 R_3 \sqrt{(1 + T_2^2 \omega^2)}} Sin(\omega t \quad \tan{}^{1} T_1 \omega \quad \tan{}^{1} T_2 \omega)$$ for an input Esint.

From this expression, we find that if $T_1 > T_2$, then $\tan{}^{1} T_1 \omega \quad \tan{}^{1} T_2 \omega > 0$. Thus if $T_1 > T_2$, then the network is a lead network. If $T_1 < T_2$, the network is a lag network.

Determination of values for angle compensation:

Frequency of sine wave (f)= 20Hz.

Phase angle to be compensated $= 14.5^0$

$$\varphi = \tan{}^{1}(2\pi f T_1) \quad \tan{}^{1}(2\pi f T_2)$$
$$Let\, T_1 = 0.1\sec$$
$$14.5 = \tan{}^{1}(2\pi * 20 * 0.1) \quad \tan{}^{1}(2\pi * 20 * T_2)$$
$$T_2 = 0.023\sec$$

<u>CALCULATION: (frequency =   Hz)</u>

Hence the values of T_1 and T_2 are chosen from which the values of R_1, R_2, C_1, and C_2 can be determined. For Example,

$$T_1 = R_1C_1 = 0.1;$$

If $C_1 = 0.1\mu F$, $R_1 = 1M\Omega$

$$T_2 = 0.023 sec$$

If $C_2 = 0.1\ \mu F$, $R_2 = 230K\Omega$.

These values produce a phase lead of 14.5^o, which is the desired compensation angle.

RESULT:

Thus the compensator is designed for the given process and the performance of the compensated system is found to work satisfactorily.

Frequency : Hz R_1 = C_1 =

R_2 = C_2 =

Frequency : Hz R_1 = C_1 =

R_2 = C_2 =