SRM VALLIAMMAI ENGINEERING COLLEGE

SRM Nagar, Kattankulathur – 603 203

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

1905506 - CONTROL AND INSTRUMENTATION

LABORATORY MANUAL

(2019 REGULATION)

2022-2023 ODD SEMESTER

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1905506 - CONTROL AND INSTRUMENTATION LAB

SYLLABUS

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.

BEYOND THE SYLLABUS EXPERIMENTS

1. Analog simulation of Type – 0 and Type – 1 Systems.
2. Determination of transfer function of AC Servomotor.

LIST OF EXPERIMENTS:

1. (a) Wheatstone Bridge

(b) Kelvin's Double Bridge

2. (a)Maxwell's Bridge

(b) Schering Bridge

3. (a) Study of Displacement Transducer – LVDT

(b) Study of Pressure Transducer – Bourdon Tube

4. Calibration of Single Phase Energy Meter

5. (a) Calibration of Wattmeter

(b) Design of Instrumentation Amplifier

6. (a)Analog – Digital converters

(b)Digital –Analog Converters

7. (a) Determination of Transfer Function of DC generator

(b) Determination of Transfer Function of DC motor

8. (a) DC Position Control System

(b) AC Position Control System

9. Synchro-Transmitter- Receiver and Characteristics

10. Design of Lag, Lead and Lag-Lead Compensators

11. (a) Simulation of Control Systems by Mathematical development tools

(b) Stability Analysis

12. Process Simulation

13. (a) Study of P, PI, PD and PID Controllers

(b) Time Domain and Frequency Domain Specifications

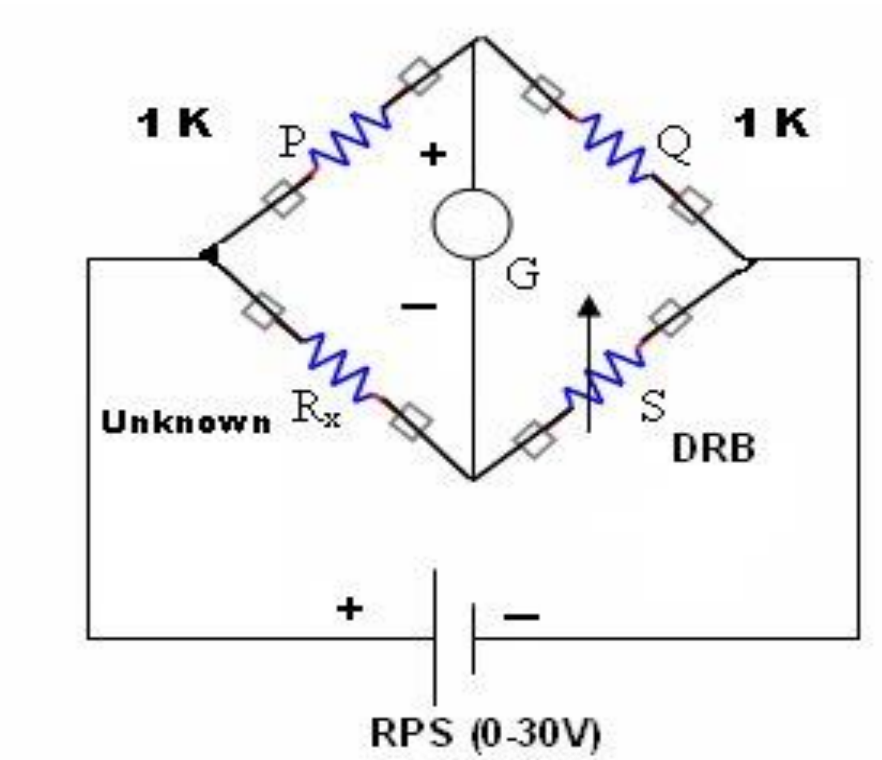
Additional Experiments

1. Analog simulation of Type – 0 and Type – 1 Systems

2. Determination of transfer function of AC Servomotor

CIRCUIT DIAGRAM

WHEATSTONE BRIDGE



Ex. No:

Date:

1(a).WHEATSTONE BRIDGE

AIM:

To measure the given medium resistance using Wheatstone bridge.

APPARATUS REQUIRED:

S.No	Name of the Trainer Kit/ Components	Quantity
1.	Wheatstone bridge trainer Kit	1
2.	Unknown Resistors specimen	5 different values
3.	Connecting wires	4
4.	DMM	1
5.	CRO	1

THEORY:

Wheatstone bridge trainer consists of basic bridge circuit as screen printed on front panel with a built in 1 kHz oscillator and an isolation transformer. The arm AC and AD consists of a 1KΩ resistor. Arms BD consists of variable resistor. The unknown resistor (R_x) whose value is to be determined is connected across the terminal BC .The resistor R_2 is varied suitably to obtain the bridge balance condition. The DMM is used to determine the balanced output voltage of the bridge circuit.

For bridge balance,

$$I_1R_1 = I_2R_2$$

For the galvanometer current to be zero the following conditions also exists

$I_1 = I_x = \frac{E}{R_1 + R_x}$ and $I_2 = I_3 = \frac{E}{R_2 + R_3}$

E = EMF of the supply, combining the above equations we obtain

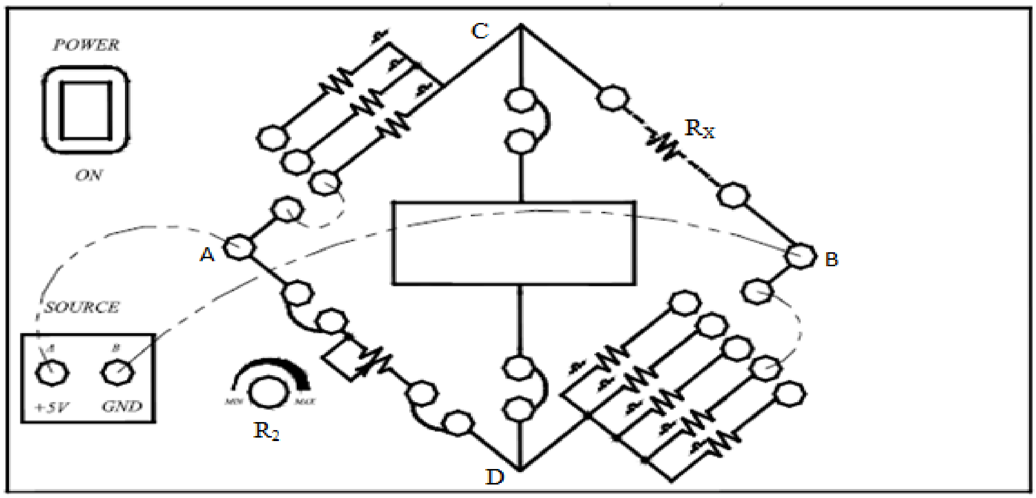
$$\frac{E}{R_1 + R_x} R_1 = \frac{E}{R_2 + R_3} R_2$$

The unknown resistance. $R_x = \frac{R_1 R_3}{R_2}$ If three of the resistances are known, the fourth may be determined.

PROCEDURE:

1. Connect the unknown resistor in the arm marked R_x.
2. Connect the DMM across the terminal CD and switch on the trainer kit.
3. Vary R_2 to obtain the bridge balance condition.
4. Find the value of the unknown resistance R_x using DMM after removing wires.
5. Compare the practical value with the theoretical value of unknown resistance R_x calculated using the formula.

PANEL DIAGRAM



TABULATION:

Sl.No	**R_1 (Ω)**	**R_2 (Ω)**	**R_3 (Ω)**	**Rx(Ω) (Actual)** $R_x = \frac{R_1 R_3}{R_2}$	**Rx(Ω) (Observed)**	**Percentage Error [(Actual-observed)/ Actual] x100**
1						
2						
3						
4						
5						

MODEL CALCULATION:

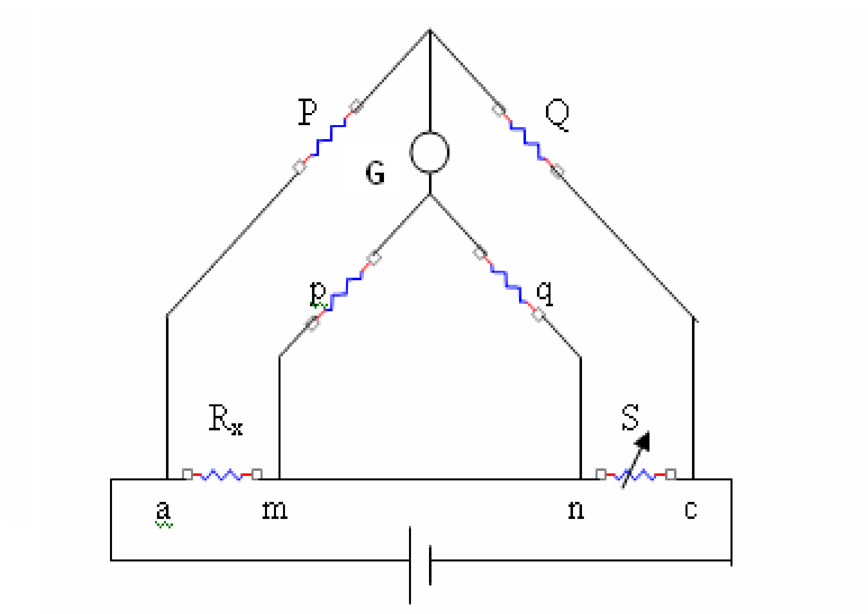
RESULT:

Review Questions

1. What are the applications of Wheatstone bridge?
2. What are standard arm and ratio arm in Wheatstone bridge?
3. What are the detectors used for DC Bridge?
4. What do you meant by sensitivity?
5. Why Wheatstone bridge cannot be used to measure low resistances?

CIRCUIT DIAGRAM

KELVIN'S DOUBLE BRIDGE



Ex. No:
Date:

1(b). KELVIN'S DOUBLE BRIDGE

AIM:

To measure the given low resistance using Kelvin's Double bridge.

APPARATUS REQUIRED:

S.No	Name of the Trainer Kit/ Components	Quantity
1.	Kelvin's Double bridge trainer kit	1
2.	Unknown Resistors specimen	5
3.	Connecting wires	6
4.	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 P/Q is kept the same as p/q, these ratios have been varied until the galvanometer reads zero.

Balance Equation:

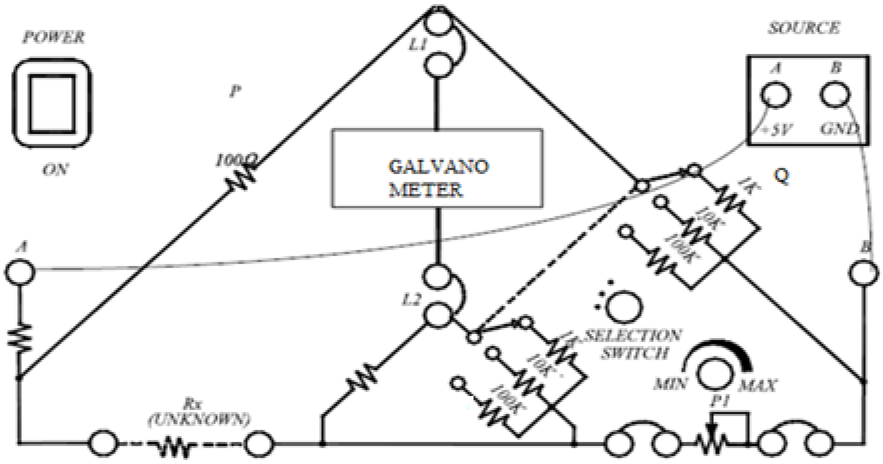
For zero balance condition,

$$\frac{P}{P+Q} I\left[R+S+\frac{(p+q)r}{p+q+r}\right] = I\left[R+\frac{p}{p+q}\left(\frac{(p+q)r}{p+q+r}\right)\right]$$ If $\frac{P}{Q}=\frac{p}{q}$ Then unknown resistance $R_x = \frac{P}{Q}P_1$

PROCEDURE:

1. Connect the unknown resistance Rx as marked on the trainer
2. Connect a galvanometer G externally as indicated on the trainer
3. Energize the trainer and check the power to be +5 V.
4. Select the values of P and Q such that P/Q = p/q = 500/50000 = 0.01
5. Adjust P_1 for proper balance and then at balance, measure the value of P_1.

PANEL DIAGRAM



TABULATION:

Sl.No	P (Ω)	Q (Ω)	P_1(Ω)	R_x(Ω) (Actual) $R_x = \frac{P}{Q} P_1$	R_x(Ω) (Observed)	% Error [(Actual-observed)/ Actual] x100

MODEL CALCULATION:

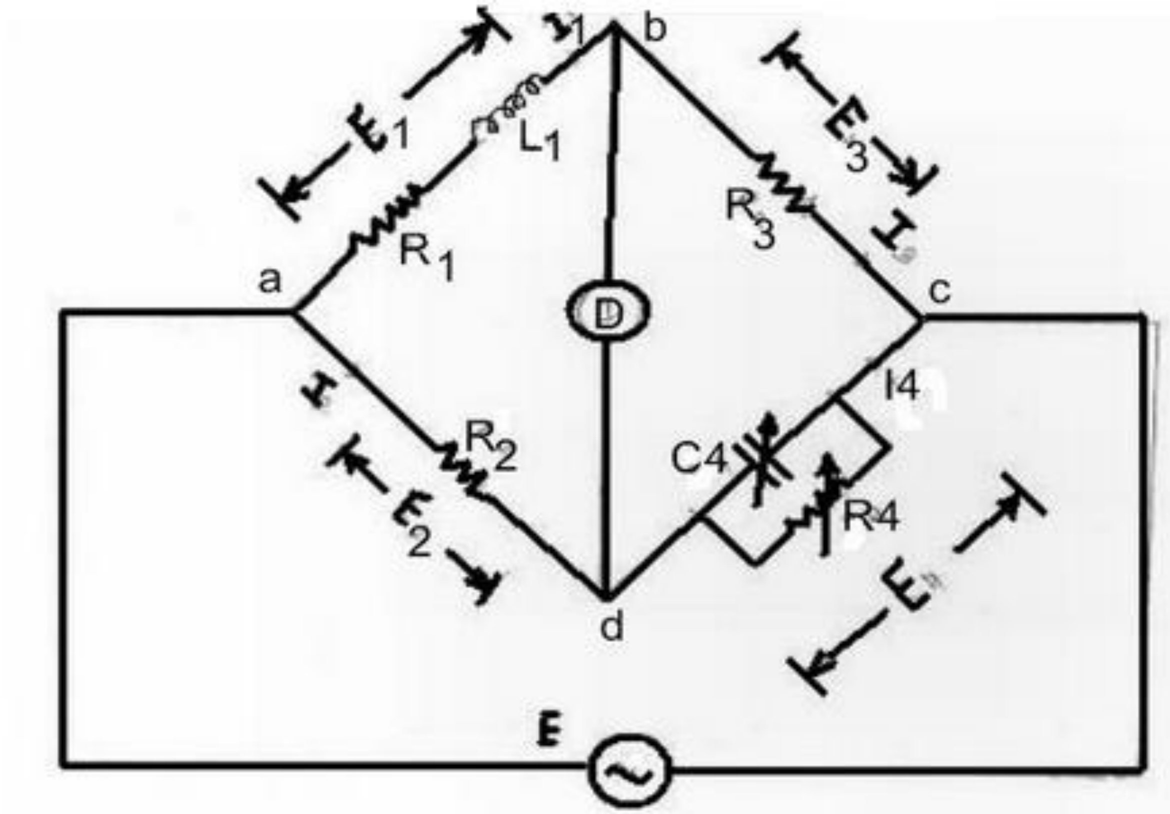
RESULT:

REVIEW QUESTIONS

1. Name the bridge used for measuring very low resistance.
2. Classify the resistances according to the values.
3. Write the methods of measurements of low resistance
4. What is the use of lead resistor in kelvin’s Double bridge?
5. Why Kelvin’s double bridge is having two sets of ratio arms?

CIRCUIT DIAGRAM

MAXWELL'S BRIDGE



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Date:

2(a). MAXWELL'S BRIDGE

AIM:

To measure the unknown inductance and Q factor of a given coil.

APPARATUS REQUIRED :

S.No	Name of the Trainer Kit/ Components	Quantity
1.	Maxwell's inductance- capacitance bridge trainer kit	1
2.	Unknown inductance specimen	3 different values
3.	Connecting wires	5
4.	Head phone/ CRO	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.

writing the equation for balance condition,

$$(R_1 + j\omega L_1)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = R_2 R_3$$

separating the real and imaginary terms, we have

$$R_1 = \frac{R_2 R_3}{R_4} L_1 = R_2 R_3 C_4$$

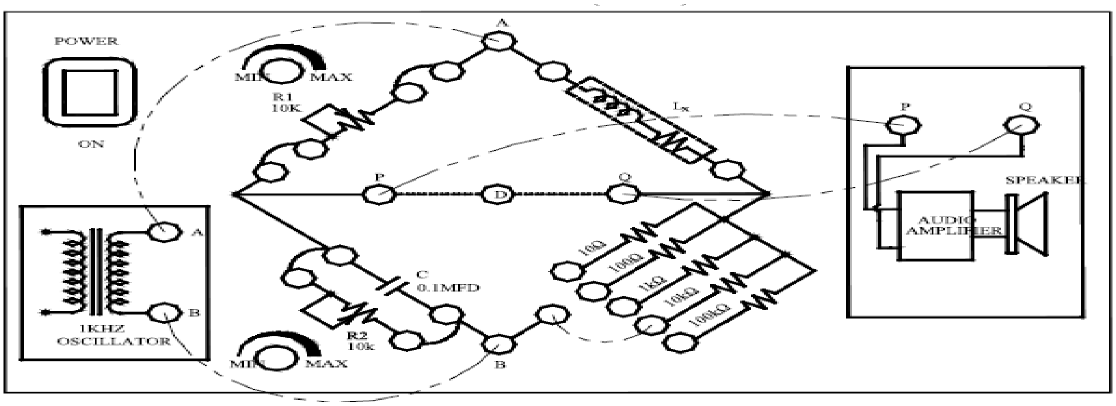
Thus we have two variables R_4 and C_4 which appear in one of the two balance equations and hence the two equations are independent. The expression for Q factor is given by

$$Q = \frac{\omega L_1}{R_1} = \omega C_4 R_4$$

FORMULA USED:

$$L_x = R_1 R_3 C \qquad Q = \frac{\omega L_x}{R_x} R_x = \frac{R_1 R_3}{R_2}$$

PANEL DIAGRAM



TABULATION:

Sl. No.	R_1 (Ω)	R_3 (Ω)	C (μF)	L_x (mH) Actual $L_x=R_1R_3C$	L_x (mH) Observed	Quality factor $Q=\omega L_x/R_x$

MODEL CALCULATION:

Procedure:

1. Connections are made as per the circuit diagram.
2. Connect the unknown inductance in the arm marked L_x.
3. Switch on the trainer kit.
4. Observe the sine wave at secondary of isolation transformer on CRO.
5. Vary R_4 and C_4 from minimum position in the clockwise direction to obtain the bridge balance condition.
6. Connect the CRO between ground and the output point to check the bridge balance.

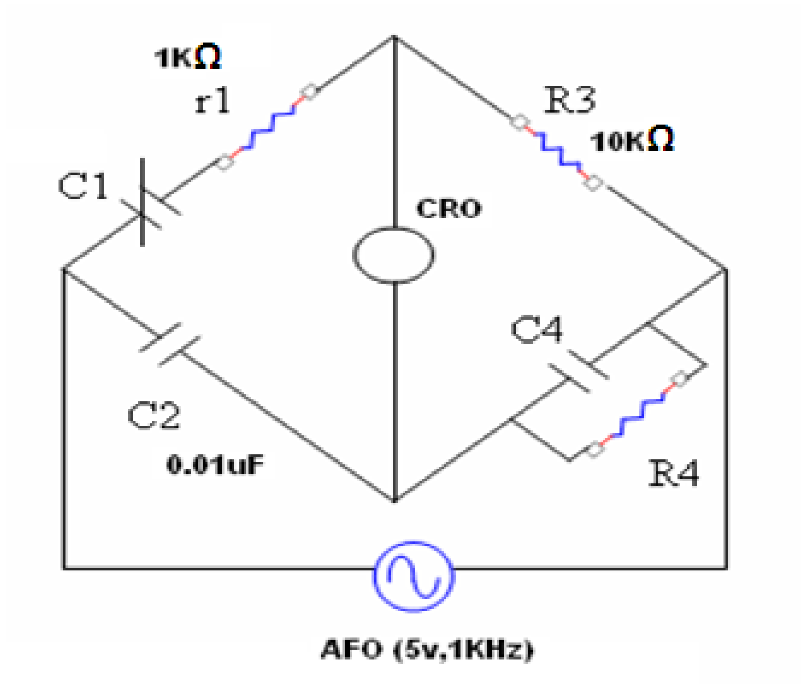
RESULT:

REVIEW QUESTIONS

1. What are the sources of errors in AC bridges?
2. List the various detectors used for AC Bridges.
3. Define Q factor of an inductor. Write the equations for inductor Q factor with RL series and parallel equivalent circuits.
4. Why Maxwell's inductance bridge is suitable for medium Q coils?
5. State merits and limitations of Maxwell's bridge when used for measurement of unknown inductance.

CIRCUIT DIAGRAM:

SCHERING BRIDGE



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2(b). SCHERING BRIDGE

AIM:

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

APPARATUS REQUIRED:

S. No.	Components / Equipments	Quantity
1.	Schering's bridge trainer kit	1
2.	Decade Capacitance Box	1
3.	Digital Multimeter	1
4.	CRO	1
5.	Connecting wires	5

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,

$Z_1Z_4=Z_2Z_3$

$$\left(r_1+\frac{1}{j\omega C_1}\right)\left(\frac{R_4}{1+j\omega C_4R_4}\right)=\frac{1}{j\omega C_2}.R_3$$

$$\left(r_1+\frac{1}{j\omega C_1}\right)R_4=\frac{R_3}{j\omega C_2}(1+j\omega C_4R_4)$$

$$r_1R_4-\frac{jR_4}{\omega C_1}=-j\frac{R_3}{\omega C_2}+\frac{R_3R_4C_4}{C_2}$$

Equating the real and imaginary terms, we obtain

$$r_1 = R_3\frac{C_4}{C_2} \quad and \quad C_1=C_2\frac{R_4}{R_3}$$

TABULATION:

S.No.	C_2 (μF)	$R_3(\Omega)$	$R_4(\Omega)$	C_1(μF)		Dissipation factor (D_1)
				True value	Measured Value $=C_2(R_4/R_3)$	

MODEL CALCULATION:

Two independent balance equations are obtained if C_4 and R_4 are chosen as the variable elements.

Dissipation Factor:

The dissipation factor of a series RC circuit is defined as a co-tangent of the phase angle and therefore by definition the dissipation factor is

$$D_1 = \tan\delta = \omega C_1 r_1 = \omega.\left(\frac{C_2 R_4}{R_3}\right) \times \left(\frac{R_3 C_4}{C_2}\right) = \omega C_4 R_4$$

FORMULAE USED:

$C_x = \frac{R_4}{R_3} C_2 D_1 = \omega C_4 R_4$ where $C_4 = C_x$ & $R_4 = R_x$

PROCEDURE:

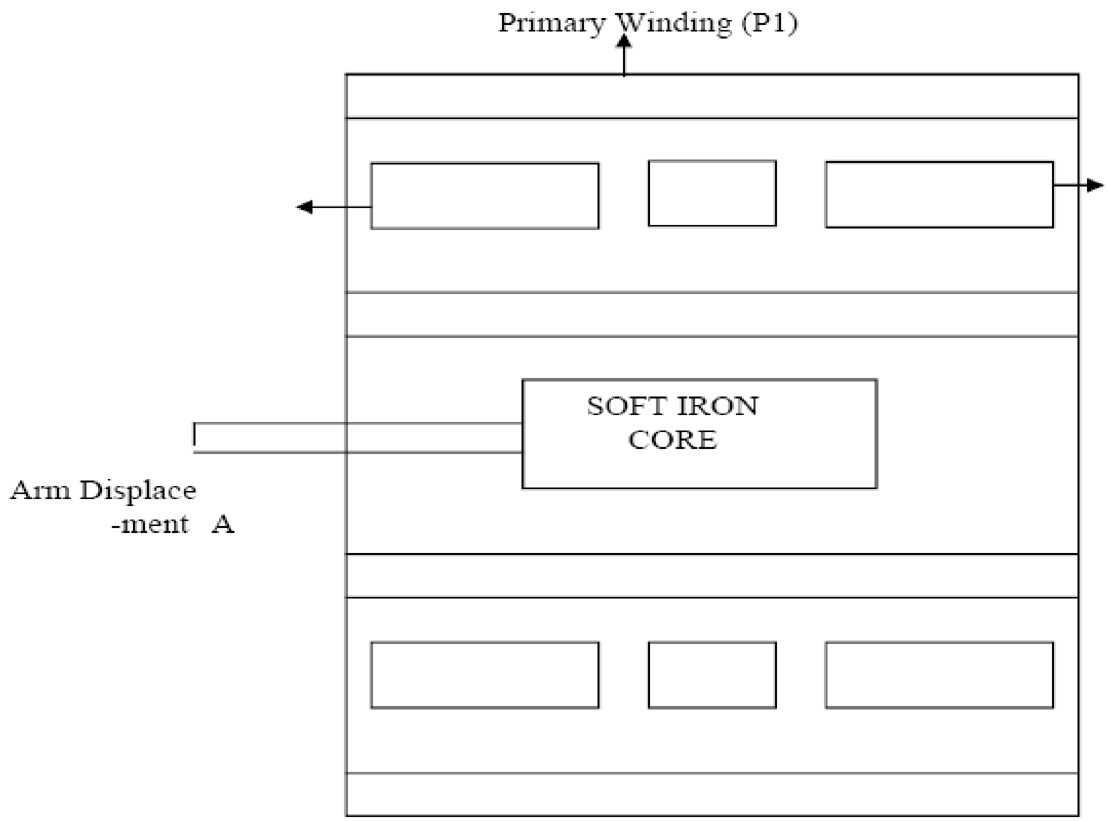
1. Switch on the trainer board and connect the unknown in the arm marked Cx.
2. Observe the sine wave at the output of oscillator and patch the circuit by using the wiring diagram.
3. Observe the sine wave at secondary of isolation transformer on CRO. Select some value of R_3.
4. Connect the CRO between ground and the output point of imbalance amplifier.
5. Vary R_4 (500 Ω 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.

RESULT:

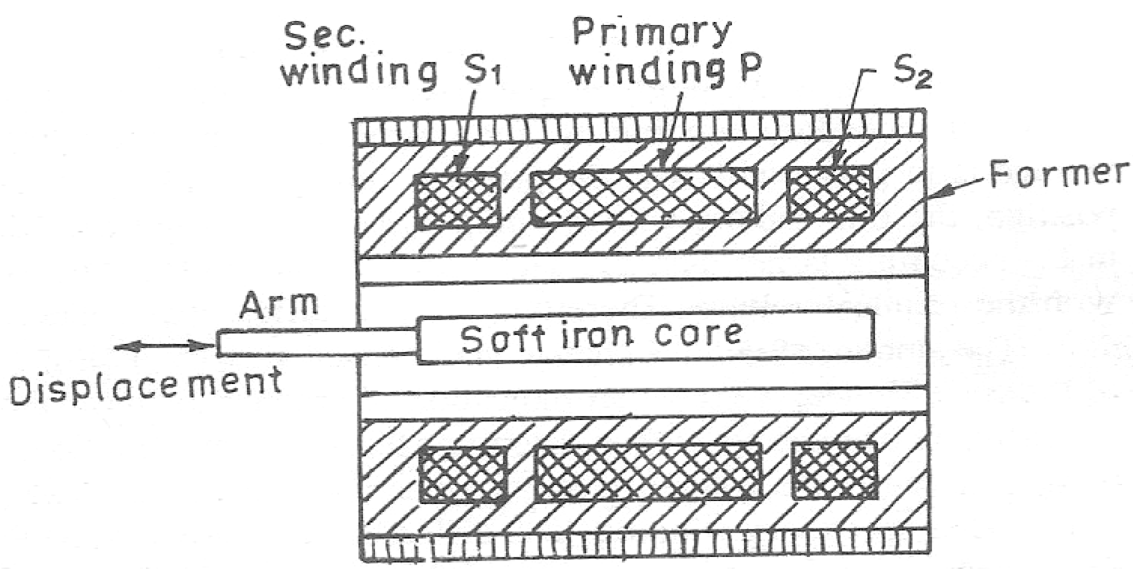
REVIEW QUESTIONS:

1. State the two conditions for balancing an AC bridge?
2. State the uses of Schering's Bridge?
3. What do you mean by dissipation factor?
4. Give the relationship between Q and D.
5. Derive the balance equations.

SCHEMATIC DIAGRAM FOR DISPLACEMENT TRANSDUCER



GENERALIZED DIAGRAM



Ex. No:
Date:

3 (a). STUDY OF DISPLACEMENT TRANSDUCER – LVDT

AIM:

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

APPARATUS REQUIRED :

S.No	Name of the Trainer Kit/ Copmponents	Quantity
1.	LVDT trainer kit containing the signal conditioning unit	1
2.	LVDT calibration jig	1
3.	Multi meter	1
4.	Patch cards	Few

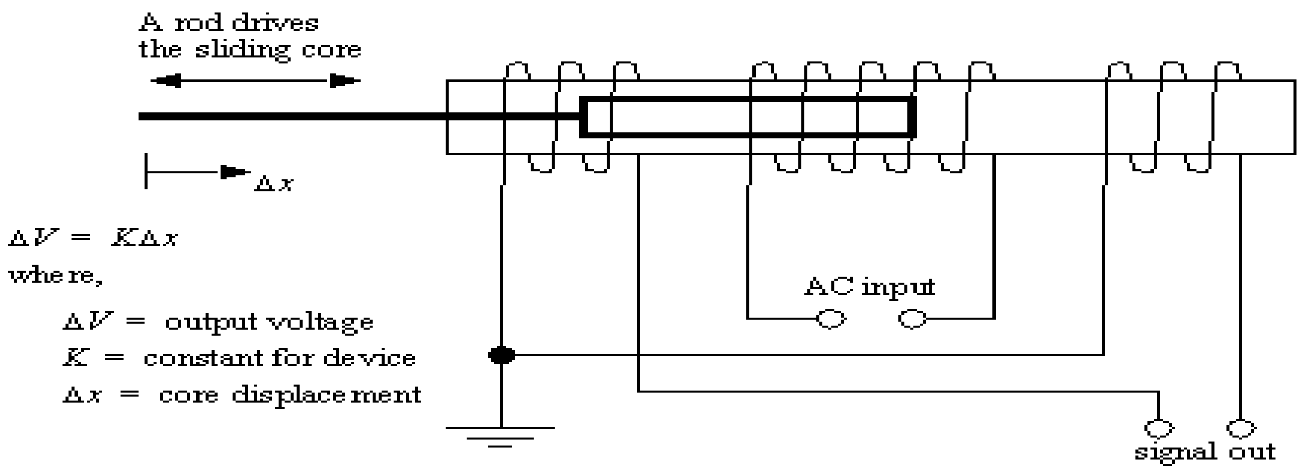
THEORY:

LVDT is the most commonly and extensively used transducer, for linear displacement measurement. The LVDT consists of three symmetrical spaced coils wound onto an insulated bobbin.

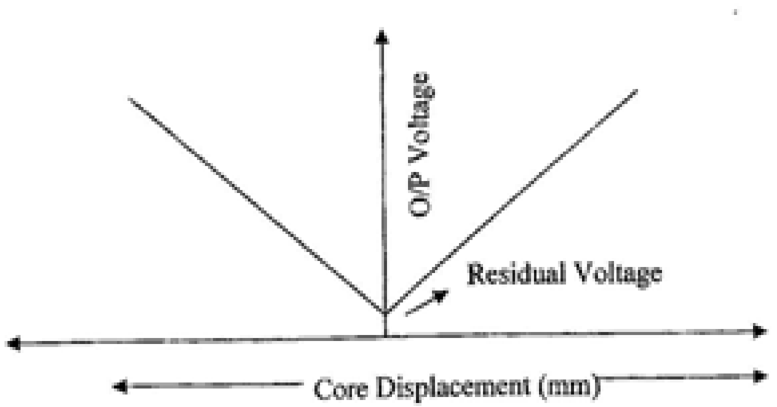
A magnetic core, which moves through the bobbin without contact, provides a path for the magnetic flux linkage between the coils. The position of the magnetic core controls the mutual inductance between the primary coil and with the two outside or secondary coils. When an AC excitation is applied to the primary coil, the voltage is induced in secondary coils that are wired in a series opposing circuit. When the core is centred between two secondary coils, the voltage induced in the secondary coils are equal, but out of phase by 180°. The voltage in the two coils cancels and the output voltage will be zero.

CIRCUIT OPERATION:

The primary is supplied with an alternating voltage of amplitude between 5V to 25V with a frequency of 50 cycles per sec to 20 K cycles per sec. The two secondary coils are identical & for a centrally placed core the induced voltage in the secondaries Es_1&Es_2 are equal. The secondaries are connected in phase opposition. Initially the net o/p is zero. When the displacement is zero the core is centrally located. The output is linear with displacement over a wide range but undergoes a phase shift of 180°. It occurs when the core passes through the zero displacement position.



MODEL GRAPH:



TABULATION

S. No.	Displacement (mm)	Output voltage (mV)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

PROCEDURE:

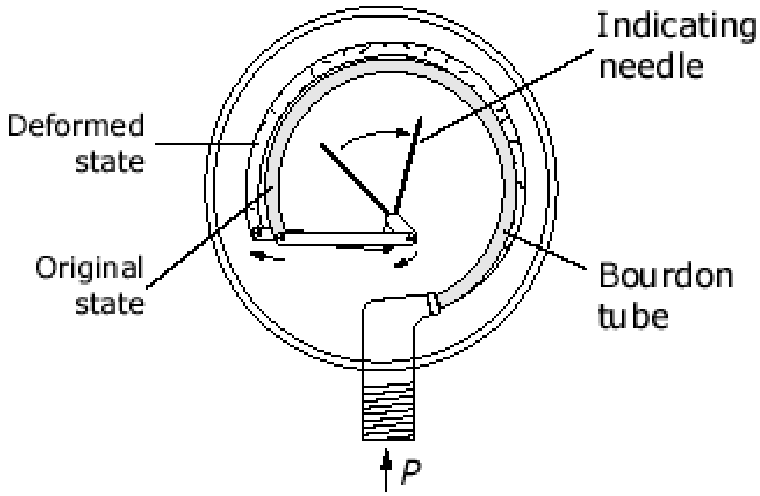
1. Switch on the power supply to the trainer kit.
2. Rotate the screw gauge in clock wise direction till the voltmeter reads zero volts.
3. Rotate the screw gauge in steps of 2mm in clockwise direction and note down the o/p voltage.
4. Repeat the same by rotating the screw gauge in the anticlockwise direction from null position.
5. Plot the graph DC output voltage Vs Displacement

RESULT:

REVIEW QUESTIONS

1. What is LVDT?
2. .What is null position in LVDT?
3. What is the normal linear range of a LVDT?
4. List the advantage of LVDT.
5. List the applications of LVDT.

DIAGRAM:



PRESSURE TRANSDUCER – BOURDON TUBE

Ex. No:
Date:

3 (b). STUDY OF PRESSURE TRANSDUCER – BOURDON TUBE

AIM:
To study the pressure transducer using Bourdon tube and to obtain its characteristics.

APPARATUS REQUIRED :

S.No	Name of the Trainer Kit/ Components	Quantity
1.	Bourdon pressure transducer trainer	1
2.	Foot Pump	1
3.	Multi meter	1
4.	Patch cards	Few

THEORY:

Pressure measurement is important not only in fluid mechanics but virtually in every branch of Engineering. The bourdon pressure transducer trainer is intended to study the characteristics of a pressure(P) to current (I) converter. This trainer basically consists of

1. Bourdon transmitter. 2. Pressure chamber with adjustable slow release valve.
3. Bourdon pressure gauge (mechanical) 4. (4- 20) mA Ammeters, both analog and digital.

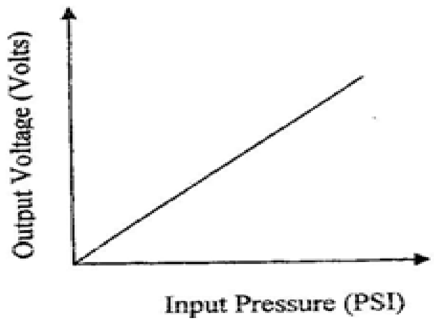
The bourdon transmitter consists of a pressure gauge with an outside diameter of 160 mm including a built-in remote transmission system. Pressure chamber consists or a pressure tank with a provision to connect manual pressure foot pump, slow release valve for discharging the air from this pressure tank, connections to mechanical bourdon pressure gauge, and the connections for bourdon pressure transmitter. Bourdon pressure gauge is connected to pressure chamber. This gauge helps to identify to what extent this chamber is pressurized.

There are two numbers of 20 mA Ammeters. A digital meter is connected in parallel with analog meter terminals and the inputs for these are terminated at two terminals (+ ve and – ve). So positive terminal and negative terminal of bourdon tube is connected to, positive and negative terminals of the Ammeters.

PROCEDURE:

1. The foot pump is connected to the pressure chamber.
2. Switch on the bourdon transducer trainer.
3. Release the air release valve by rotating in the counter clockwise direction.
4. Record the pressure and Voltage.
5. Use the foot pump and slowly inflate the pressure chamber, so that the pressure in the chamber increases gradually.
6. Tabulate the result.
7. Draw the graph. Input pressure Vs Output voltage.

MODEL GRAPH



TABULATION

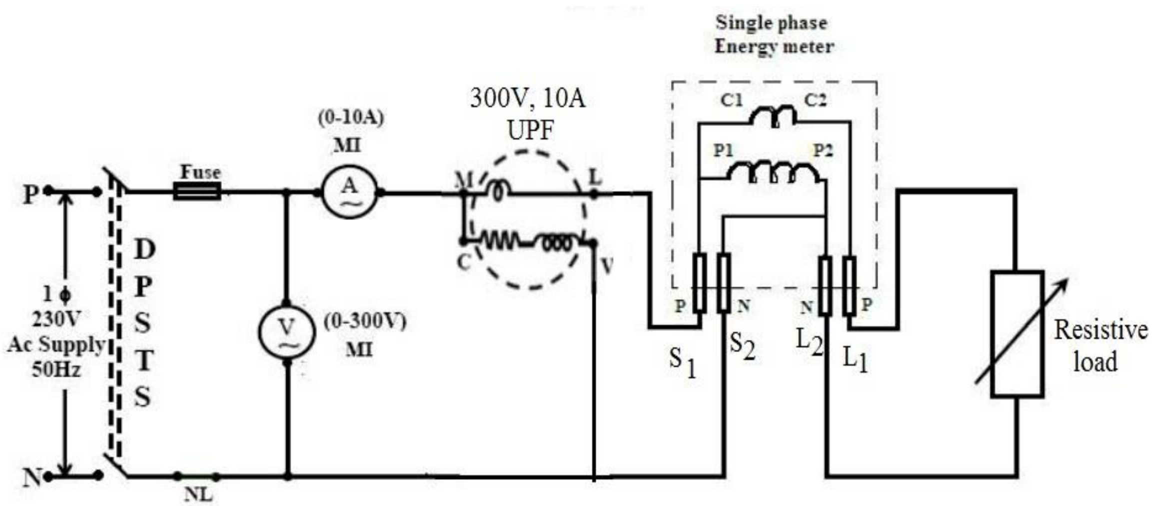
Sl. No.	Input Pressure (PSI)	Output Pressure (Kg/ cm^2)	Output Voltage mV
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

RESULT:

REVIEW QUESTIONS

1. Define Transducer. What are active and passive transducers?
2. List any four pressure measuring transducers?
3. What is the advantage of pinion in bourdon tube?
4. Write the operational principle of bourdon tube.
5. State the advantages of bourdon tube over bellows & diaphragms.

CIRCUIT DIAGRAM



DPSTS - Double Pole single Throw Switch
MI - Moving Iron

Ex.No:

Date :

4. CALIBRATION OF SINGLE PHASE ENERGY METER

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

APPARATUS REQUIRED:

S. No.	Components / Equipments	Specification	Quantity
1	Energy Meter	Single Phase	1
2	Standard Wattmeter	300V, 10A, UPF	1
3	Voltmeter (MI)	0-300V	1
4	Ammeter (MI)	0-10A	1
5	Resistive Load	230V, 3KW	4
6	Connecting wires		10

THEORY:

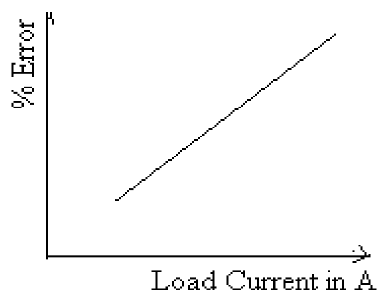
The energy meter is an integrated type instrument where the speed of rotation of aluminium disc is directly proportional to the amount of power consumed by the load and the no of revs/min is proportional to the amount of energy consumed by the load. In energy meter the angular displacement offered by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

TABULATION:

Voltmeter Reading, V (Volt)	Ammeter Reading, I (Amp)	Wattmeter Reading, W (Watt)	Time Period, t (Sec)	No. of revolutions	Energy Meter Reading (kwh)		% Error
					Measured	True	

MODEL GRAPH:



MODEL CALCULATION:

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:

$$\% Error = \frac{True Value - Measured Value}{True\ Value} \times 100$$

Wattmeter Reading(P) = VI watts

True Energy= No. of revolutions/Energy Meter Constant

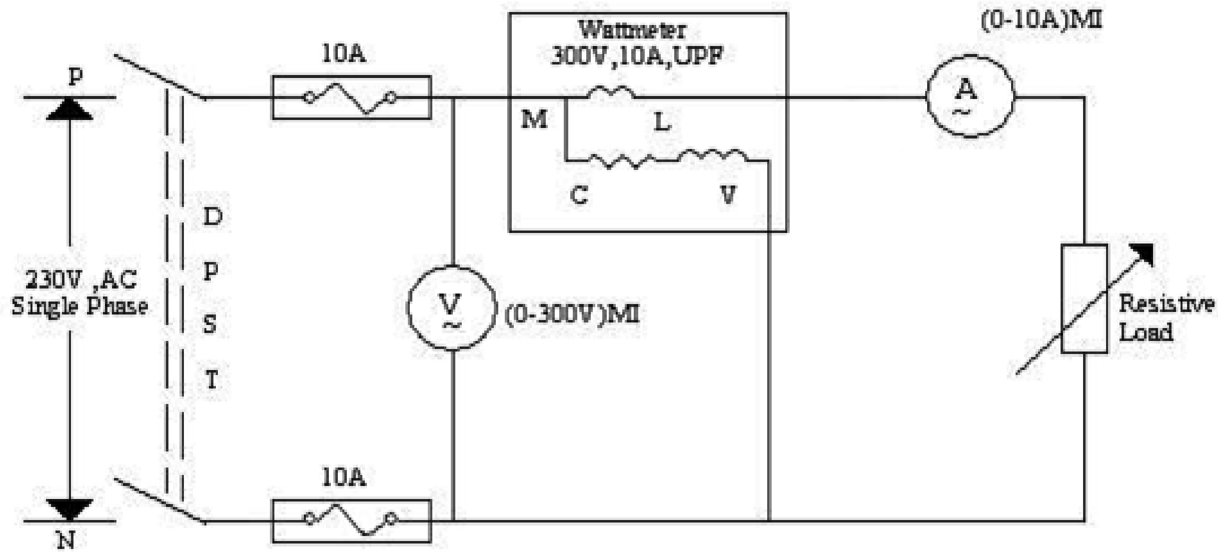
$$\text{Measured Energy} = \frac{VI \cos\Phi t}{3600} = \text{wattmeter reading x time period (kwh)}$$

RESULT:

REVIEW QUESTIONS

1. What do you meant by calibration?
2. What is the need for lag adjustment devices in single phase energy meter?
3. How damping is provided in energy meter?
4. What is "Creep" in energy meter? What are the causes of creeping in an energy meter?
5. How is creep effect in energy meters avoided?

CIRCUIT DIAGRAM:



Ex.No.:

Date :

5(a) CALIBRATION OF WATTMETER

AIM: To calibrate the given Wattmeter by direct loading and obtain its percentage error.

APPARATUS REQUIRED:

S. No.	Components / Equipments	Specification	Quantity
1.	Wattmeter	300V, 10A, UPF	1
2.	Voltmeter (MI)	0-300V	1
3.	Ammeter (MI)	0-10A	1
4.	Resistive Load	230V, 3KW	1
5.	Connecting wires	---	8

THEORY:

In Electro Dynamometer wattmeter there are 2 coils connected in different circuits to measure the power. The fixed coil or held coil is connected in series with the load and so carry the current in the circuit. The moving coil is connected across the load and supply and carries the current proportional to the voltage.

The various parts of the wattmeter are 1. Fixed coil and Moving coil 2.. Controlling springs and Damping systems 3. Pointer Here a spring control is used for resetting the pointer to the initial position after the de-excitation of the coil. The damping system is used to avoid the overshooting of the coil and hence the pointer. A mirror type scale and knife edge pointer is provided to remove errors due to parallax.

PROCEDURE:

1. Connections are given as per the circuit diagram.
2. Power supply is switched on and the load is turned on.
3. The value of the load current is adjusted to the desired value.
4. The readings of the voltmeter, ammeter& wattmeter are noted.
5. The procedure is repeated for different values of the load current and for each value of load current all the meter readings are noted.

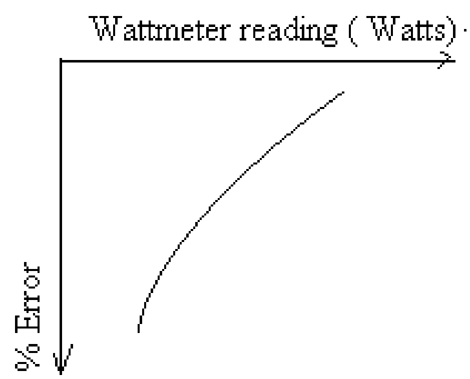
TABULATION

S.No	Voltmeter reading (Volts)	Ammeter Reading (Amp)	Wattmeter Reading (Watt)		% Error
			Measured	True value P = V*I	

FORMULA USED:

$$\% \, Error = \frac{Truevalue - Measuredvalue}{True \; Value} \times 100$$

MODEL GRAPH:



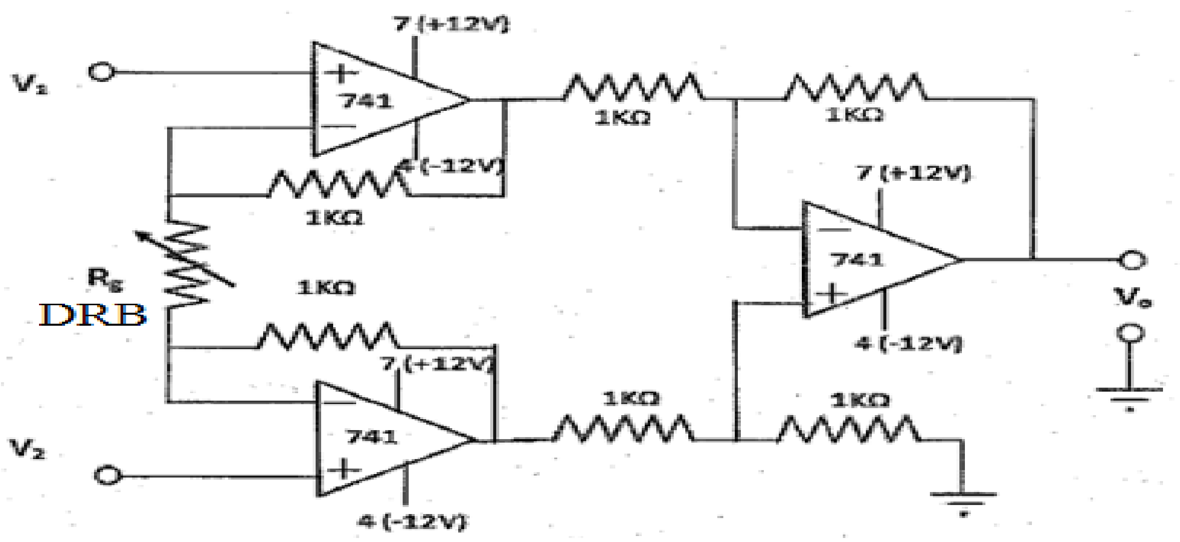
MODEL CALCULATION:

RESULT:

REVIEW QUESTIONS

1. What do you mean by calibration?
2. What are the common errors in Wattmeter?
3. Can we Measure power using one Wattmeter in a 3-Phase supply?
4. How do we measure Reactive Power.?
5. How do you compensate Pressure coil in Wattmeter?

CIRCUIT DIAGRAM : INSTRUMENTATION AMPLIFIER



OBSERVATION:

S.No	V_1 (V)	V_2 (V)	$V_d=(V_1-V_2)$ Volts	V_o (V) (Practical)	Gain $A= V_{out}/V_d$	V_o (V) (Theoretical)

FORMULA:

$$V_0 = -\left(\frac{R_2}{R_1}\right)\left(1+\frac{2R}{R_g}\right)V_d$$

$V_o = A*V_d$

Where

$$-\left(\frac{R_2}{R_1}\right)\left(1+\frac{2R}{R_g}\right) = A$$

MODEL CALCULATIONS:

Ex.No:
Date :

5(b) DESIGN OF INSTRUMENTATION AMPLIFIER

AIM:

To design an instrumentation amplifier

APPARATUS REQUIRED:

S.No.	Components	Specification	Quantity
1.	Op-Amp	IC 741	3
2.	Resistor	1 KΩ	6
3.	Regulated Power Supply	(0-30)V	2
4.	Decade Resistance Box	-	1
5.	Bread Board	-	1
6.	Connecting Wires	-	Few

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:

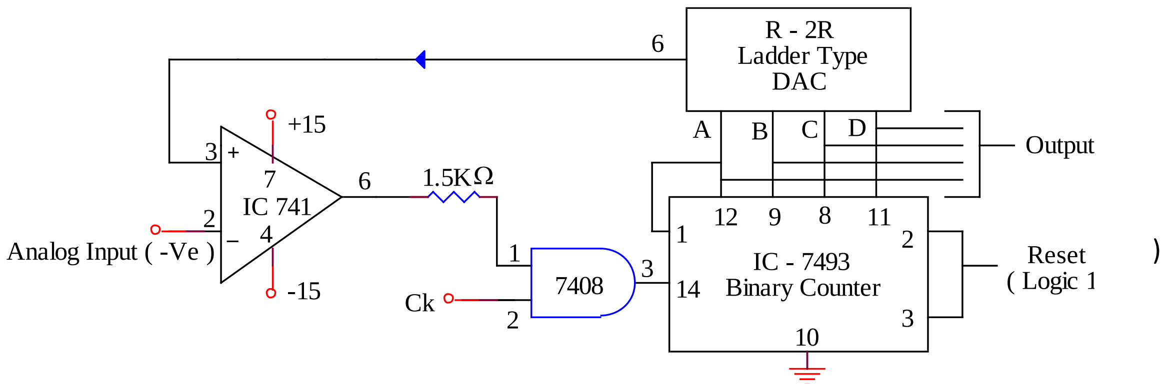
1. Give the connections as per the circuit diagram.
2. Switch on the RPS
3. Set Rg, V1 and V2 to particular values
4. Repeat Step 3 for different values of Rg, V1 and V2
5. Calculate the theoretical output voltage using the given formula and compare with practical value.

RESULT:

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?

CIRCUIT DIAGRAM :ADC



For DAC R = 1.5KΩ 2R = 3.3KΩ R_f = 6.8KΩ

TABULATION :

S.No.	Analog Quantity	Digital Quantity

MODEL CALCULATION :

Ex.No.
Date:

6(a) ANALOG – DIGITAL CONVERTER

AIM:

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

APPARATUS REQUIRED :

1. Digital Trainer kit,
2. IC 7493, 7408, 741,
3. RPS
4. Breadboard

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 Vp by the DAC. Vp is then compared with the analog input voltage Vin .This process continues until Vp>=Vin.After which the contents of the register /counter are not changed.Thue the output of the register /counter is the requried digital output.

PROCEDURE:

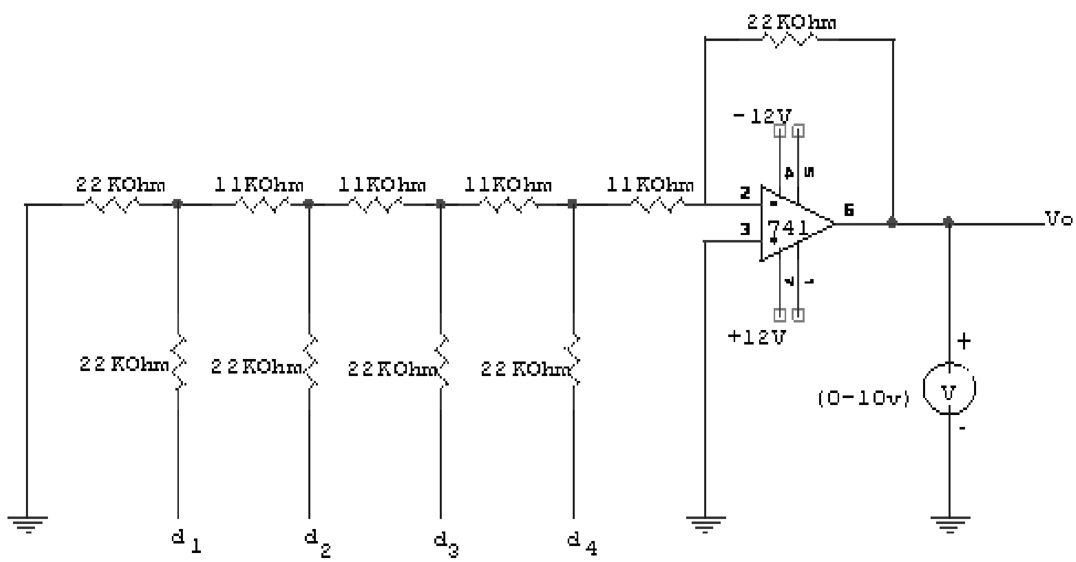
(i) By making use of the R-2R ladder DAC circuit set up the circuit as shown in the figure.
(ii) Apply various input voltages in the range of 0 to 10V at the analog input terminal.
(iii) Apply clock pulses and observe the stable digital output at Q_D,Q_C,Q_B and Q_A for each analog input voltage.

RESULT:

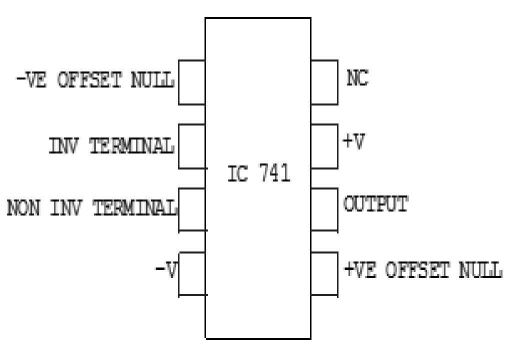
REVIEW QUESTIONS

1. What is ADC?
2. What are the types of ADC?
3. State Shannon's sampling theorem?
4. What are the advantages of Successive Approximation type over ramp type?
5. State the advantages of ramp type over successive approximation type?

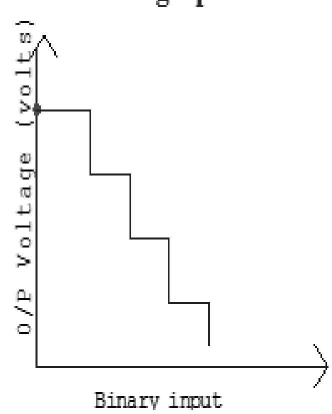
CIRCUIT DIAGRAM:



Pin diagram



Model graph



Ex. No:
Date:

6(b) DIGITAL –ANALOG CONVERTER

AIM: To design and test a 4 bit D/A Converter by R - 2R ladder network.

APPARATUS REQUIRED:

S.No	Name of the Trainer Kit/ Components	Specification	Quantity
1.	IC Trainer kit	-	1
2.	IC 741	-	1
3.	Regulated power supply	(0-15)V	1
4	Resistors	11KΩ	4
5.	Resistors	22KΩ	6
6.	Connecting wires	-	Few
7.	DMM	-	1

THEORY:

The input is an n-bit binary word 'D' and is combined with a reference voltage 'V_R' to give an analog output signal. The output of D/A converter can either be a voltage or current . For a voltage output D/A converter is described as

$$V_0 = \left(\frac{-V_{ref}\,.R_f}{n.R}\right)\left(\frac{d_1}{2^1}+\frac{d_2}{2^2}+\frac{d_3}{2^3}+\frac{d_4}{2^4}+........+\frac{d_n}{2^n}\right)$$

Where, $\mathbf{V_0}$ is the output voltage, $\mathbf{d_1, d_2, d_3 \ldots d_n}$ are n bit binary word with the decimal point located at the lift. , $\mathbf{d_1}$is the MSB with a weight of $V_{fs}/2$, $\mathbf{d_2}$ is the LSB with a weight of $V_{fs}/2^n$

PROCEDURE:

1) Set up the circuit as shown in the circuit diagram
2) Measure the output voltage for all binary inputs(0000 to 1111).
3) Plot the graph for binary input versus output voltage.

FORMULA:

$$V_0 = \left(\frac{-V_{ref}\,.R_f}{n.R}\right)\left(\frac{d_1}{2^1}+\frac{d_2}{2^2}+\frac{d_3}{2^3}+\frac{d_4}{2^4}\right)$$

Where V_{ref} is the full scale voltage

TABULATION:

Sl. No	D_1	D_2	D_3	D_4	R-2R Ladder	
					Theoretical Output (V)	Practical Output (V)
1	0	0	0	0		
2	0	0	0	1		
3	0	0	1	0		
4	0	0	1	1		
5	0	1	0	0		
6	0	1	0	1		
7	0	1	1	0		
8	0	1	1	1		
8	1	0	0	0		
10	1	0	0	1		
11	1	0	1	0		
12	1	0	1	1		
13	1	1	0	0		
14	1	1	0	1		
15	1	1	1	0		
16	1	1	1	1		

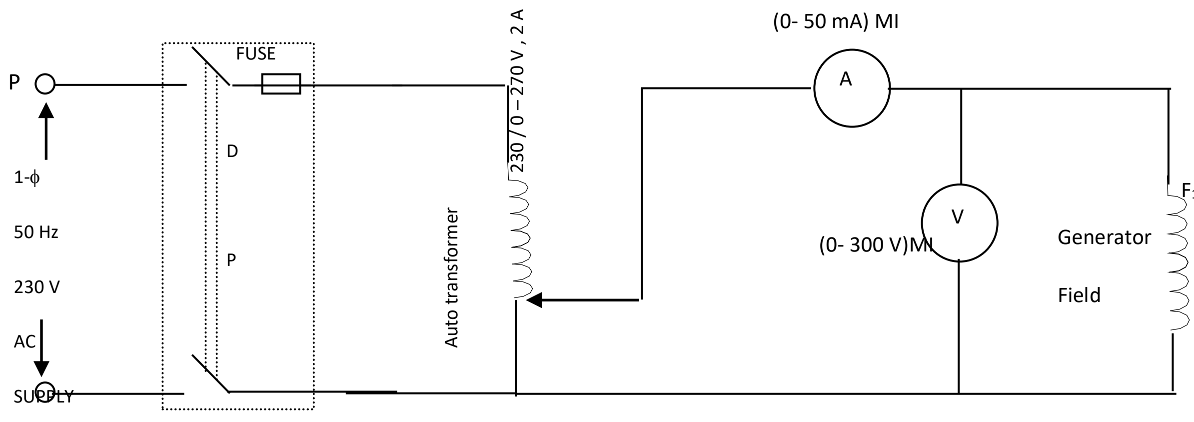
MODEL CALCULATION:

RESULT:

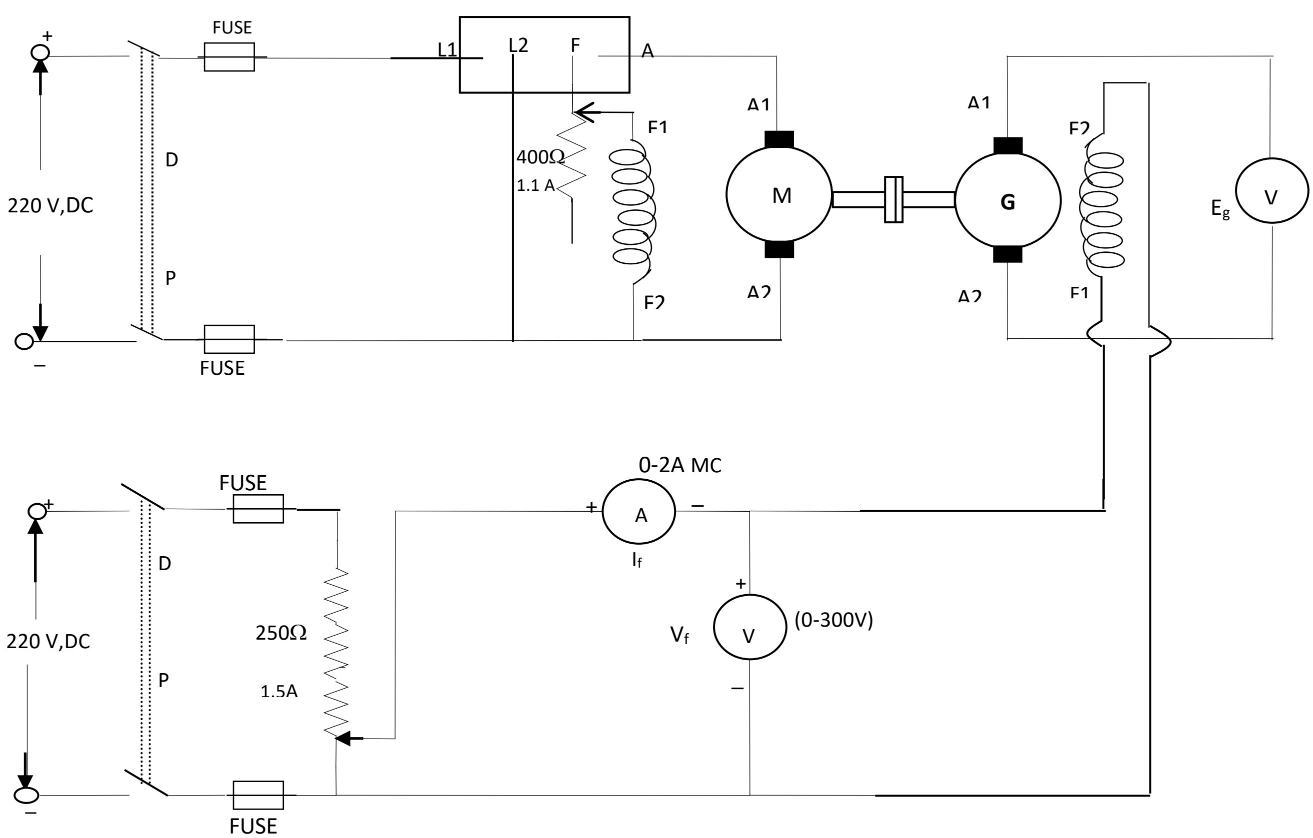
REVIEW QUESTIONS:

1. Draw the block diagram of DAC
2. What are the different types of DAC?
3. What are the advantages of R-2R ladder type DAC over Weighted resistor type DAC?
4. Define Resolution and Quantization
5. Define aperture time.

CIRCUIT DIAGRAM:



Circuit diagram to find L_f



Circuit diagram to find k_g and R_f

Ex. No:
Date:

7.(a) DETERMINATION OF TRANSFER FUNCTION OF DC GENERATOR

AIM:

To obtain the transfer function of a separately excited DC generator.

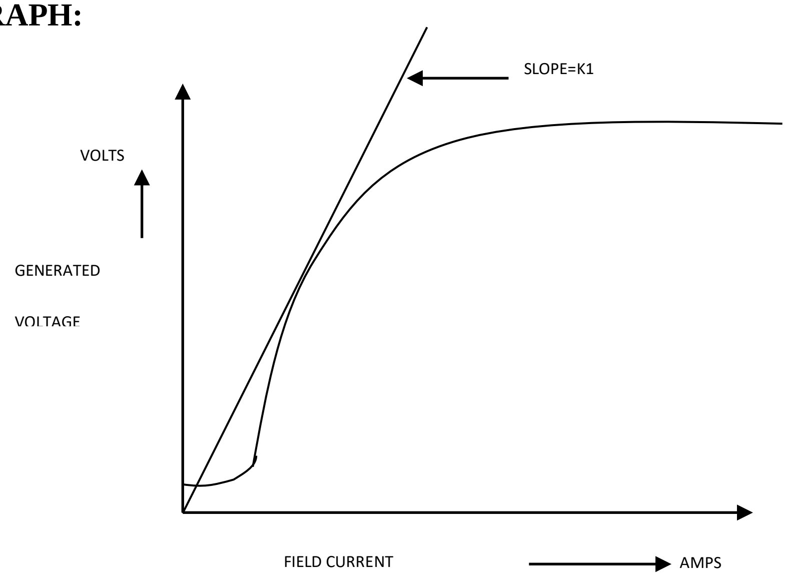
APPARATUS REQUIRED:

S.No.	Item	Specification / Range	Quantity
1.	DC Generator		
1.	Auto transformer	1-ϕ, 50 Hz	1
		230 V / 0 – 270 V, 6 A	
2.	Voltmeters	(0 –300 V) MI	1
		(0 – 300 V) MC	2
3.	Ammeter	(0 – 2 A) MC	1
		(0 – 50 mA) MI	1
4.	Rheostat	400 Ω, 1.1 A	1
		250 Ω, 1.5 A	1
5.	Tachometer		1
6.	Starter	0 - 1500 rpm	
		4 point, 10 A	
7.	Connecting Wires	-	12

PRECAUTIONS:

1. The DPSTS should be in off position.
2. The 3-point/4-point starter should be in off position.
3. At the time of starting the motor field rheostat should be in minimum resistance position and generator field rheostat should be in maximum resistance position.
4. There should not be any load connected to the generator terminals.

GRAPH:

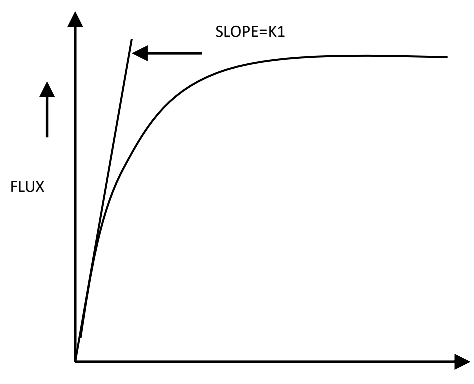


Field current VS Generated voltage

THEORY: A DC generator can be used, as a power amplifier in which the power required to excite the field circuit is lower than the power output rating of the armature circuit. The voltage induced eg the armature circuit is directly proportional to the product of the magnetic flux, ϕ, setup by the field and the speed of rotation, ω, of the armature which is expressed as

$$e_g = k_1 \phi \, \omega$$

The flux is a function of field current and the type of iron used in the field. A typical magnetization showing flux as a function of field current is shown in figure



Upto saturation the relation is approximately linear and the flux is directly proportional to field current i.e.

$$\phi = k_2 \, i_f$$

Combining both equations,

$$e_{.g.} = k_1 \, k_2 \, \omega \, i_f$$

When used as a power amplifier the armature is driven at a constant speed and the equation becomes

$$e_{.g.} = k_g \, i_f$$

A generator field winding is represented with L_f and R_f as inductance and resistance of the field

$$e_f = L_f \frac{di_f}{dt} + R_f i_{f...}$$

circuit.

The equations for the generator are,

Finding Laplace transform of the above equation

$$E_f(s) = (sL_f + R_f) I_f s$$

$$E_g(s) = k_g I_f(s))$$

$$\frac{E_g(S)}{E_f(S)} = \frac{k_g}{SL_f + R_f}$$

Combining the above two equations,

$$\frac{E_g(s)}{E_f(s)} = \frac{K}{1 + s\tau_f}.$$

$$Where K = \frac{k_g}{R_f}$$

$$and \tau_f = \frac{L_f}{R_f}$$

Then the transfer function of a DC generator is given as,

TABULATION:

To find R_f :

S.No.	Field Voltage V_f (Volts)	Field Current I_f (Amps)	Field Resistance R_f (Ohms)	Generated Voltage E_g (volts)

To find R_a:

Sl.No.	Ammeter Reading I (amps)	Voltmeter Reading V (volts)	Armature Resistance R_a (ohms)

PROCEDURE:

To find k_g and R_f :

1. Make the connections as shown in circuit diagram. (Refer figure)
2. By observing the precautions switch ON the supply.
3. Start the motor by using 4-point starter and run it for the rated speed of the generator by adjusting motor field rheostat.
4. Adjust the generator field rheostat in steps and take both ammeter (field current) and voltmeter (generated voltage) readings. Also note down field voltage readings.(Refer: Table)
5. Throughout the experiment the speed of the generator must be kept constant (rated value).
6. A typical variation of the generated voltage for different field current is shown in figure
7. Slope of the curve at linear portion will be the value of k_g in volts/amp.
8. The ratio of V_f and I_f gives the field resistance R_f . Find its average value. The effective value of the field resistance is , $R_{eff} = R_f \times 1.2$

To find L_f :

1. Make the connections as shown in circuit diagram (Refer Figure:)
2. By observing the precautions (i.e. Initially the auto-transformer should be in minimum Voltage Position) switch on DPSTS.
3. By varying the auto- transformer position in steps, values of ammeter and voltmeter readings are taken. (Refer : Table)
4. The ratio of voltage to current gives the impedance, Zf of the generator field winding. Inductance L_f is calculated as follow.

$$X_f = \sqrt{Z_f^2 - R_{eff}^2} \quad \Omega \qquad\qquad L_f = \frac{X_f}{2\pi f} henries$$

Substituting the values of k_g , L_f and R_f in equation (1.7), transfer function of the dc generator is obtained.

To find Z_a:

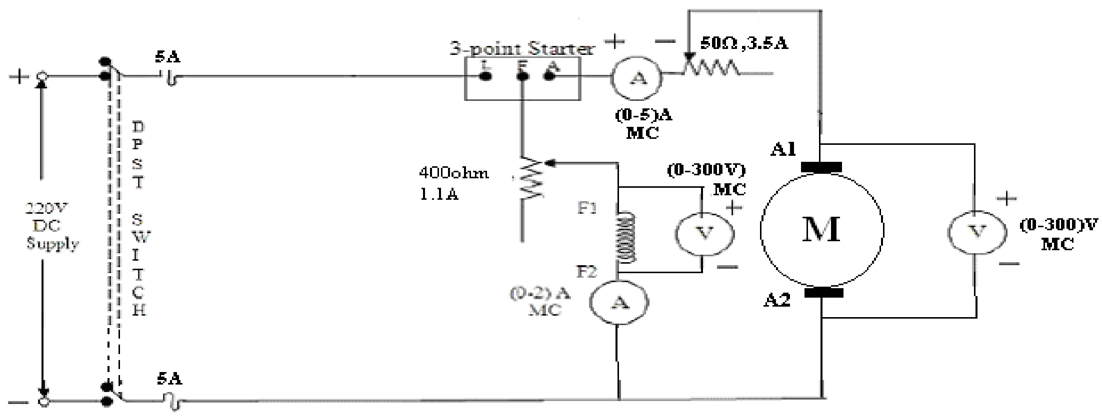
Sl.No.	Ammeter Reading I (amps)	Voltmeter Reading V (volts)	Armature Impedance Z_a (ohms)	X_a (Ohms)	L_a (Henry)

MODEL CALCULATION:

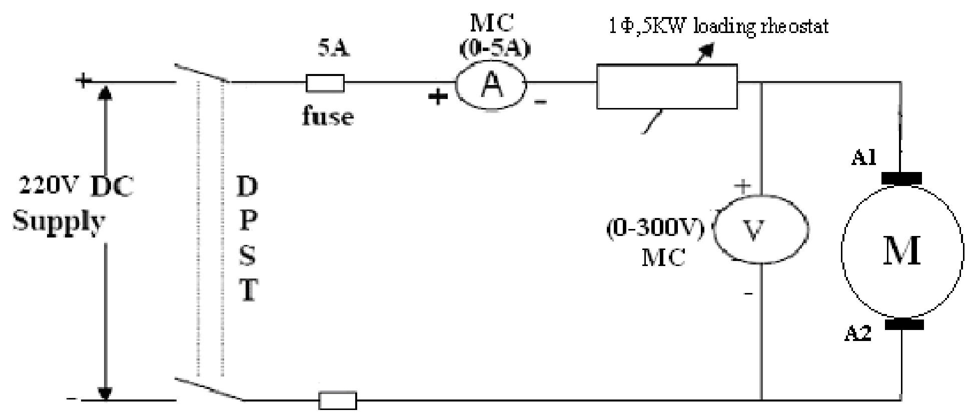
RESULT:

CIRCUIT DIAGRAM:

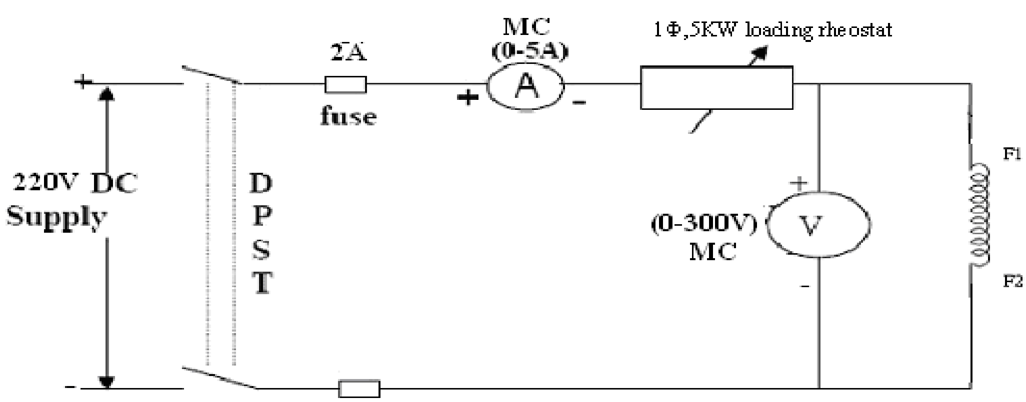
ARMATURE AND FIELD CONTROLLED DC MOTOR:



TO MEASURE ARMATURE RESISTANCE R_a:



TO MEASURE FIELD RESISTANCE R_f:



Ex. No:

Date:

7.(b) DETERMINATION OF TRANSFER FUNCTION OF DC MOTOR

AIM:

1. To determine the transfer function of an armature controlled DC motor.
2. To determine the transfer function of an field controlled DC motor.

APPARATUS REQUIRED:

S.No	Name	Range	Qty	Type
1	Ammeter	(0-5A),(0-2A),(0-10A),(0-100mA)	Each 1	MC
2	Voltmeter	(0-300V),(0-300V) (0-300V),(0-150V)	Each1 Each1	MC MI
3	Auto transformer	1Φ,230V/(0-270V),5A	1	
4	Rheostat	400Ω/1.1A,50Ω/3.5A,250 Ω/1.5A.	Each1	
5	Tachometer		1	
6	Stopwatch		1	
7	Connecting Wires		12	

THEORY:

TRANSFER FUNCTION OF ARMATURE CONTROLLED DC MOTOR

The differential equations governing the armature controlled |DC motor speed control system are

$$V_a = I_a R_a + L_a \frac{di_a}{dt} + e_b \quad (1)$$

$$T = K_t \; I_a \quad (2)$$

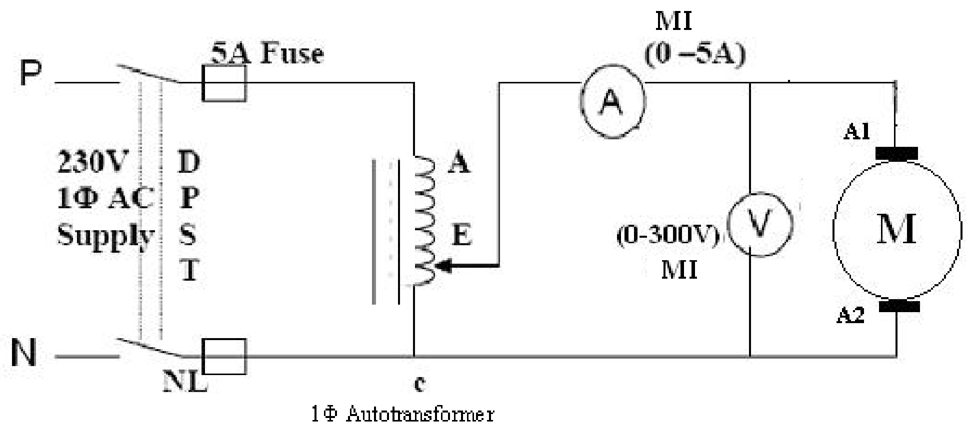
$$T = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt} \quad (3)$$

$$e_b = K_b \frac{d\theta}{dt} \quad (4)$$

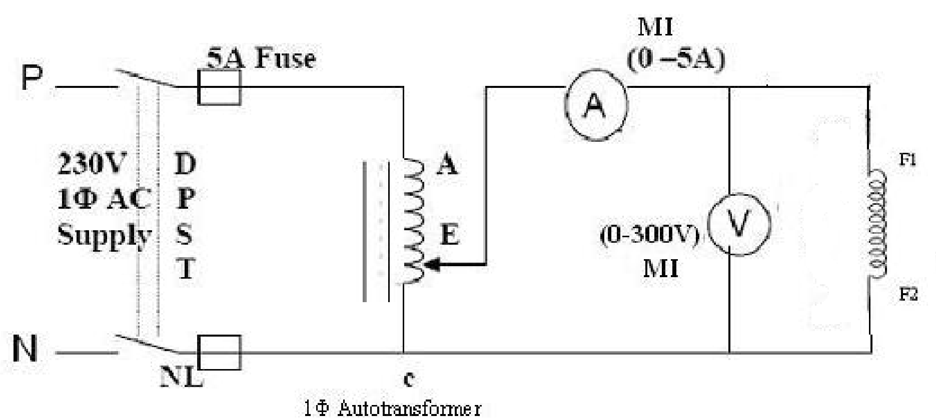
On taking Laplace transform of the system differential equations with zero initial conditions we get

$$V_a(s) = I_a(s) R_a + L_a s I_a(s) + E_b(s) \quad (5)$$

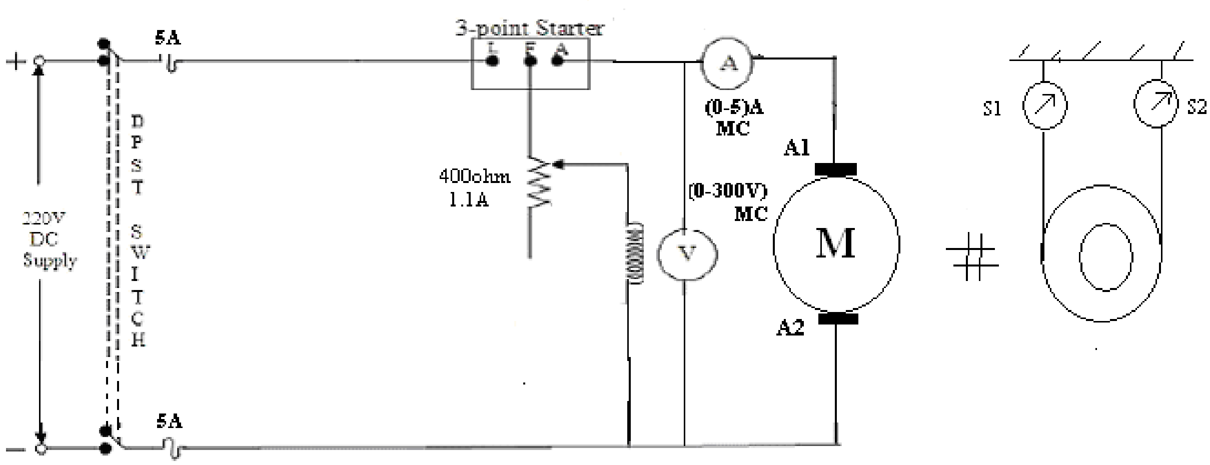
TO MEASURE ARMATURE INDUCTANCE(La):



TO MEASURE FIELD INDUCTANCE(L_F):



TO MEASURE Ka



$$T(s) = K_t I_a(s) \quad (6)$$

$$T(s) = Js^2\theta(s) + Bs\theta(s) \quad (7)$$

$$E_b(s) = K_b s\theta(s) \quad (8)$$

on equating equation (6) and (7)

$$I_a(s) = \frac{Js^2 + Bs}{K_t}\theta(s) \quad (9)$$

Equation (5) can be written as

$$V_a(s) = (R_a + sL_a)I_a(s) + E_b(s) \quad (10)$$

Substitute $E_b(s)$ and $I_a(s)$ from eqn (8),(9) respectively in equation 10

$$V_a(s) = \left[\frac{(R_a + sL_a)(Js^2 + Bs) + K_b K_t s}{K_t}\right]\theta(s)$$

The required transfer function is

$$\frac{\theta(s)}{V_a(s)} = \frac{K_t}{(R_a + sL_a)(Js^2 + Bs) + K_b K_t s}$$

$$\frac{\theta(s)}{V_a(s)} = \frac{K_t / R_a B}{s(1 + sT_a)(1 + sT_m) + \frac{K_b K_t}{R_a B}}$$

Where L_a / R_a =T_a= electrical time constant

J /B =T_m =mechanical time constant

TRANSFER FUNCTION OF FIELD CONTROLLED DC MOTOR

The differential equations governing the field controlled DC motor speed control system are,

$$V_f = R_f I_f + L_f \frac{di_f}{dt} \quad (11)$$

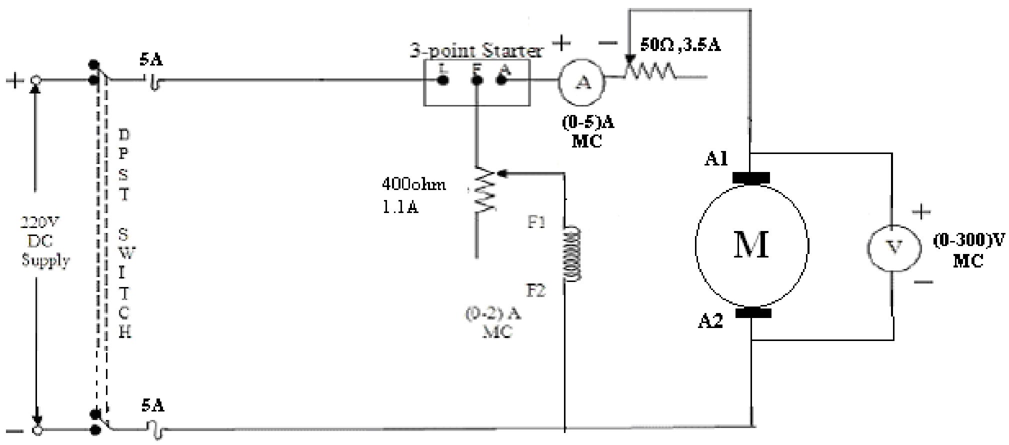
$$T(s) = K_{t_f} I_f(s) \quad (12)$$

$$T(s) = Js^2\theta(s) + Bs\theta(s) \quad (13)$$

Equation (12) and (13)

$$K_{t_f} I_f(s) = Js^2\theta(s) + Bs\theta(s) \quad (14)$$

TO FIND K_b



TABULATION:

To find R_a:

V_a(V)	I_a(A)	R_a(Ω)

To find R_f:

V_f(V)	I_f(A)	R_f(Ω)

$$I_f(s) = \frac{s(Js+Bs)}{K_{t_f}}\theta(s)$$ (15)

The equation (4) becomes

$$V_f(s) = (R_f + sL_f)\, I_f(s)$$ (16)

On substituting $I_f(s)$ from equation (7) and (8), we get

$$V_f(s) = (R_f + sL_f)\,\frac{s(Js+Bs)}{K_{t_f}}\,\theta(s)$$ (17)

$$\frac{\theta(s)}{V_f(s)} = \frac{K_{t_f}}{s(R_f+sL_f)(B+sJ)}$$ (18)

$$\frac{\theta(s)}{V_f(s)} = \frac{K_m}{s(1+sT_f)(1+sT_m)}$$ (19)

Where

Motor gain constant $K_m = K_{tf} / R_{fb}$

Field time constant $T_f = L_f/R_f$

Mechanical time constant $T_m = J/B$

PROCEDURE:

To find armature resistance R_a:

1. Connections were given as per the circuit diagram.
2. By varying the loading rheostat take down the readings on ammeter and voltmeter.
3. Calculate the value of armature resistance by using the formula $R_a = V_a / I_a$.

To find armature resistance L_a:

1. Connections were given as per the circuit diagram.
2. By varying the AE positions values are noted.
3. The ratio of voltage and current gives the impedance Z_a of the armature reading. Inductance L_a is calculated as follows.

$$X_a = \sqrt{Z_a^2 - R_a}$$

$$L_a = \frac{X_a}{2\pi f}$$

To find La:

V_a(V)	I_a(A)	Z_a(Ω)	L_a(Ω)

To find L_f:

V_f(V)	I_f(A)	Z_f(Ω)	L_f(Ω)

ARMATURE CONTROLLED DC MOTOR:

V_a (V)	I_a (A)	N(RPM	T(NM)	Ω(Rad)	K_b	K_t	E_b

To find armature k_a:

1. Connections are made as per the circuit diagram.
2. Keep the rheostat in minimum position.
3. Switch on the power supply.
4. By gradually increasing the rheostat, increase the motor to its rated speed.
5. By applying the load note down the readings of voltmeter and ammeter.
6. Repeat the steps 4 to 5 times.

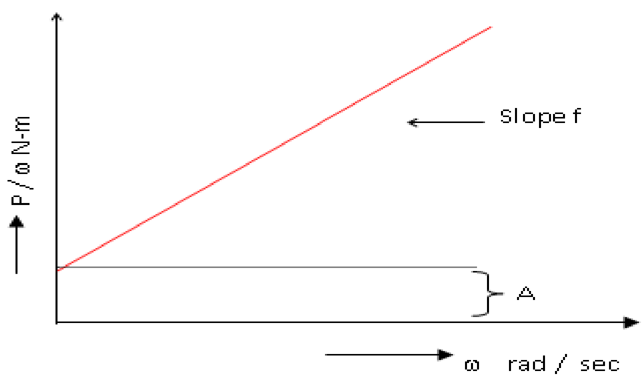
To find k_b:

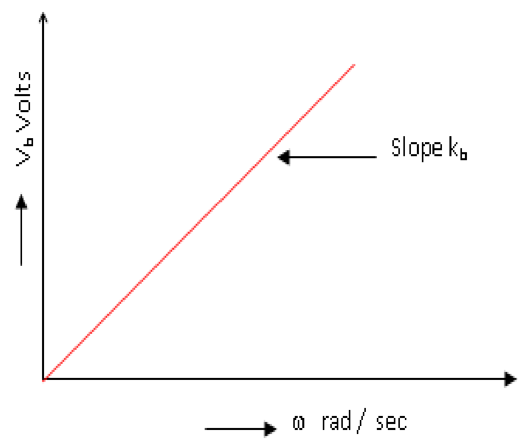
1. Connections are made as per the circuit diagram.
2. By observing the precautions switch on the supply.
3. Note down the current and speed values.
4. Calculate E_b and $\boldsymbol{\omega}$.

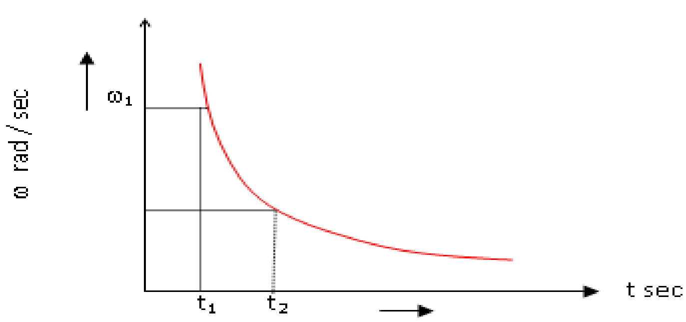
FIELD CONTROLLED DC MOTOR:

V_a (V)	I_a (A)	N(RPM)	T_m(NM)	ω(Rad)	E_b(V)	K_m	T(NM)	K_{tf}	T_f(NM)

MODEL GRAPH:



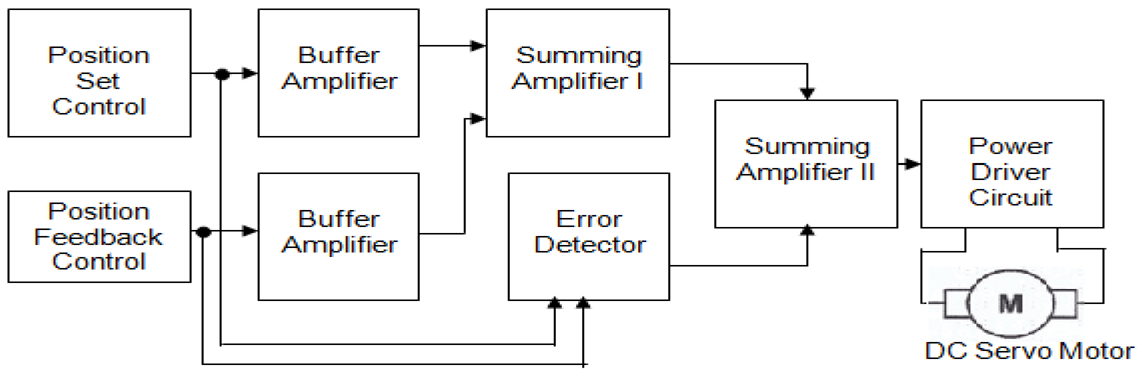




MODEL CALCULATION

RESULT:

BLOCK DIAGRAM:



Ex. No:
Date:

8(a). DC POSITION CONTROL SYSTEM

AIM:

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

APPARATUS REQUIRED:

S.NO	APPARATUS	SPECIFICATION	QUANTITY
1.	DC Servo Motor Position Control Trainer	-	1
2.	Connecting Wires	-	13

THEORY:

DC Servo Motor Position Control Trainer has consisted various stages. They are Position set control (T_X), Position feed back control (R_X), buffer amplifiers, summing amplifiers, error detector and power drivter circuits. All these stages are assembled in a separate PCB board. Apart from these, wo 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 upto 270°. But the servo potentiometers are can be rotate upto 360°. For example, 1K Ω servo potentiometer give its value from o to 1 KΩ for one complete rotation (360°).

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:

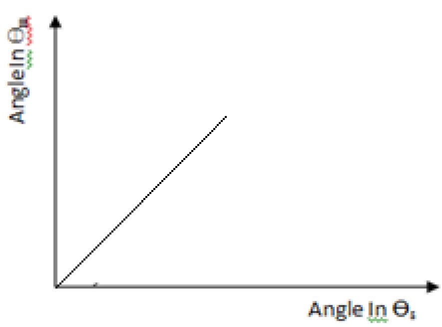
A 1 K Ω servo potentiometer is used in this stage. A + 5 V power supply is connected to this potentiometer. The feed point of this potentiometer is connected to the buffer amplifiers. A same value of another servo potentiometer is provided for position feedback control circuit. This potentiometer is mechanically mounted with DC servomotor through a proper gear arrangement. Feed point of this potentiometer is also connected to another buffer circuit. To measuring the angle of rotations, two dials are placed on the potentiometer shafts. 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.

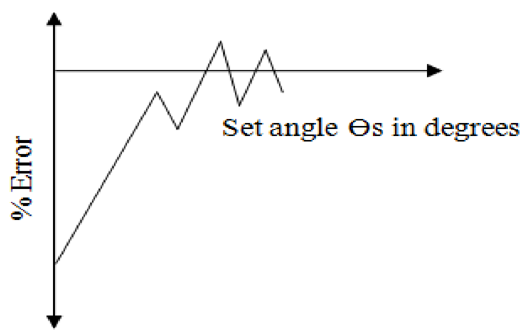
Buffer amplifier for transmitter and receiver and summing amplifier are constructed in one quad operational amplifier. The error detector is constructed in a single opamp IC LM 310. And another quad operational amplifier constructs other buffer stages.

TABULATION:

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

MODEL GRAPH:





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 $\Theta_s$vsΘ_m and $\Theta_s$vs % error.

FORMULA USED:

Error in degree $= \Theta_s - \Theta_m$

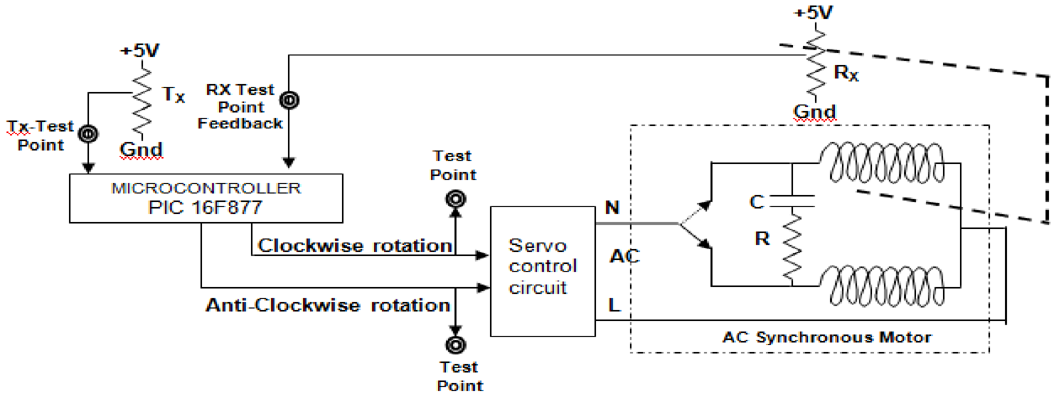
Error in percentage $= ((\Theta_s - \Theta_m) / \Theta_s) * 100$

RESULT:

REVIEW QUESTIONS:

1. Which motor is used for position control?
2. Differentiate DC servo motor and DC shunt motor.
3. How the mechanical rotation is converted to electrical signals?
4. What are the time domain specifications?
5. What are the advantages of dc servo motor?

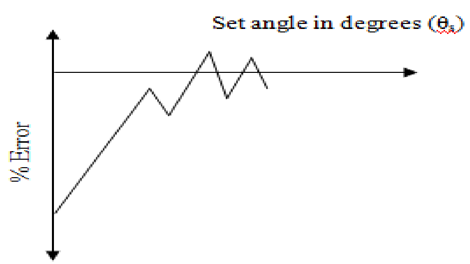
BLOCK DIAGRAM :



TABULATION:

S. No.	Set Angle in degrees(set Θ_s)	Measured angle in degrees(Θ_m)	Error in degrees ($\Theta_s - \Theta_m$	Error in % $[(\Theta_s - \Theta_m) / \Theta_s] \times 100$

MODEL GRAPH:



Ex. No:
Date:

8(b). AC POSITION CONTROL SYSTEM

AIM:

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

APPARATUS REQUIRED:

S.NO	APPARATUS	SPECIFICATION	QUANTITY
1.	AC Servo Motor Position Control Trainer	-	1
2.	Connecting Wires	-	As required

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 350^0 as set by the Transmitter's angular position transducer (potentiometer), in the range of 10^0 to 350^0. 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:

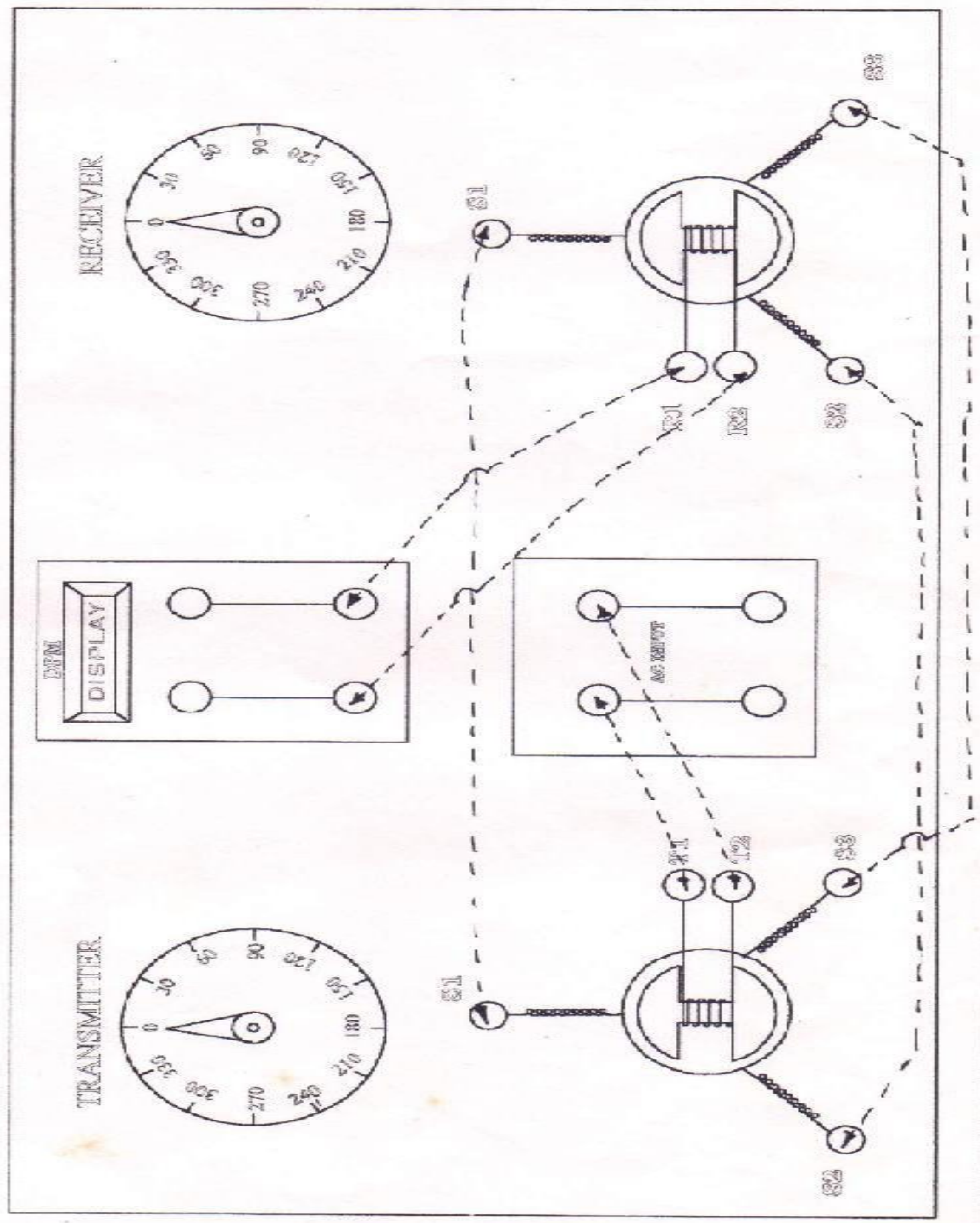
1. Connect the trainer kit with motor setup through 9 pin D connector.
2. Switch ON the trainer kit.
3. Set the angle in the transmitter by adjusting the position set control as Θ_s.
4. Now, the motor will start to rotate and stop at a particular angle which is tabulated as Θ_m.
5. Tabulate Θ_m for different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

RESULT:

REVIEW QUESTIONS:

1. What is meant by Synchro?
2. How the rotor position is controlled in AC position controller?
3. What are the different types of rotor that are used in ac servomotor?
4. What is electrical zero of Synchro?
5. What are the applications of Synchro?

Synchro transmitter and receiver angle difference Vs output error voltage



Ex. No:
Date:

9. SYNCHRO TRANSMITTER & RECEIVER CHARACTERISTICS

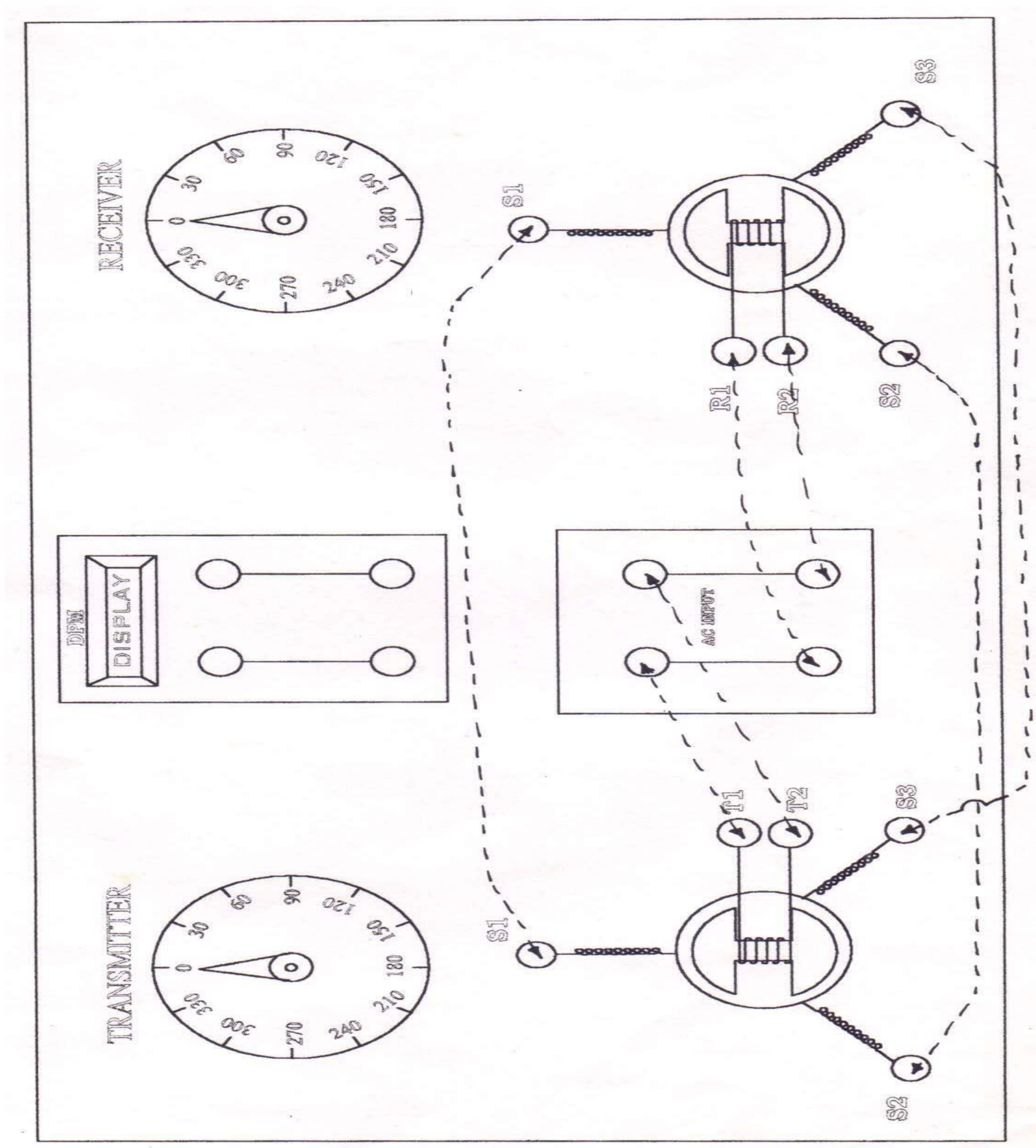
AIM:
1. To study the operation of synchro transmitter and receiver as a error detector
2. To study the operation of Synchro Transmitter and Receiver.

APPARATUSREQUIRED:
Synchro transmitter and receiver kit
Patch cords

PROCEDURE:
Synchro transmitter and receiver as an error detector
1. Connect the R1-R2 terminals of transmitter to power supply.
2. Short S1-S2, S2-S2, S3-S3 winding of transmitter and receiver.
3. Connect the R1-R2 terminals of receiver to digital panel meter.
4. As the power is switched ON transmitter and receiver shaft will come to the same position on the dial.
5. Set the transmitter rotor in zero position and rotate the receiver rotor.
6. Take the error voltage display on the digital panel meter corresponding to the angle difference between transmitter and receiver.
7. Tabulate the reading as per the following table.

Synchro Transmitter and Receiver
1. Arrange power supply, synchro transmitter and synchro receiver near to each other.
2. Connect power supply output to R1-R2 terminals of the transmitter and receiver.
3. Short S1-S2, S2-S2, and S3-S3 winding of transmitter and receiver with the help of patch cords.
4. Switch on the unit, supply neon will glow on.
5. As the power is switched on transmitter and receiver shaft will come to the same position on the dial.
6. Vary the shaft position of the transmitter and observe the corresponding change in the shaft position of the receiver.
7. Repeat the above steps for different angles of the shaft of the transmitter, you should have observed that the receiver shaft move by an equal amount as that of a transmitter.

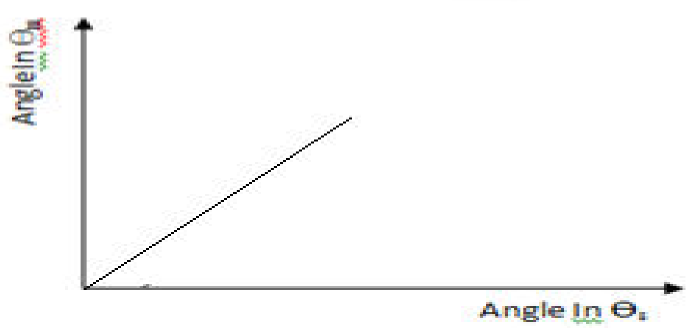
Synchro Transmitter stator angle Vs receiver rotor angle characteristics



Tabulation for rotor angle versus receiver angle:

S.No	Transmitter angular position (degrees)	Receiver angular position (degrees)

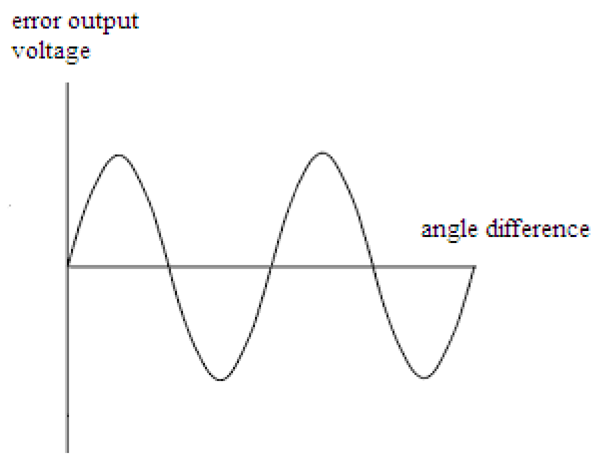
Model Graph:



Tabulation for error voltage Vs difference between transmitter and receiver rotor angle

S.No	Transmitter position (degrees)	Receiver position (degrees)	Error output Voltage (Volts)	Angle of Difference (degrees)

Model Graph



MODEL CALCULATION

RESULT:

Answers

```
num =    20

den =    1     5     4     0

Transfer function:

       20

-----------------

s^3 + 5 s^2 + 4 s

 Gm =    1.0000

Pm =  7.3342e-006

Wcp = 2.0000

Wcp = 2.0000

PM = -135

Wg = 0.7016

beta =  5.7480

tau =   11.4025

 Transfer function:

11.4 s + 1

-----------

65.54 s + 1

 Transfer function:

              228 s + 20

---------------------------------------

65.54 s^4 + 328.7 s^3 + 267.2 s^2 + 4 s

Gm1 = 5.2261

Pm1 = 38.9569

Wcg1 = 1.9073

Wcp1 = 0.7053
```

Ex. No:
Date:

10. DESIGN OF LEAD, LAG AND LEAD-LAG COMPENSATORS

AIM :

To Design the Lead, Lag and Lead-Lag compensator for the system using MATLAB Software.

APPARATUS REQUIRED :

1. MATLAB Software.

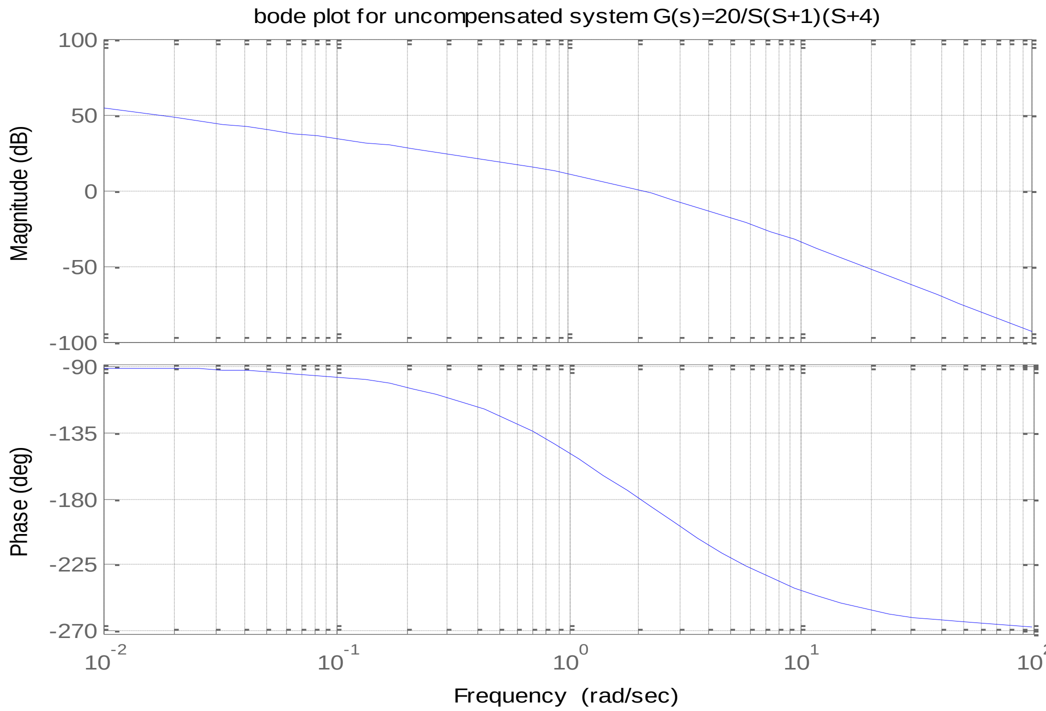
DESIGN PROCEDURE

1. Design a Phase Lag compensator for the unity feedback transfer function G(s)=K /s(s+1)(s+4) has specifications : a. Phase Margin>_ 40^0 b. The steady state error for ramp input is less than or equal to 0.2 and check the results using MATLAB Software.

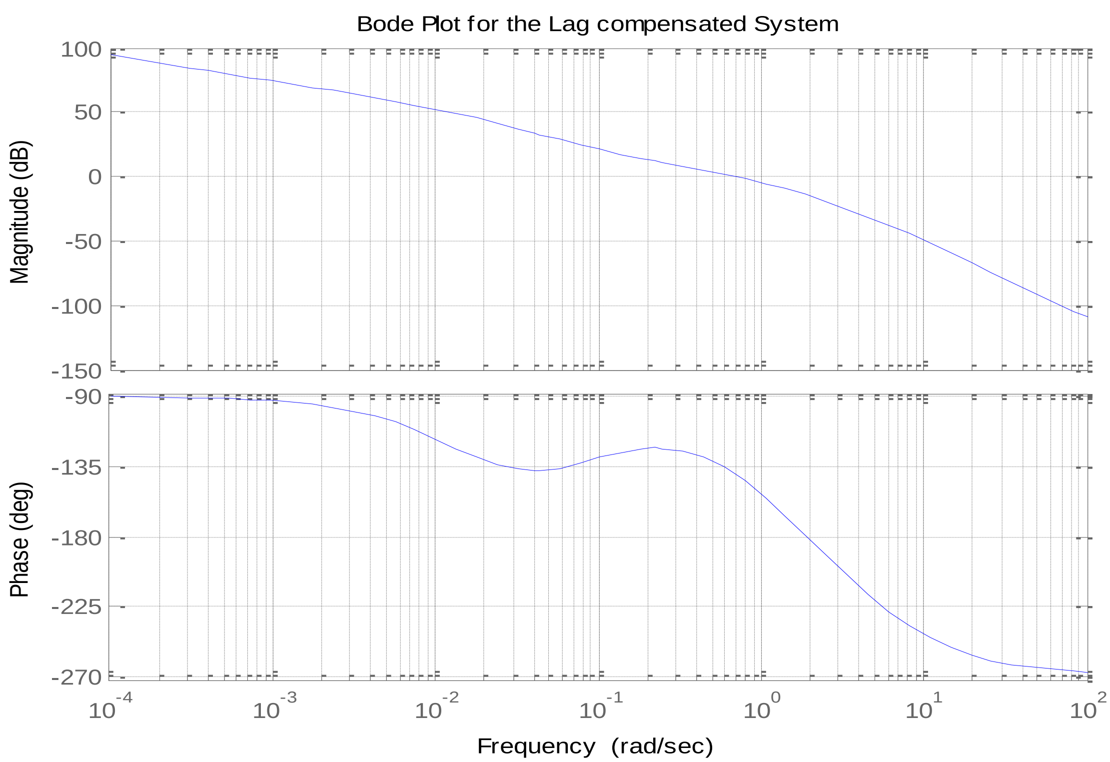
Solution

```
num=[20]

den=[1 5 4 0]

G=tf(num,den)

figure(1);

bode(num,den);

Title('bode plot for uncompensated system G(s)=20/S(S+1)(S+4)')

grid;

[Gm,Pm,Wcp,Wcp]=MARGIN(num,den)
```

```
Gmdb=20*log10(Gm);

W=logspace(-1,1,100)';

[mag,ph]=BODE(G,W);

ph=reshape(ph,100,1);

mag=reshape(mag,100,1);

PM=-180+40+5

Wg=interp1(ph,W,PM)

beta=interp1(ph,mag,PM)

tau=8/Wg

D=tf([tau 1],[beta*tau 1])

Gc=D*G

figure(2);

bode(Gc);

Title('Bode Plot for the Lag compensated System')

grid;

[Gm1,Pm1,Wcg1,Wcp1]=MARGIN(Gc)
```


bode plot for uncompensated system G(s)=20/S(S+1)(S+4)
Magnitude (dB)
100
50
0
-50
-100
Phase (deg)
-90
-135
-180
-225
-270
10^-2
10^-1
10^0
10^1
10^2
Frequency (rad/sec)

`


Bode Plot for the Lag compensated System
Magnitude (dB)
100
50
0
-50
-100
-150
Phase (deg)
-90
-135
-180
-225
-270
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
Frequency (rad/sec)

2. Design a Phase Lead compensator for the unity feedback transfer function G(s)=K /s(s+2) has specifications : a. Phase Margin>_ 55^0 b. The steady state error for ramp input is less than or equal to 0.33 and check the results using MATLAB Software. (Assume K=1)

Solution

```
num=[5]

den=[1 2 0]

G=tf(num,den)

figure(1);

bode(num,den);

Title('Bode Plot for uncompensated system G(s)=5/s(s+2)')

grid;

[Gm,Pm,Wcg,Wcp]=MARGIN(num,den)

GmdB=20*log10(Gm)

PM=55-Pm+3

alpha=(1-sin(PM*pi/180))/(1+sin(PM*pi/180))

Gm=-20*log10(1/sqrt(alpha))

w=logspace(-1,1,100)';

[mag1,phase1]=BODE(num,den,w);

mag=20*log10(mag1);

magdB=reshape(mag,100,1);

Wm=interp1(magdB,w,-20*log10(1/sqrt(alpha)))
```

```
tau=1/(Wm*sqrt(alpha))

D=tf([tau 1],[alpha*tau 1])

Gc=D*G

figure(2);

bode(Gc);

Title('Bode Plot for the Lead Compensated System')

grid;

[Gm1,Pm1,Wcg1,Wcp1]=MARGIN(Gc)
```

Answers

```
num =    5
den =     1     2     0
Transfer function:
    5
---------
s^2 + 2 s
Gm =   Inf
Pm =   47.3878
Wcg =   Inf
Wcp =  1.8399
GmdB =   Inf

PM =  10.6122

alpha =   0.6890

Gm =  -1.6181

Wm = 2.0853

tau =    0.5777

 Transfer function:

0.5777 s + 1

------------

0.398 s + 1
```

Transfer function:

2.889 s + 5

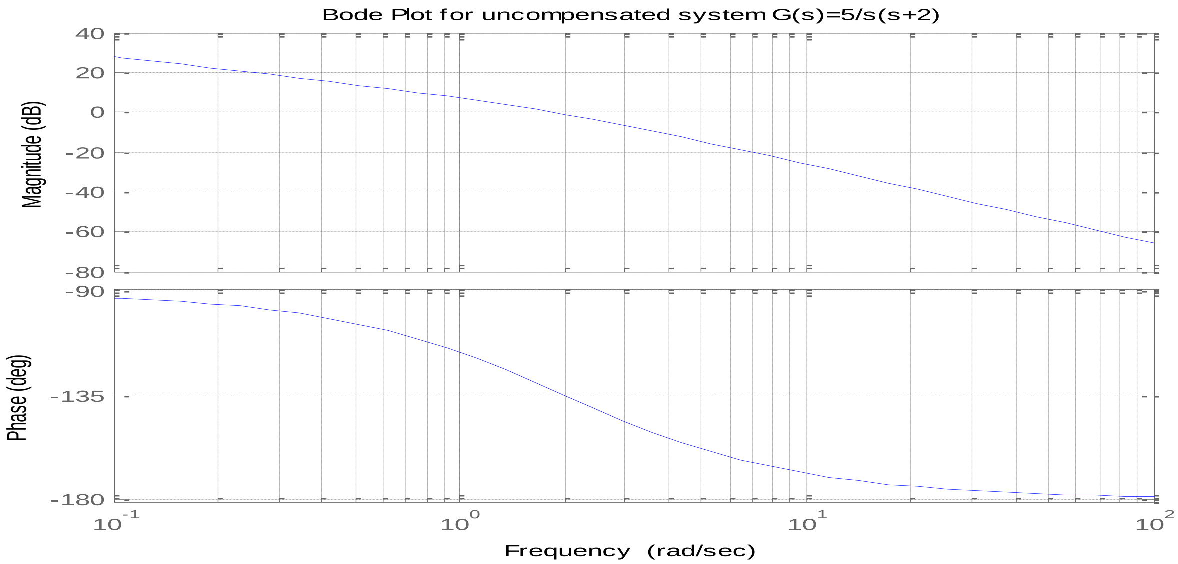
0.398 s^3 + 1.796 s^2 + 2 s

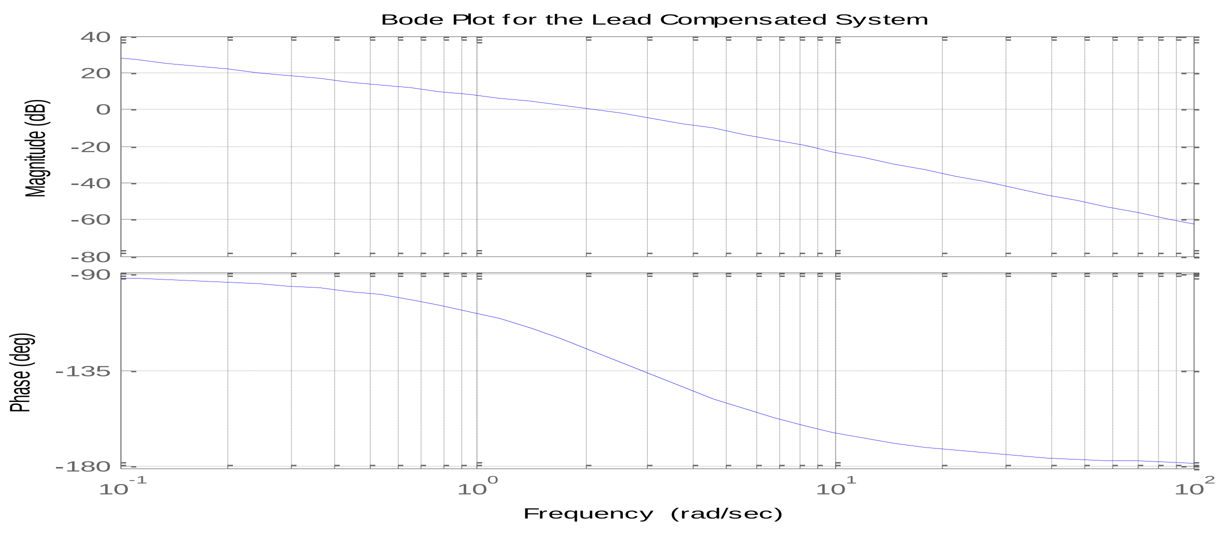
Gm1 = Inf

Pm1 = 54.4212

Wcg1 = Inf

Wcp1 = 2.0849





3. Design a Phase Lead-lag compensator for the unity feedback transfer function G(s)=K /s(s+1)(s+2) has specifications : a. Phase Margin>_ 50^0 b. The Velocity error constant Kv=10 sec-^{1} and check the results using MATLAB Software. (Assume K=1).

Solution

```
num=[20]

den=[1 3 2 0]

G=tf(num,den)

figure(1);

bode(num,den);

Title('bode Plot for Uncompensated System G(s)=20/S(S+1)(S+2)')

grid;

[Gm,Pm,Wcg,Wcp]=MARGIN(num,den)

GmdB=20*log10(Gm);

W=logspace(-1,1,100)';

%Bode Plot for Lag Section

[mag,ph]=BODE(G,W);

ph=reshape(ph,100,1);

mag=reshape(mag,100,1);

PM=-180+50+5

Wg=interp1(ph,W,PM)

beta=interp1(ph,mag,PM)

tau=8/Wg

D=tf([tau 1],[beta*tau 1])

%Bode Plot for Lead section

alpha=20/beta

mag=20*log10(mag)

Gm=-20*log10(1/sqrt(alpha))
```

```
Wm=interp1(mag,W,-20*log10(1/sqrt(alpha)))

tau=1/(Wm*sqrt(alpha))

E=tf([tau 1],[alpha*tau 1])

Gc1=D*E*G

figure(2);

bode(Gc1);

Title('Bode Plot for the Lag-lead compensated System')

grid;

 [Gm1,Pm1,Wcg1,Wcp1]=MARGIN(Gc1)
```

Answers

```
num =    20
den =     1     3     2     0
 Transfer function:
       20
-----------------
s^3 + 3 s^2 + 2 s
Gm = 0.3000
Pm = -28.0814
Wcg =  1.4142
Wcp =   2.4253
PM = -125
Wg =    0.4247
beta =   21.2032
tau =  18.8362
 Transfer function:
18.84 s + 1
-----------
399.4 s + 1
 alpha = 0.9433
Gm =   -0.2537
Wm = 2.4546
tau =  0.4195
Transfer function:
0.4195 s + 1
------------
0.3957 s + 1
  Transfer function:
```

158 s^2 + 385.1 s + 20

----

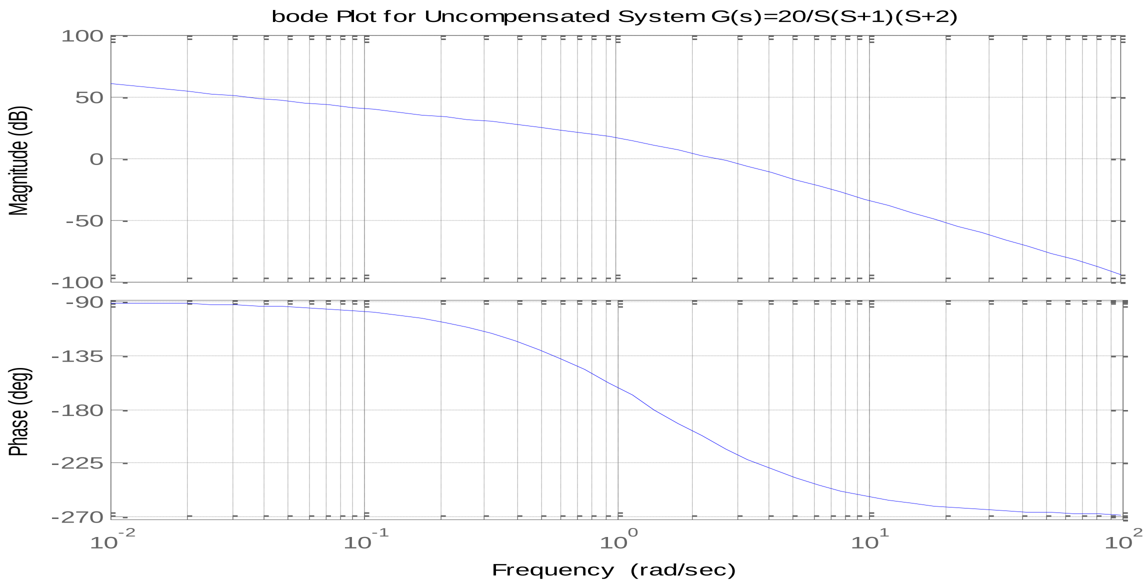
158 s^5 + 873.9 s^4 + 1516 s^3 + 802.6 s^2 + 2 s

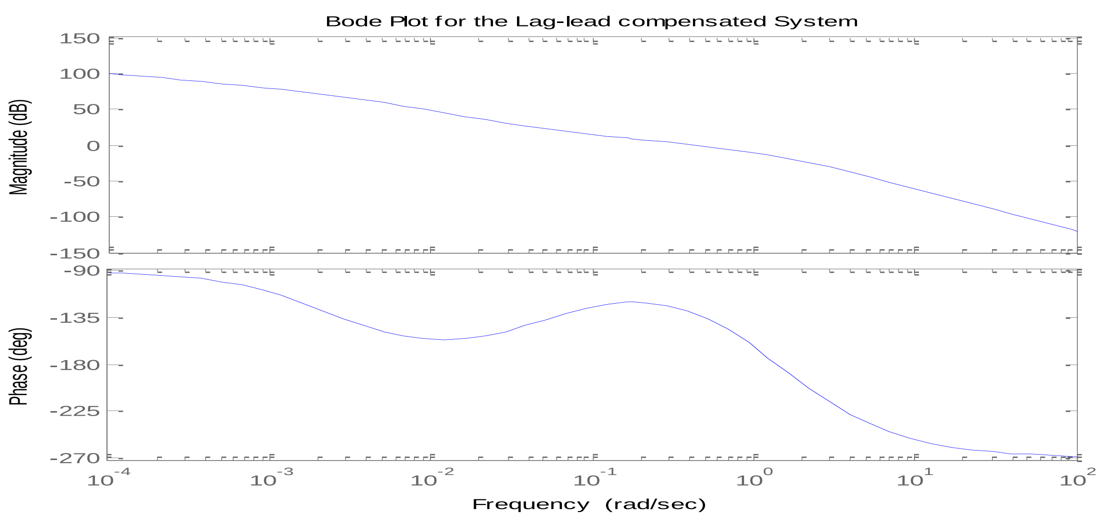
Gm1 = 6.1202

Pm1 = 48.5839

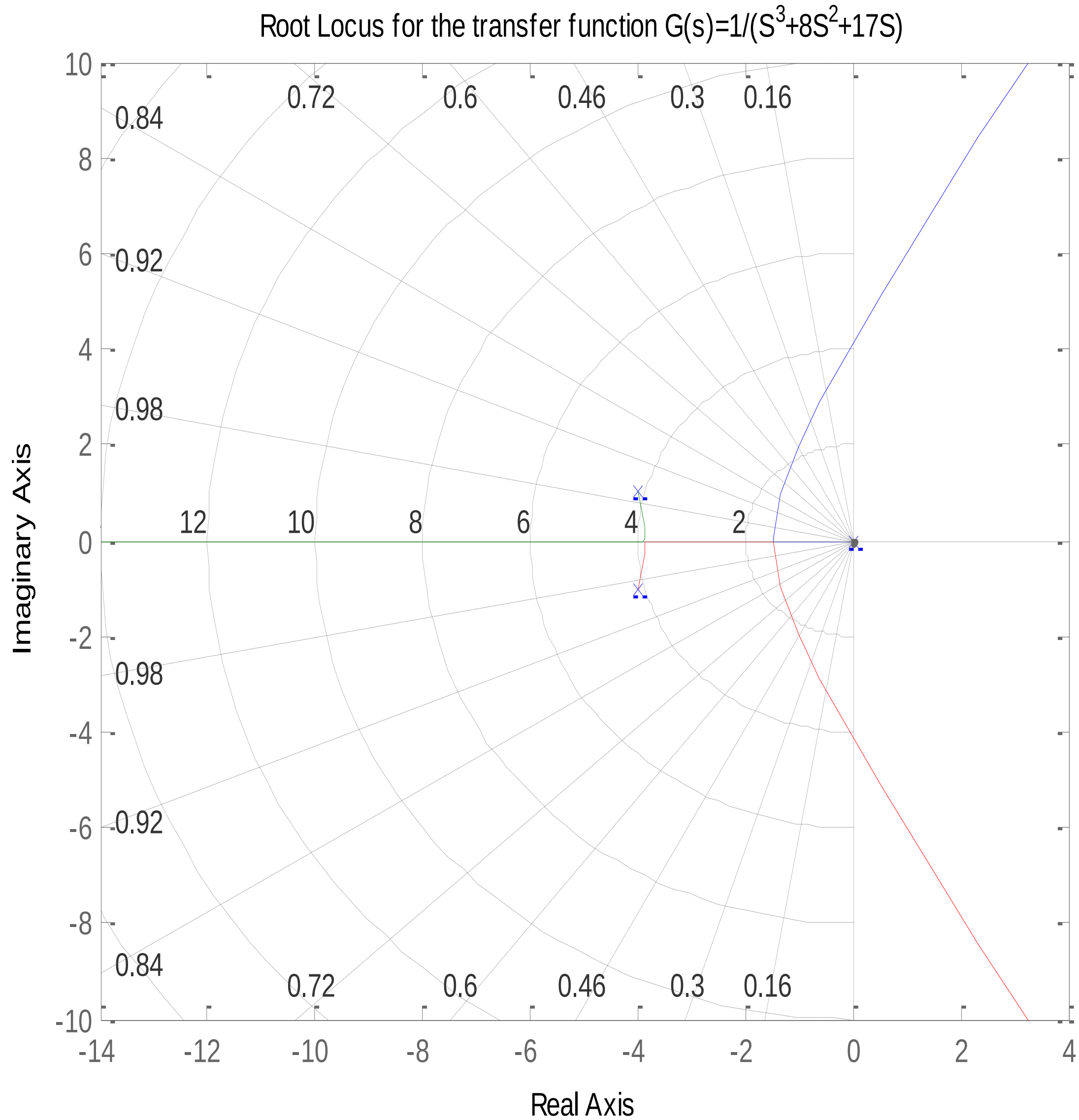
Wcg1 = 1.3976

Wcp1 = 0.4279





RESULT



Root Locus for the transfer function G(s)=1/(S^3+8S^2+17S)
Imaginary Axis
Real Axis
0.84
0.72
0.6
0.46
0.3
0.16
0.92
0.98
12
10
8
6
4
2
-14
-12
-10
-8
-6
-4
-2
0
2
4
10
8
6
4
2
0
-2
-4
-6
-8
-10

Ex. No:
Date:

11. SIMULATION OF CONTROL SYSTEM AND STABILITY ANALYSIS

AIM:-

To check the stability analysis of the given system or transfer function using MATLAB Software.

APPARATUS REQUIRED

1. MATLAB Software

DESIGN PROCEDURE :

1. Root Locus : The open loop transfer function of a unity feedback system $G(s)=K/s(s^2+8s+17)$ Draw the root locus manually and Check the same results using MATLAB Software. (Assume K=1)

Solution

```
% Rootlocus of the transfer function G(s)=1/(S^3+8S^2+17S)

num=[1];

den=[1 8 17 0];

figure(1);

rlocus(num,den);

Title('Root Locus for the transfer function G(s)=1/(S^3+8S^2+17S)')

grid;
```

2. BODE PLOT : The open loop transfer function of a unity feedback system $G(s)=K/s(s^2+2s+3)$ Draw the Bode Plot manually Find (i)Gain Margin (ii)Phase Margin (iii)Gain cross over frequency (iv)Phase cross over frequency (v) Resonant Peak

(vi)Resonant Frequency (vii)Bandwidth and Check the same results using MATLAB Software. (Assume K=1)

Solution

```
%Draw the Bode Plot for the given transfer functionG(S)=1/S(S2+2S+3) %Find (i)Gain Margin (ii) Phase Margin (iii) Gain Cross over Frequency %(iv) Phase Cross over Frequency (v)Resonant Peak (vi)Resonant %Frequency (vii)Bandwidth

num=[1 ];

den=[1 2 3 0];

w=logspace(-1,3,100);

figure(1);

bode(num,den,w);

title('Bode Plot for the given transfer function G(s)=1/s(s^2+2s+3)')

grid;

[Gm Pm Wcg Wcp] =margin(num,den);

Gain_Margin_dB=20*log10(Gm)

Phase_Margin=Pm

Gaincrossover_Frequency=Wcp

Phasecrossover_Frequency=Wcg

[M P w]=bode(num,den);

[Mp i]=max(M);

Resonant_PeakdB=20*log10(Mp)

Wp=w(i);
```

```
Resonant_Frequency=Wp

for i=1:1:length(M);

    if M(i)<=1/(sqrt(2));

            Bandwidth=w(i)

        break;

    end;

end;
```

Answer

Gain_Margin_dB =15.5630

Phase_Margin = 76.8410

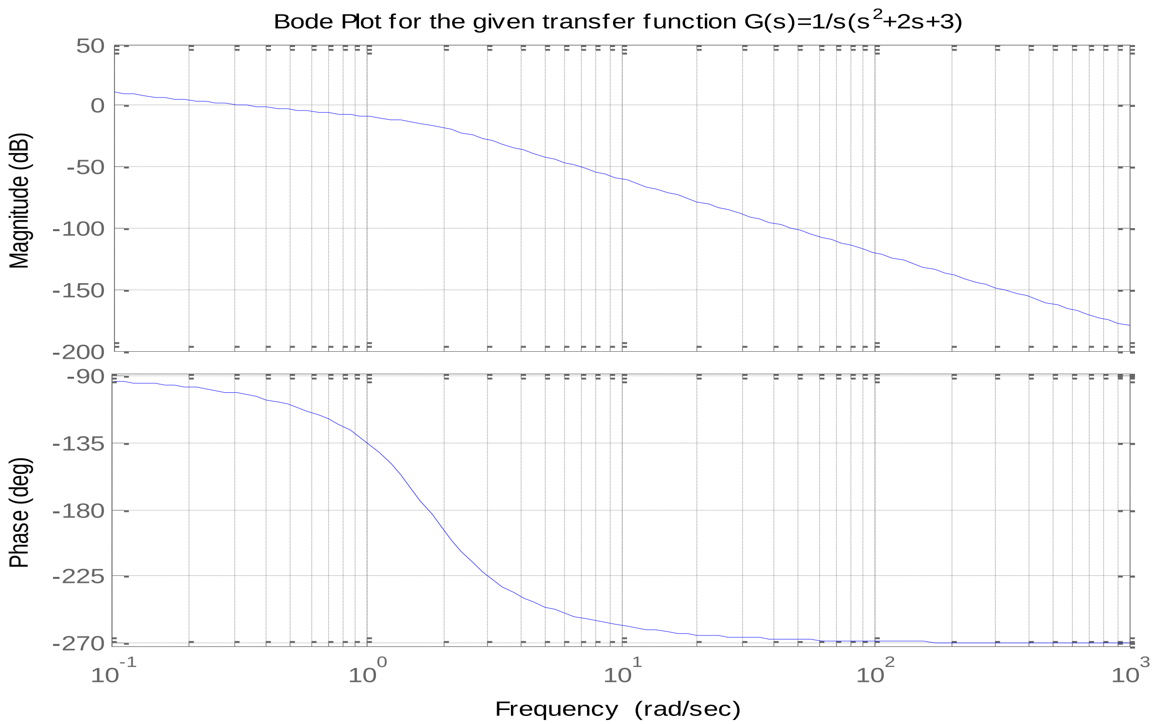
Gaincrossover_Frequency = 0.3374

Phasecrossover_Frequency= 1.7321

Resonant_PeakdB = 10.4672

Resonant_Frequency = 0.1000

Bandwidth = 0.5356



3. Nyquist Plot : The open loop transfer function of a unity feedback system $G(s)=K/s(s^2+2s+3)$ Draw the Nyquist Plot manually Find (i)Gain Margin (ii)Phase Margin (iii)Gain cross over frequency (iv)Phase cross over frequency and Check the same results using MATLAB Software. (Assume K=1)

Solution

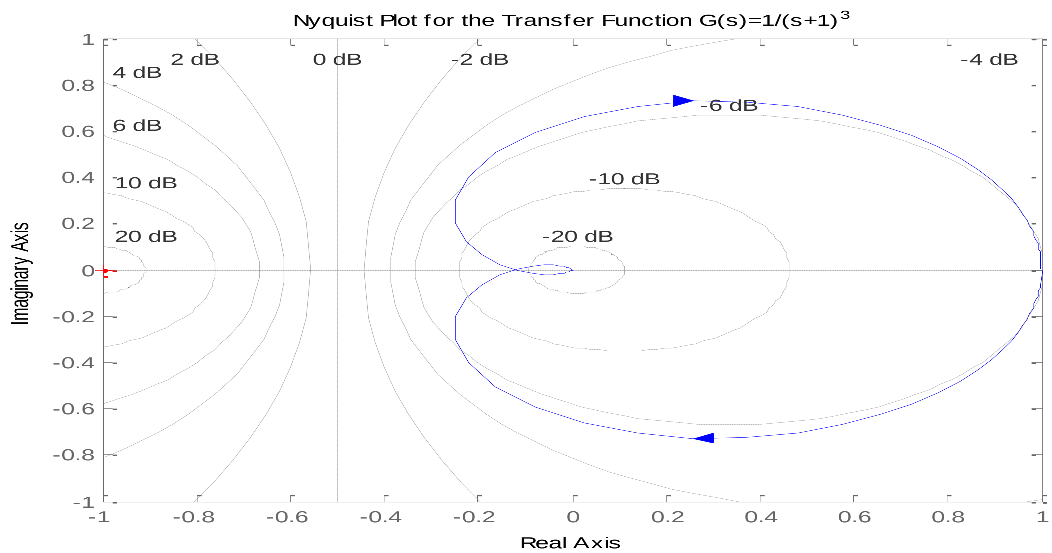
```
%Nyquist Plot for the Transfer Function G(s)=1/(s+1)^3

num=[1];

den=[1 3  3 1];

figure(1);

nyquist(num,den)

Title('Nyquist Plot for the Transfer Function G(s)=1/(s+1)^3')

[Gm,Pm,Wcg,Wcp] =margin(num,den)

grid;

[Gm,Pm,Wcg,Wcp] =margin(num,den);
```

Gain_Margin=Gm

Phase_Margin=Pm

PhaseCrossover_Frequency=Wcg

GainCrossover_Frequency=Wcp



Answer

Gain_Margin = 8.0011

Phase_Margin = -180

PhaseCrossover_Frequency = 1.7322

GainCrossover_Frequency = 0

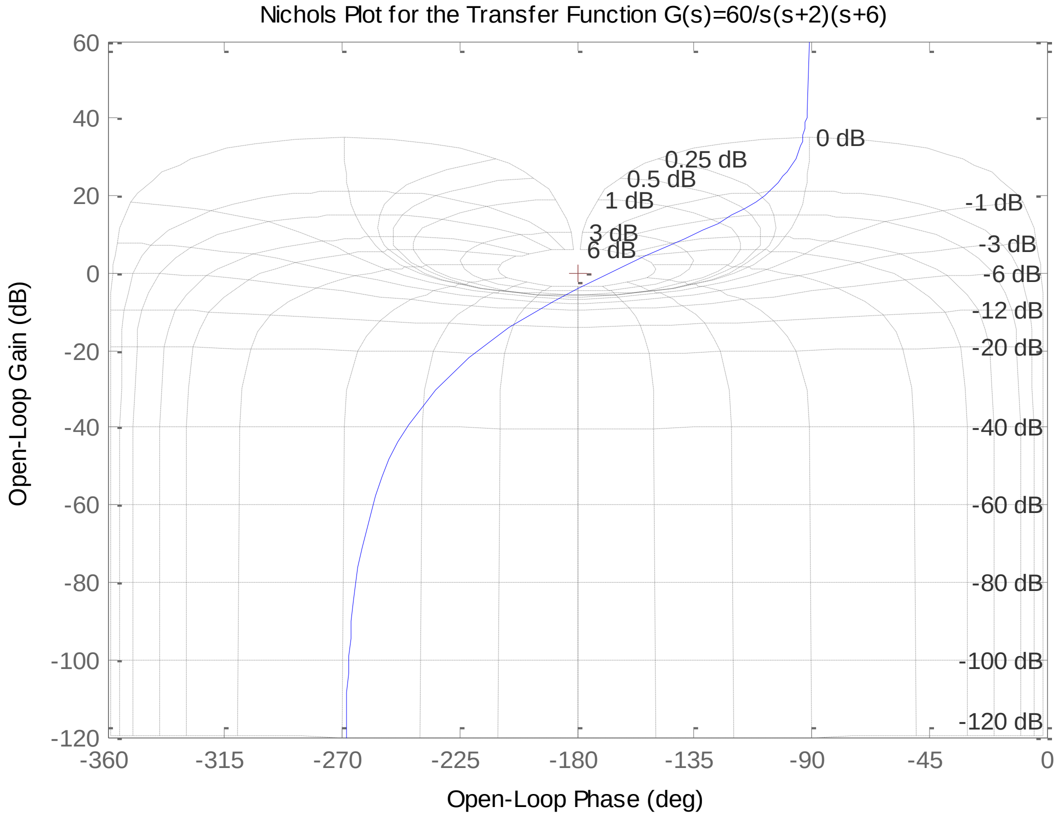
4. Nichols Chart : The open loop transfer function of a unity feedback system G(s)=60 /s(s+2)(s+3) Draw the Nichol's Chart manually Find (i)Gain Margin (ii)Phase Margin (iii)Gain cross over frequency (iv)Phase cross over frequency (v) Resonant Peak (vi)Resonant Frequency (vii)Bandwidth and Check the results using MATLAB Software. (Assume K=1)

Solution

num=[60];

den=[1 8 12 0];

```
figure(1);
nichols(num,den)
Title('Nichols Plot for the Transfer Function G(s)=60/s(s+2)(s+6)')
grid;
[Mag,Ph,w] =bode(num,den);
[Gm,Pm,Wcg,Wcp] =margin(num,den);
Gain_Margin=Gm
GainMargin_dB=20*log10(Gm)
Phase_Margin=Pm
PhaseCrossover_Frequency=Wcg
GainCrossover_Frequency=Wcp
[Mp,k] =max(Mag);
Resonant_Peak=Mp;
Resonant_PeakdB=20*log10(Gm)
Resonant_Frequency=w(k)
% In Nichol's Chart the bandwidth is obtained in -3dB
n=1;
while 20*log10(Mag(n))>=-3
    n=n+1;
end;
Bandwidth=w(n)
```



Answer

GainMargin_dB = 4.0824

Phase_Margin = 12.1738

PhaseCrossover_Frequency = 3.4641

GainCrossover_Frequency = 2.7070

Resonant_PeakdB = 4.0824

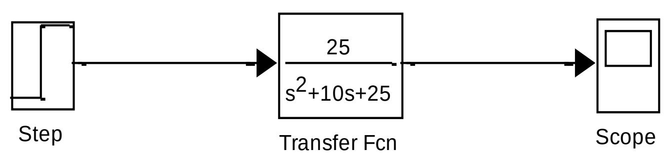
Resonant_Frequency = 0.1000

Bandwidth = 3.4641

RESULT

2. Second Order System

1. Critically Damped System



Ex. No:
Date:

12. PROCESS SIMULATION

AIM :

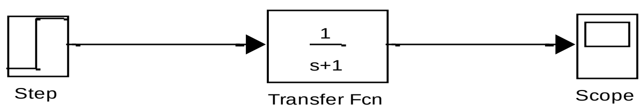
To check the process simulation result with first order and second oprder system with the step input.

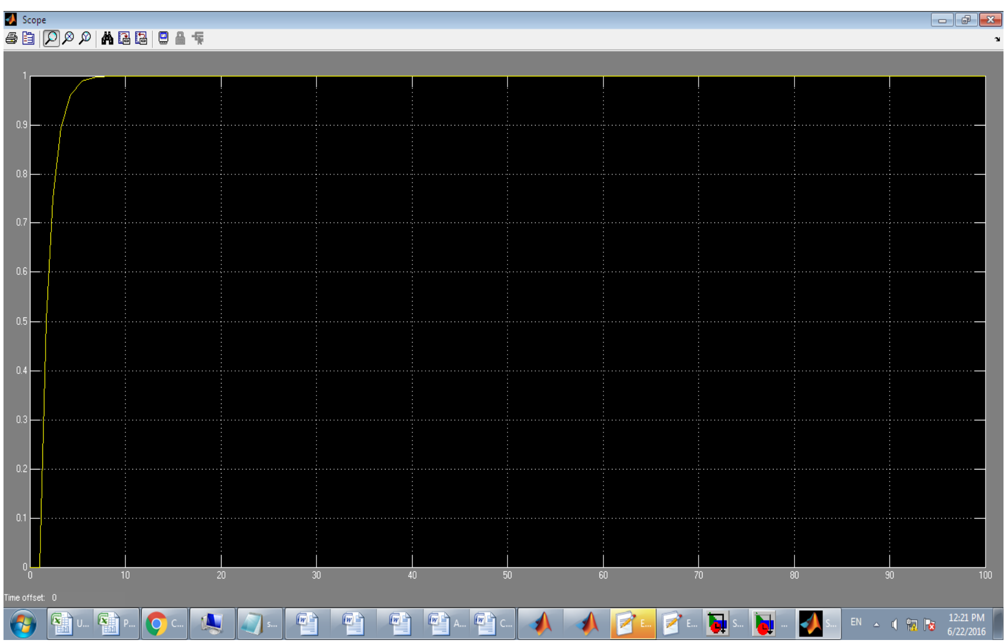
APPARATUS REQUIRED:

1. MATLAB Software.

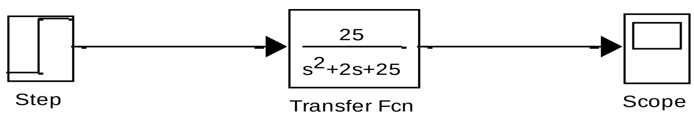
DESIGN OF SIMULINK BLOCK

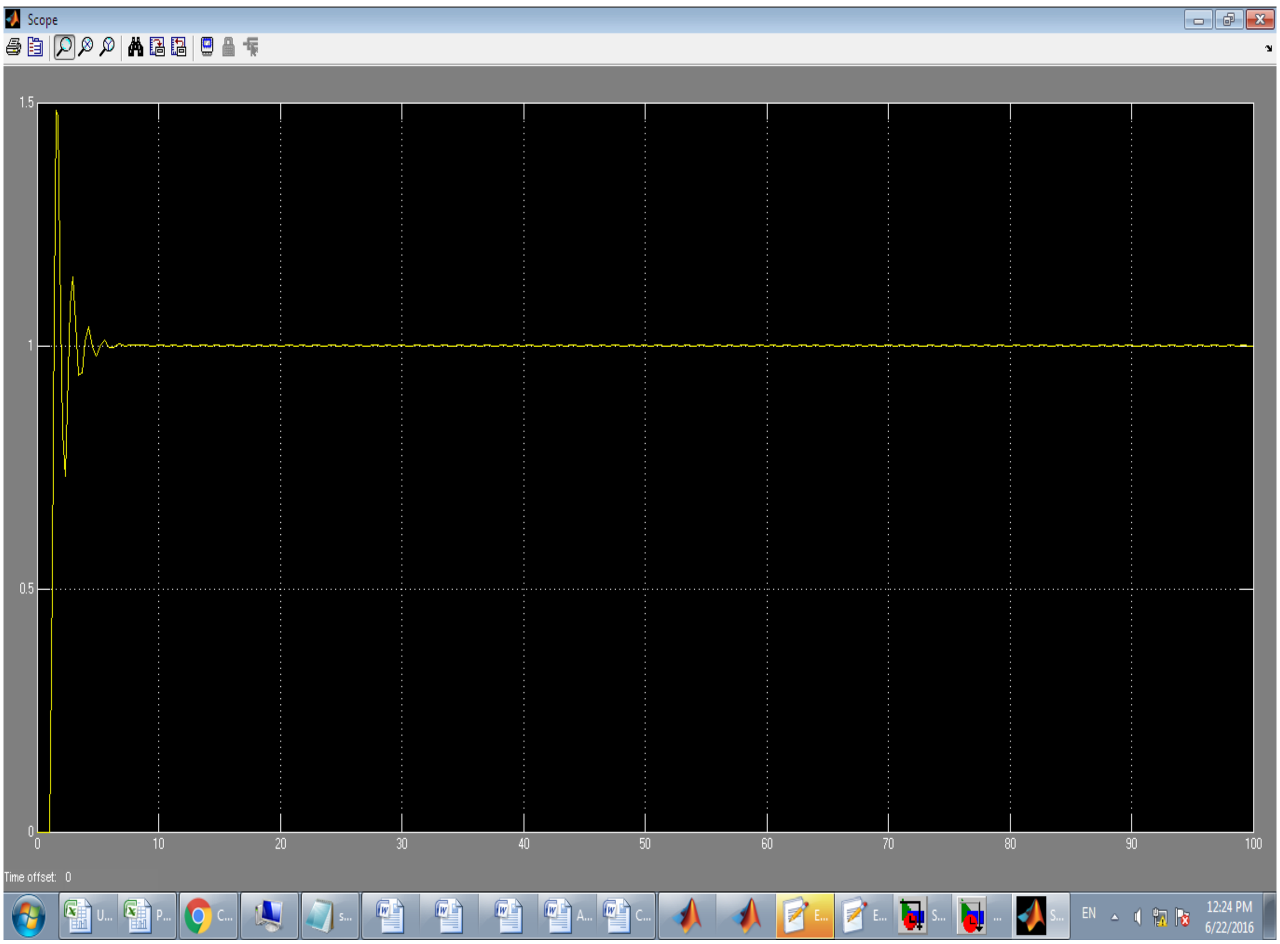
1.First Order System



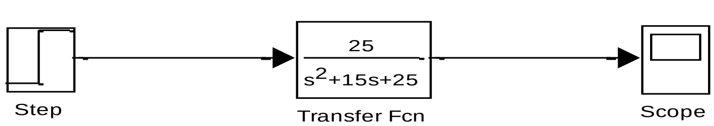


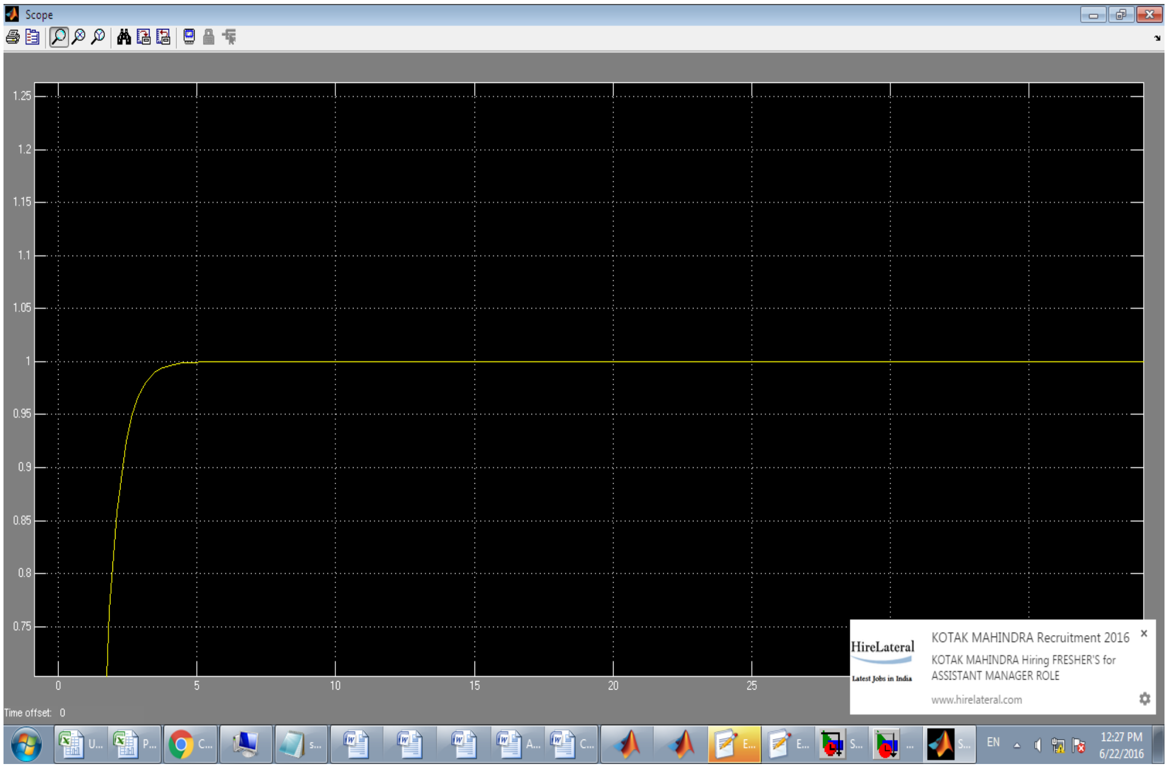
2. Under Damped System



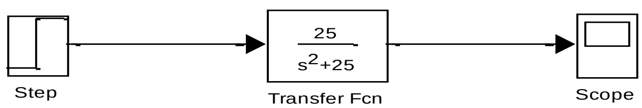


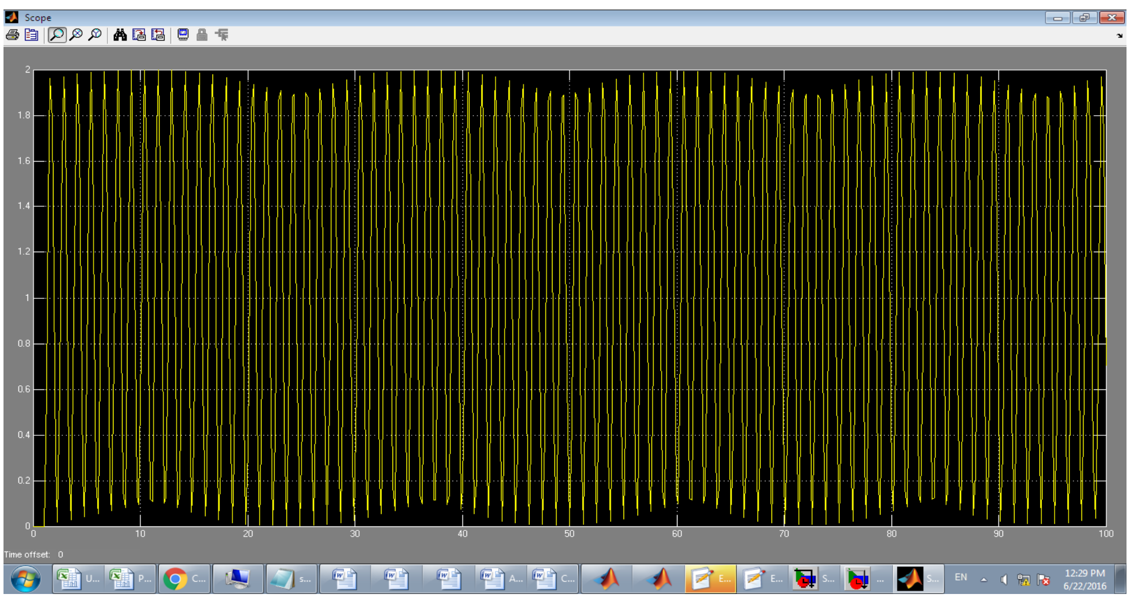
3. Over Damped System





4. UnDamped System



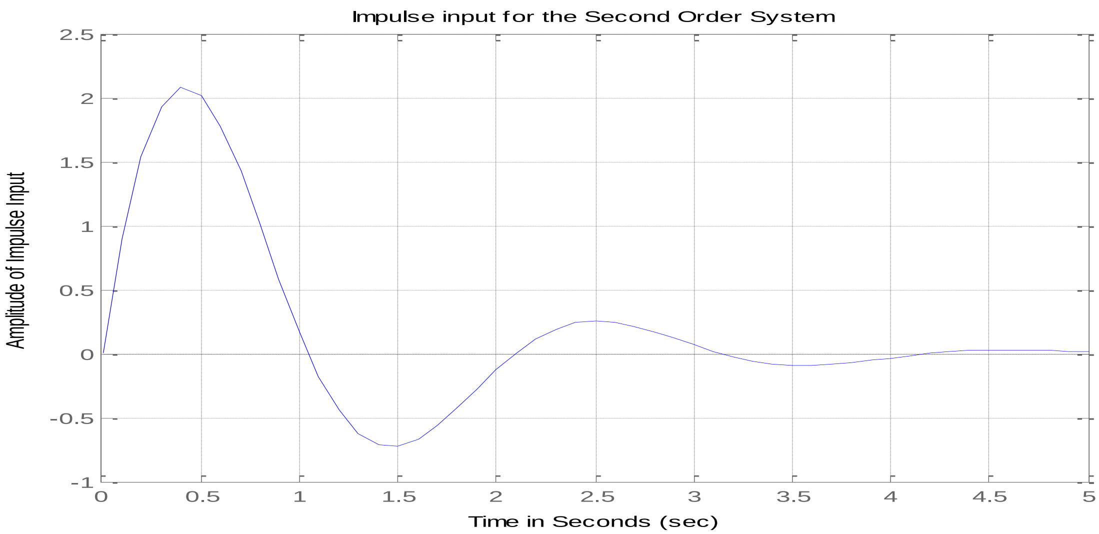


1. The Second order system has the transfer functions (i)Under Damped Second Order System G(s)=10/(s2+2s+10) (ii) Undamped Second Order system G(s)=10/(s2+10) (iii)Critically Damped Second Order System G(s)=10/(s2+7.32s+10) (iv)Over Damped Second Order System

G(s)=10/(s2+3s+10) for that apply step input and check the result 4-cases using MATLAB Software.

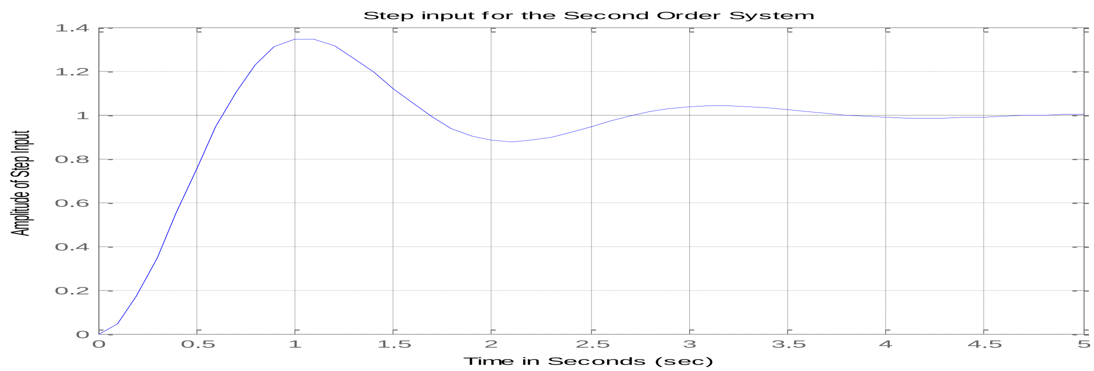
ANS

```
% Time Domain Specifications

num1=[10];

den1=[1 2 10];

%Transfer Function Form

G=tf(num1,den1)

% Natural frequency and Damping Ratio

[Wn Z P] = damp(G)

Wn=Wn(1);

Z=Z(1);

t=0:0.1:20

%(i) Under Damped System For Step Input

figure(1);

step(num1,den1,t)

title('Under Damped Second Order System Response for Step Input');

grid;
```



% (ii) Undamped Second Order System has the T.F=10/(S^2+10) with the Damping ratio=0 for Step Input

```
num2=[10];

den2=[1 0 10];

figure(2);

step(num2,den2,t)

title('Undamped Second Order System Response for Step Input');

grid;
```



% (iii) Critically damped Second Order System has the T.F=10/(S^2+7.32*s+10) with the Damping ratio=1 for step input

num3=[10];

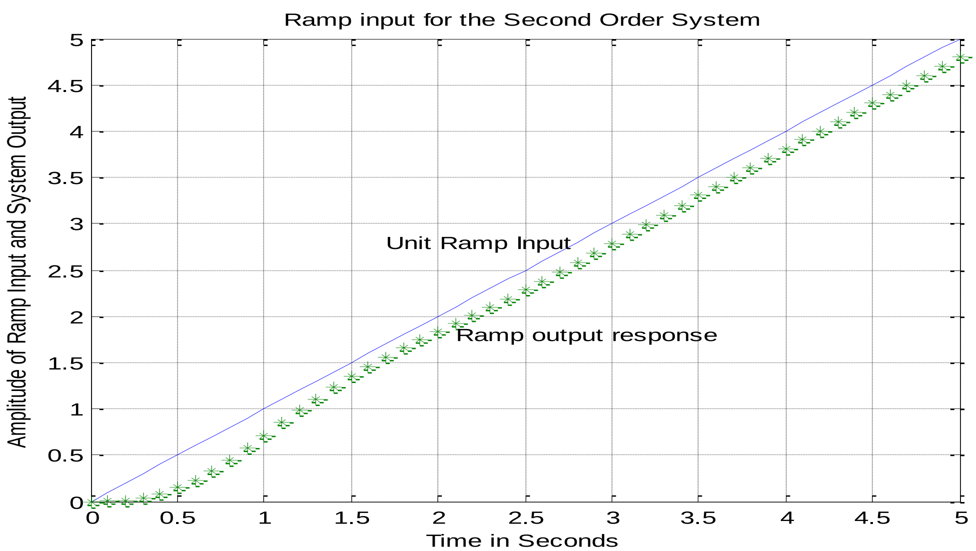
den3=[1 7.32 10];

figure(3);

step(num3,den3,t)

title('Critically Damped Second Order System Response for Step Input');

grid;



(iv) Critically damped Second Order System has the T.F=10/(S^2+3*s+10)with the Damping ratio=1.5 for step input

num4=[10];

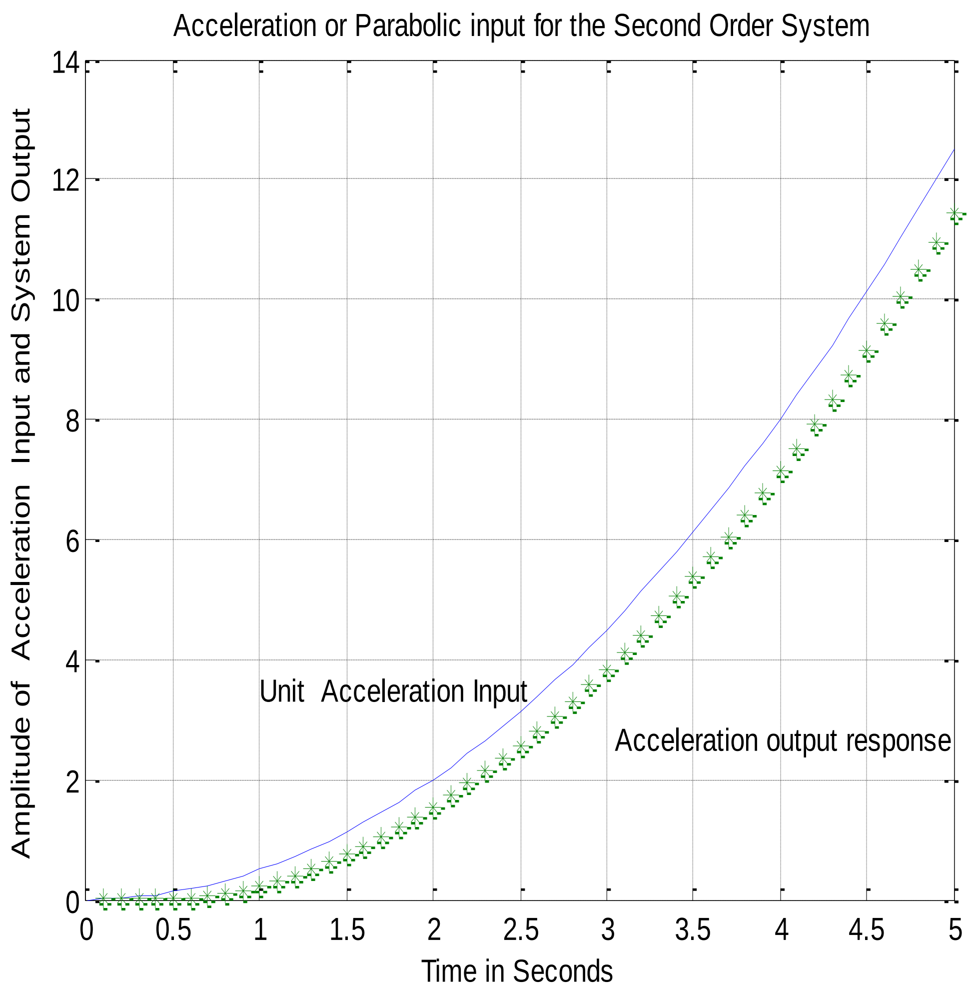
den4=[1 3 10];

figure(4);

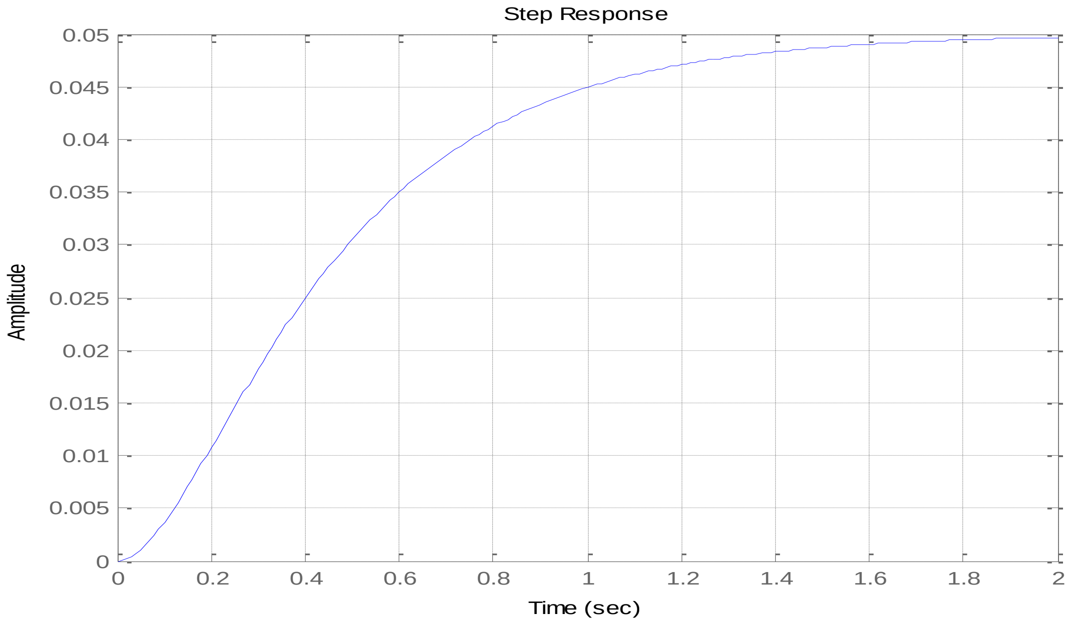
step(num4,den4,t)

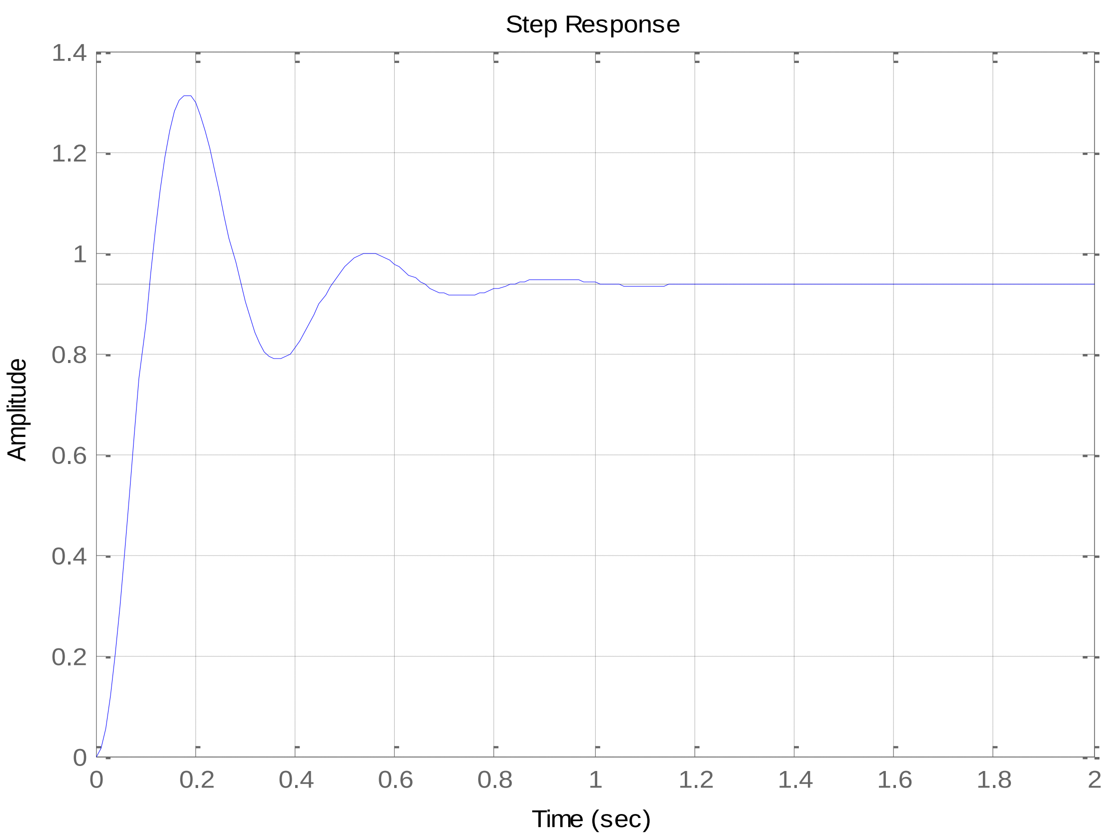
title('Over Damped Second Order System Response for Step Input');

grid;


Acceleration or Parabolic input for the Second Order System
Amplitude of Acceleration Input and System Output
Time in Seconds
Unit Acceleration Input
Acceleration output response
0
2
4
6
8
10
12
14
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

RESULT :


Step Response
Amplitude
Time (sec)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2


Step Response
Amplitude
Time (sec)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Ex. No:
Date:

13 (A) STUDY OF P, PI, PD and PID CONTROLLERS

AIM

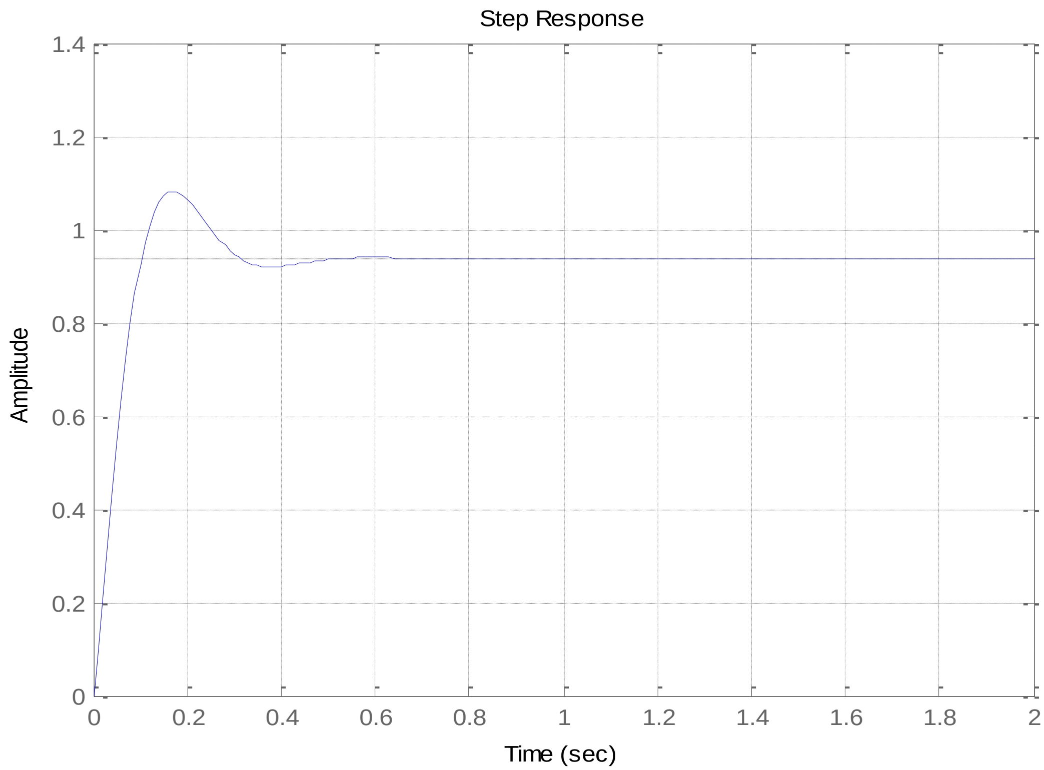
To obtain the response of the P, PI, PD, PID controller using MATLAB software.

APPARATUS REQUIRED

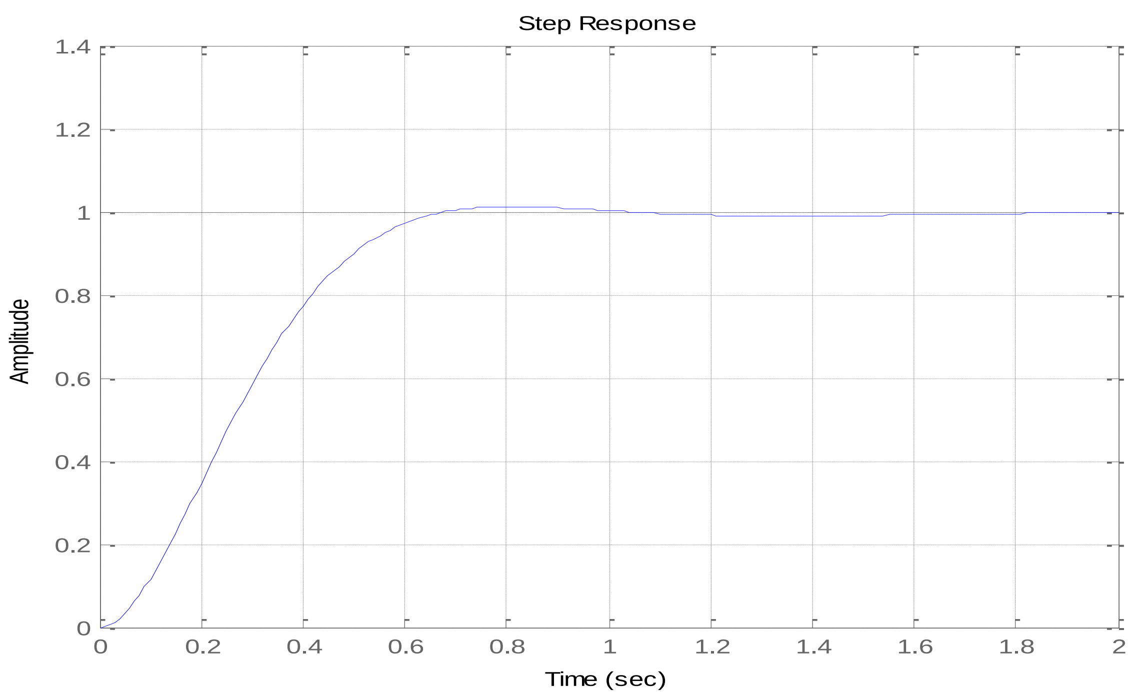
1. MATLAB Software

PROGRAM

```
% Step Response for OLTF 1/(s^2+10s+20)

num=[1];

den=[1 10 20];

figure(1);

step(num,den)


% Proportional Controller

Kp=300;

num1=[Kp];

den1=[1 10 20+Kp];

t=0:0.01:2;

figure(2);

step(num1,den1,t)

grid;
```

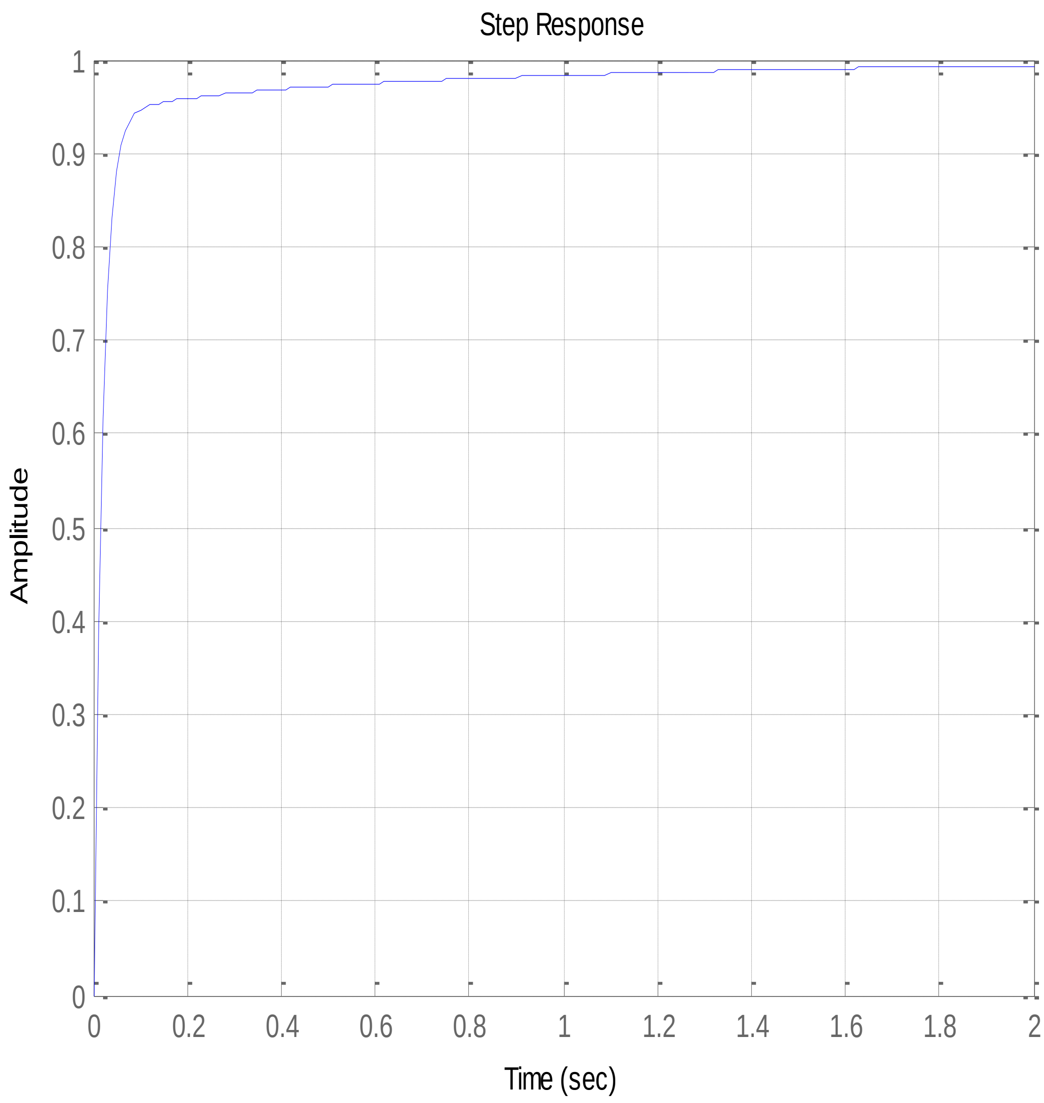


Step Response
Amplitude
Time (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2



Step Response
Amplitude
Time (sec)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

```
% Proportional Derivative Controller

Kp=300;

Kd=10;

num2=[Kd Kp];

den2=[1 10+Kd 20+Kp];

t=0:0.01:2;

figure(3);

step(num2,den2,t)

grid;


% Proportional Integral Controller

Kp1=30

Ki=70;

num3=[Kp1 Ki]

den3=[1 10 20+Kp1 Ki]

t=0:0.01:2;

figure(4);

step(num3,den3,t)

grid;
```


Step Response
Amplitude
Time (sec)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

```
%Proportional Integral Derivative Controller

Kp2=350;

Kd2=50;

Ki2=300;

num4=[Kd2 Kp2 Ki2]

den4=[1 10+Kd2 20+Kp2 Ki2]

t=0:0.01:2;

figure(5);

step(num4,den4,t)

grid;
```

RESULT

Answer

Transfer function:

100

----

s^2 + 15 s

Transfer function:

100

----

s^2 + 15 s + 100

(i)Wn = 10.0000

10.0000

Z = 0.7500

0.7500

P = -7.5000 + 6.6144i

-7.5000 - 6.6144i

(ii) Kp = Inf

Kv = 6.6667

Ka = 0

(iii)Wd = 6.6144

Theta= 0.7227

(iv) Td = 0.1525

(v) Tr = 0.3655

(vi) Tp = 0.4747

(vii)MpPercentage = 2.8427

(viii) Ts = 0.5333

Ts = 0.4000

Ex. No:
Date:

13(B) TIME DOMAIN AND FREQUENCY DOMAIN SPECIFICATIONS

AIM

To obtain the time domain and Frequency Domain Specifications for the given system using MATLAB Software.

APPARATUS REQUIRED

1. MATLAB Software

DESIGN PROCEDURE :

1. The open loop transfer function G(s)=100/s(s+15) has a unity feedback. Find (i) Natural Frequency and Damping Ratio (ii)Position, Velocity, Acceleration Error Constants (iii)Damped Frequency and Theta (iv)Delay Time (v) Rise Time (vi)Peak Time (vii)Maximum Peak over shoot percentage (viii) Settling Time for 2% and 5% and Calculate the same results using MATLAB Software.

Solution

```
% Time Domain Specifications

num=[100];

den=[1 15 0];

%Transfer Function Form

G=tf(num,den)

% Unity Feedback System

C=feedback(G,1)

% (i)Natural frequency and Damping Ratio
```

```
[Wn Z P] = damp(C)

Wn=Wn(1);

Z=Z(1);

%(ii)Position,Velocity,Acceleration Error Constants

% Position Error Constant

Kp=dcgain(G)

%Differentiator  Part

num1=[1 0];den1=[1];G1=tf(num1,den1);

%Velocity Error Constant

Gv=G1*G;

Kv=dcgain(Gv)

% Acceleration Error Constant

Ga=Gv*G1;

Ka=dcgain(Ga)

%(iii) Damped Frequency and Theta

% Damped Frequency of oscillation

Wd=Wn*sqrt(1-(Z^2))

%Angle of Theta

Theta=atan((sqrt(1-(Z^2)))/Z)

%(iv)Delay Time(Td)

Td=(1+0.7*Z)/Wn
```

```
%(v)Rise Time

Tr=(3.14-Theta)/Wd

%(vi)Peak Time

Tp=3.14/Wd

%(vii)Percentage of Peak over shoot

MpPercentage=exp((-3.14*Z)/(sqrt(1-Z^2)))*100

%(viii) Settling Time

% For 2%

Ts=4/(Z*Wn)

% For 5%

Ts=3/(Z*Wn)
```

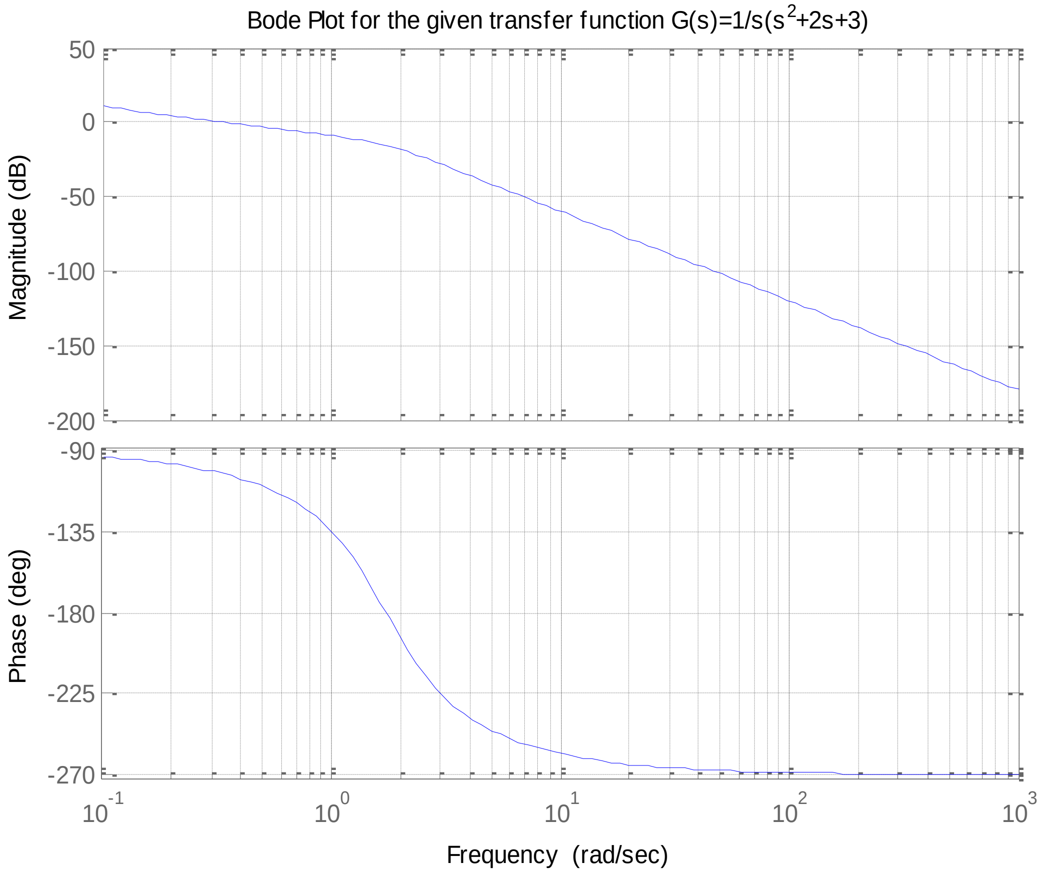
2. The open loop transfer function of a unity feedback system $G(s)=K/s(s^2+2s+3)$ Draw the Bode Plot manually Find (i)Gain Margin (ii)Phase Margin (iii)Gain cross over frequency (iv)Phase cross over frequency (v) Resonant Peak (vi)Resonant Frequency (vii)Bandwidth and Check the same results using MATLAB Software. (Assume K=1)

Solution

```
%Draw the Bode Plot for the given transfer functionG(S)=1/S(S2+2S+3) %Find (i)Gain Margin
%(ii) Phase Margin (iii) Gain Cross over Frequency %(iv) Phase Cross over Frequency
%(v)Resonant Peak (vi)Resonant %Frequency  (vii)Bandwidth

num=[1 ];

den=[1 2 3 0];

w=logspace(-1,3,100);

figure(1);

bode(num,den,w);

title('Bode Plot for the given transfer function G(s)=1/s(s^2+2s+3)')
```

```
grid;
[Gm Pm Wcg Wcp] =margin(num,den);
Gain_Margin_dB=20*log10(Gm)
Phase_Margin=Pm
Gaincrossover_Frequency=Wcp
Phasecrossover_Frequency=Wcg
[M P w]=bode(num,den);
[Mp i]=max(M);
Resonant_PeakdB=20*log10(Mp)
Wp=w(i);
Resonant_Frequency=Wp
for i=1:1:length(M);
   if M(i)<=1/(sqrt(2));
          Bandwidth=w(i)
      break;
   end;
end;
```

Answer



Gain_Margin_dB =15.5630

Phase_Margin = 76.8410

Gaincrossover_Frequency = 0.3374

Phasecrossover_Frequency= 1.7321

Resonant_PeakdB = 10.4672

Resonant_Frequency = 0.1000

Bandwidth = 0.5356

RESULT

Closed loop transfer function of the type – 1-second order system is

$$C(s)/R(s) = G(s) / [1 + G(s) H(s)]$$

where

$H(s) = 1$

$G(s) = K K_1 K_2 / s (1 + sT_1)$

Where

K is the gain

K_1 is the gain of Integrator = 9.6

K_2 is the gain of the time constant – 1 block =10

T_1 is the time constant of time constant – 1 block = 1 ms

THEORY:

The type number of the system is obtained from the number of poles located at origin in a given system. Type – 0 system means there is no pole at origin. Type – 1 system means there is one pole located at the origin. The order of the system is obtained from the highest power of s in the denominator of closed loop transfer function of the system. The first order system is characterized by one pole or a zero. Examples of first order systems are a pure integrator and a single time constant having transfer function of the form K/s and K/(sT+1). The second order system is characterized by two poles and up to two zeros. The standard form of a second order system is $G(s) = \omega_n^2 / (s^2 + 2\zeta\omega_n s + \omega_n^2)$ where ζ is damping ratio and ω_n is undamped natural frequency.

PROCEDURE:

1. To find the steady state error of type – 0 first order system

1. Connections are made in the simulator kit as shown in the block diagram.
2. The input square wave is set to 2 Vpp in the CRO and this is applied to the REF terminal of error detector block. The input is also connected to the X- channel of CRO.
3. The output from the simulator kit is connected to the Y- channel of CRO.
4. The CRO is kept in X-Y mode and the steady state error is obtained as the vertical displacement between the two curves.

BEYOND THE SYLLABUS EXPERIMENTS:

Ex. No. **14.ANALOG SIMULATION OF TYPE – 0 and TYPE – 1 SYSTEMS**

Date:

AIM:

To study the time response of first and second order type –0 and type- 1 systems.

APPARATUS / INSTRUMENTS REQUIRED:

1. Linear system simulator kit
2. CRO
3. Patch cords

FORMULAE USED:

Damping ratio, $\zeta = \sqrt{(\ln M_P)^2 / (\pi^2 + (\ln M_P)^2)}$

Where M_P is peak percent overshoot obtained from the time response graph

Undamped natural frequency, $\omega_n = \pi / [t_p \sqrt{(1 - \zeta^2)}]$

where t_p is the peak time obtained from the time response graph

Closed loop transfer function of the type – 0 second order system is

$$C(s)/R(s) = G(s) / [1 + G(s) H(s)]$$

where

$H(s) = 1$

$G(s) = K K_2 K_3 / (1+sT_1) (1 + sT_2)$

where K is the gain

K_2 is the gain of the time constant – 1 block =10

K_3 is the gain of the time constant – 2 block =10

T_1 is the time constant of time constant – 1 block = 1 ms

T_2 is the time constant of time constant – 2 block = 1 ms

5. The gain K is varied and different values of steady state errors are noted.

2. To find the steady state error of type – 1 first order system

1. The blocks are Connected using the patch chords in the simulator kit.
2. The input triangular wave is set to 2 Vpp in the CRO and this applied o the REF terminal of error detector block. The input is also connected to the X- channel of CRO.
3. The output from the system is connected to the Y- channel of CRO.
4. The experiment should be conducted at the lowest frequency to allow enough time for the step response to reach near steady state.
5. The CRO is kept in X-Y mode and the steady state error is obtained as the vertical displacement between the two curves.
6. The gain K is varied and different values of steady state errors are noted.
7. The steady state error is also calculated theoretically and the two values are compared.

3. To find the closed loop response of type– 0 and type- 1 second order system

1. The blocks are connected using the patch chords in the simulator kit.
2. The input square wave is set to 2 Vpp in the CRO and this applied to the REF terminal of error detector block. The input is also connected to the X- channel of CRO.
3. The output from the system is connected to the Y- channel of CRO.
4. The output waveform is obtained in the CRO and it is traced on a graph sheet. From the waveform the peak percent overshoot, settling time,rise time, peak time are measured. Using these values ω_n and ξ are calculated.
5. The above procedure is repeated for different values of gain K and the values are compared with the theoretical values.

Time Response of first order system

A first order system whose input -output relationship is given by

$$\frac{C(s)}{R(s)} = \frac{1}{(1+sT)}$$

Here we are analyzing the output of the system for a step input **R**(s) = 1 / s

$$\therefore \quad C(s) = \frac{1}{1+sT} R(s)$$

Taking inverse laplace transform of C(s), we get

$$c(t) = 1 - e^{-t/T} \qquad \text{for } t \geq 0.$$

From the equation we can see that c(t) = 0 initially (i.e., at t = 0) and finally becomes unity (i.e., at $t \to \infty$).

$$\textbf{at} \quad t = T, \quad c(t) = 1 - e^{-1} = 0.632.$$

Therefore, one of the important characteristics of such curve is that at t = T sec. system response is 63.2% of final steady value.

Smaller the time constant T, faster the system response.

$$\frac{dc}{dt} = \frac{1}{T} e^{-t/T}$$

$$\text{at } t = 0, \quad \frac{dc}{dt} = \frac{1}{T}$$

Another important characteristic of the exponential response curve is that at t = 0, slope of the tangent line is 1/ T.

Frequency Response:

A sinusoidal transfer function may be represented by two separate plots, one giving the magnitude versus frequency and the other phase angle in degree versus frequency. A bode diagram consists of two graphs, plot of magnitude of a sinusoidal transfer function and other is a plot of phase angle both drawn to logarithmic scale. The standard representation of logarithmic magnitude of G (jω) is 20 log |G (jω)| where the base of the logarithm is 10. The unit is decibel.

The main advantage of using a semi log sheet and using logarithmic plot is that multiplication of magnitudes can be converted to addition. The experimental determination of transfer function can be made simple if frequency response data are represented in the bode diagram.

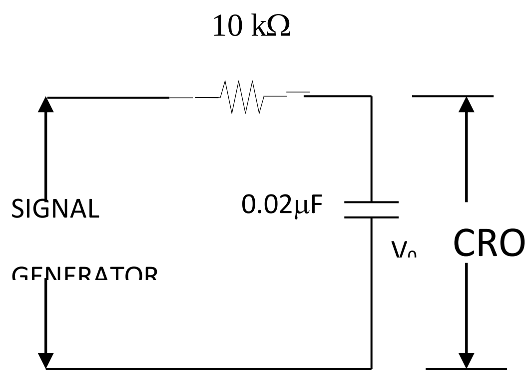
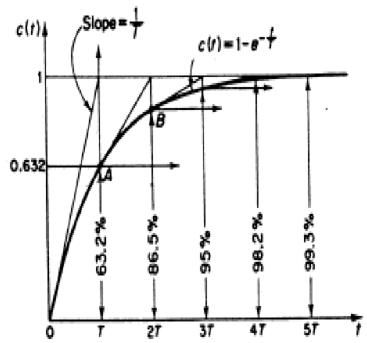


Figure: Circuit diagram for study of first order system

MODEL GRAPHS:

Time (Step) response of the first order



Time Response of second order system

An RLC circuit is considered as a simple second system. Fig. shows a simple order system whose input is e_i and output is e_o.

$$e_i(t) = Ri(t) + L\frac{di}{dt} + \frac{1}{C}\int idt$$

$$e_o(t) = \frac{1}{C}\int idt$$

Taking laplace transform of the above equations, we get

$$E_i(s) = I(s)\left(R + Ls + \frac{1}{Cs}\right)$$

$$E_o(s) = I(s)\frac{1}{Cs}$$

$$\therefore TransferFunction = \frac{E_0(s)}{E_i(s)} = \left(\frac{1}{s^2LC + RCs + 1}\right)$$

$$= \left(\frac{1}{Lc}\right)\left(\frac{1}{s^2 + \frac{R}{L}s + \frac{1}{LC}}\right) \qquad \text{-----------} \quad (1)$$

A general form of second order system transfer function is given by,

$$\frac{E_o(s)}{E_i(s)} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \qquad \text{------------} \quad (2)$$

Where ω_n is the undamped natural frequency.

ζ is the damping ratio of the system

Also $\zeta\,\omega_n = \sigma$ is called attenuation

Comparing equation (1) and (2), we get

$$\omega_n = \frac{1}{\sqrt{LC}} \quad \text{And} \quad 2\zeta\omega_n = \frac{R}{L}$$

$$\therefore \zeta = \frac{R}{2L} \times \sqrt{LC} = \frac{R}{2}\sqrt{\frac{C}{L}}$$

Dynamic behavior of second order system is defined in terms of two parameters ζ and ω_n.

If 0< ζ <1 the closed loop poles are complex conjugates and lie in the left half of s plane.

Then, the system is under-damped and the transient response is oscillatory.

If ζ =1, the system is called critically damped. Over-damped system corresponds to ζ >1. In the under-damped and over-damped case the transient response is not oscillatory.

For ζ <1 the step response of the system is given by

$$e_o(t) = 1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin(\omega_d t + \phi)$$

Where ω_d = damped natural frequency $= \omega_n\sqrt{1-\zeta^2}$

$$\phi = \tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{\zeta}\right)$$

The frequency of oscillation is the damped natural frequency ω_d & this varies with damping ratio ζ .

Fig. Shows the time response of the under-damped second order system along with the following time-domain specifications.

DELAY TIME:

Delay time is the time required for the response to reach from 0% to 50% of the steady state value.

RISE TIME:

Rise time is the time required for the response to reach from 10% to 90% of the steady state value for under-damped systems.

$$t_r = \frac{\pi - \phi}{\omega_d} \sec.$$

PEAK TIME:

Peak time is the time required to reach the response first peak of the overshoot

$$t_p = \frac{\pi}{\omega_d} \sec.$$

% PEAK OVERSHOOT:

Maximum overshoot is the maximum value of the response measured from unity.

$$M_P = e^{-\zeta\pi / \sqrt{1-\zeta^2}} \times 100$$

If the final steady state is different from unity maximum overshoot is given by $\frac{c(t_p) - c(\infty)}{c(\infty)} \times 100$

SETTLING TIME:

Settling time is for the response to settle around the steady state value with the variation not exceeding a permissible tolerance level.

$$t_s = \frac{4}{\zeta\omega_n} \text{ for 2\% tolerance}$$

$$t_s = \frac{3}{\zeta\omega_n} \text{ for 5\% tolerance}$$

Frequency Response

Frequency response of the system is given by

$$G(j\omega) = \frac{1}{LC(j\omega)^2 + RC(j\omega) + 1} = \frac{1}{1 - \left(\frac{\omega}{\omega_n}\right)^2 + 2\zeta\left(\frac{j\omega}{\omega_n}\right)} = \frac{1}{1 - u^2 + j2\zeta u}$$

Where $u = \frac{\omega}{\omega_n}$

$\therefore$ Magnitude of G(j ω) = $\frac{1}{\sqrt{(1-u^2)^2 + (2\zeta u)^2}}$

$\therefore$ Phase angle of G(j ω) = $\phi = \tan^{-1}\left(\frac{2\zeta u}{1-u^2}\right)$

PROCEDURE:

1. Connections are made as shown in figure.
2. Keep the appropriate value for resistance and inductance using Decade Resistance Box (DRB) and Decade inductance Box respectively.
3. Step input (square pulse of very low frequency i.e. large time period)) is given at input and output is observed across the capacitor using CRO.
4. Output shows a damped oscillation before it comes to steady state. Maximum overshoot or peak overshoot is noted.
5. A graph is plotted showing the variation of output voltage with time.
6. To get frequency response a sinusoidal signal is given as input and output (peak to peak value) is noted.
7. The input voltage is kept constant and output is noted for different frequency. Also the phase angle is noted, the output waveforms are noted using CRO.
8. The magnitude in decibel and phase angle in degree is plotted as a function of frequency ω ran/sec. In the semi log graph sheet.

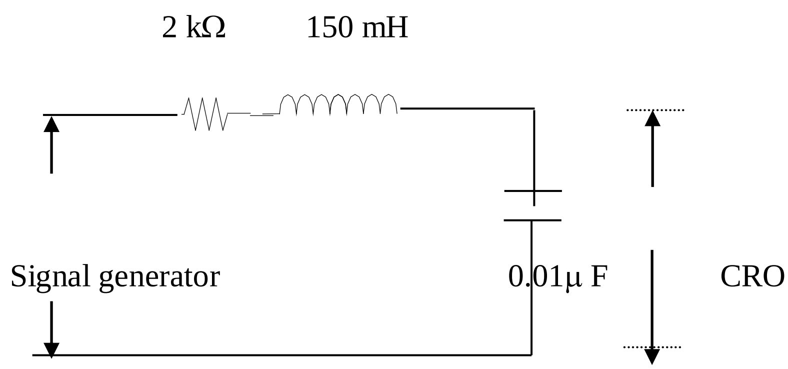


Figure: Circuit diagram for Study of Second order system

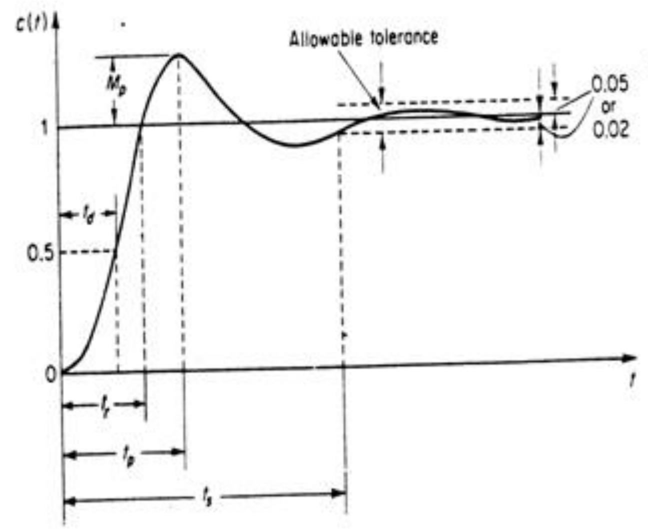
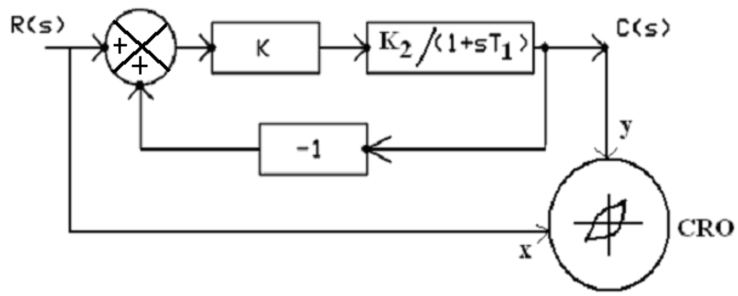


Figure: Response of second order system for unit step input

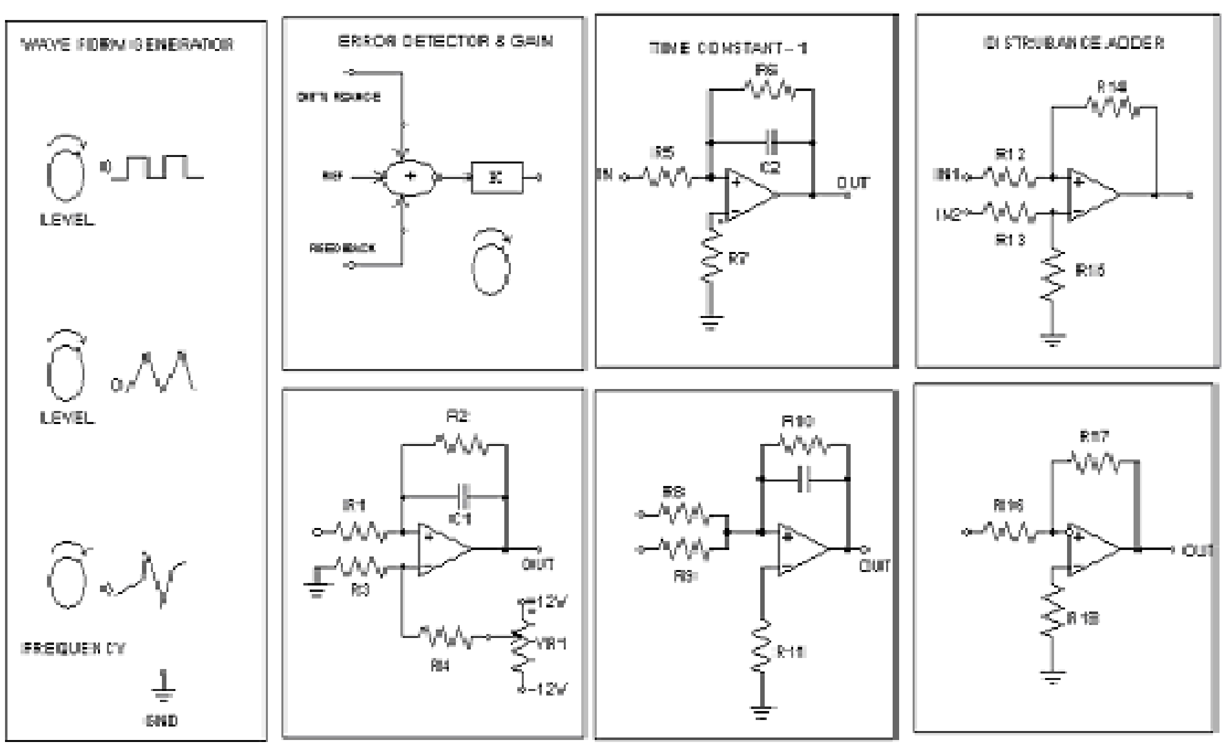
RESULT:

Block diagram of Type-0 first order system



PATCHING DIAGRAM TO OBTAIN THE STEADY STATE ERROR OF

TYPE – 0 FIRST ORDER SYSTEM



Ex. No. **15. Determination of transfer function of AC Servomotor**

Date:

Aim:

To derive the transfer function of the given A.C Servo Motor and experimentally determine the transfer function parameters such as motor constant k_1 and k_2.

Apparatus required:

S.No	Apparatus	Quantity
1	Transfer function of AC servomotor trainer kit	1
2	Two phase AC servomotor with load setup and loads	1
3	PC power chord	2
4	SP_6 patch chord	4
5	9 pin cable	1

Specifications of AC Servomotor

Main winding Voltage - 230V

Control Winding Voltage - 230V

No load current per phase - 300 mA

Load current per phase - 350 mA

Input power - 100 W

Power Factor - 0.8

No load speed - 1400 rpm

Moment of inertia (J) - 0.0155 kg m^2

Viscous friction co-efficient (B) - 0.85 x 10^{-4} kg-m-sec

Formula Used:

Torque T = (9.18 x r x S) Nm

$Motor\ Constant\ K_1 = \frac{\Delta T}{\Delta V}$ $Motor\ Constant\ K_2 = \frac{\Delta T}{\Delta N}$

Where ,

r - Radius of the shaft, m = 0.0186 m

ΔT - Change in torque, Nm

ΔV - Change in control winding voltage , V

ΔN - Change in speed , rpm

S - Applied load in kg

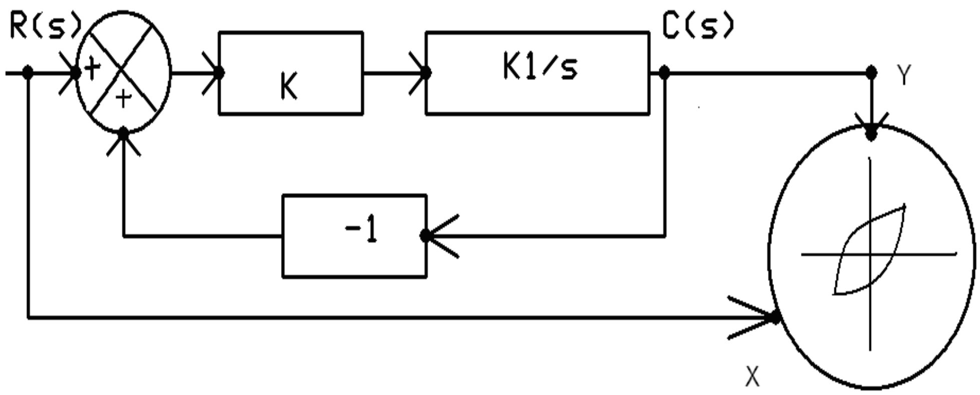
Theory:

It is basically a 2Φ induction motor except for certain special design features. AC servomotor differs in 2 ways from a normal induction motor. The servomotor rotor side is built in high resistance. So the X/R ratio is small, which results in linear mechanical characteristics. Another difference of AC servomotor is that excitation voltage applied to 2 stator of winding should have a phase difference of 90^o.

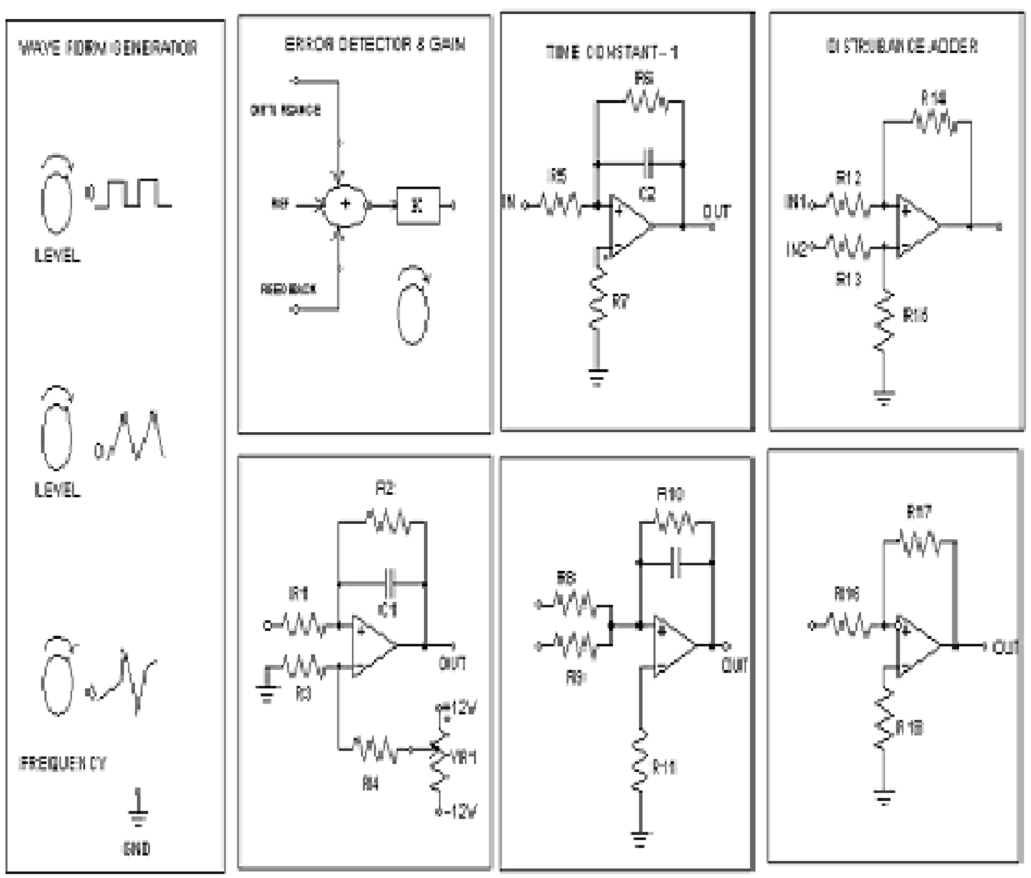
Working principle:

When the rotating magnetic field swaps over the rotor conductors emf is induced in the rotor conductors. This induced emf circulates current in the short circuited rotor conductor. This rotor current generate a rotor flux a mechanical force is developed to the rotor and hence the rotor moving the same direction as that of the rotating magnetic field.

Block diagram of Type- 1 First order system



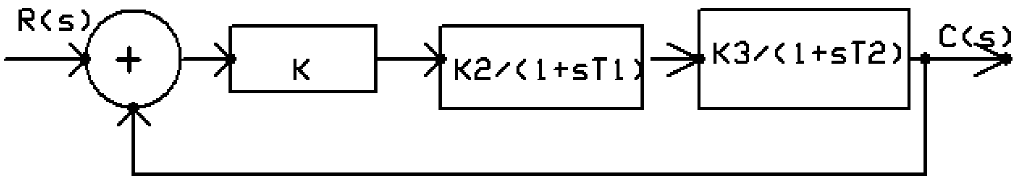
PATCHING DIAGRAM TO OBTAIN THE STEADY STATE ERROR OF TYPE – 1 FIRST ORDER SYSTEM



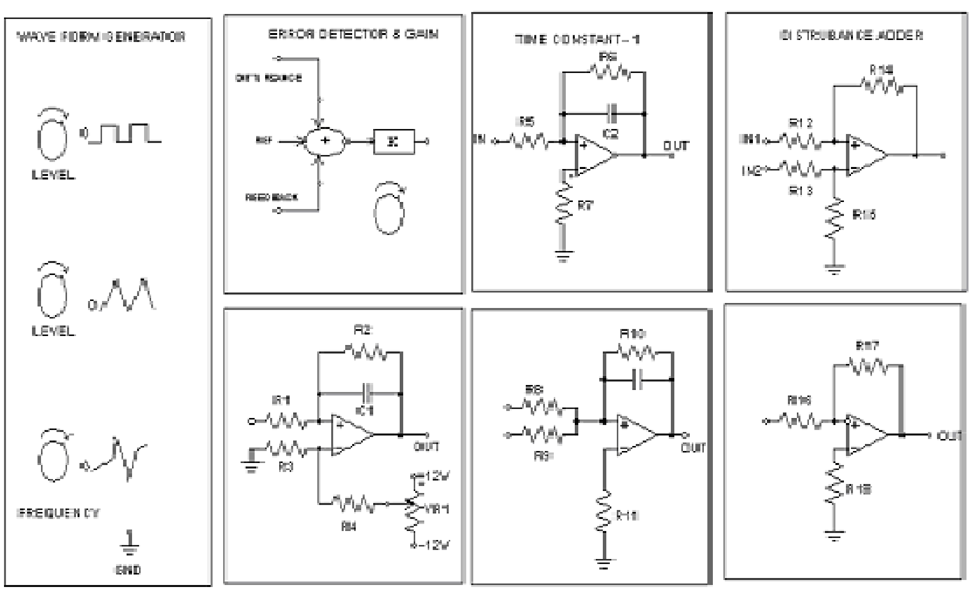
OBSERVATIONS:

S. No.	Gain, K	Steady state error, e_{ss}
1		
2		
3		

Block diagram to obtain closed loop response of Type-0 second order system



PATCHING DIAGRAM TO OBTAIN THE CLOSED LOOP RESPONSE OF TYPE – 0 SECOND ORDER SYSTEM



OBSERVATIONS:

Transfer function of a AC servomotor

Let T_m – Torque developed by the motor (Nm)

T_1 – Torque developed by the load (Nm)

k_1 – Slope of control phase voltage versus torque characteristics

k_2 – Slope of speed torque characteristics

k_m – Motor gain constant

τ_m – Motor time constant

g – Moment of inertia (Kgm^{-2})

B – Viscous friction co-efficient (N/m/sec)

e_c – Rated input voltage, volt

$\frac{d\omega}{dt}$ – Angular speed

Transfer function of AC servomotor:

Torque developed by motor, $T_m = k_1 e_c - k_2 \frac{d\theta}{dt}$ …………………….. (1)

Load torque, $T_l = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt}$ ……………………………………..(2)

At equilibrium, the motor torque is equal to the load torque.

$k_1 e_c - k_2 \frac{d\theta}{dt} = J\frac{d^2\theta}{dt^2} + B\frac{d\theta}{dt}$ ………………………………..(3)

On taking laplace transform of equation (3), with zero initial conditions, we get

$$Js^2\theta(S) + Bs\theta(S) = k_1E_c(S) - k_2s\theta(S)$$

$$(Js^2 + Bs + k_2s)\theta(S) = k_1E_c(S)$$

$$\frac{\theta(s)}{E_c(s)} = \frac{k_1}{(Js^2 + Bs + k_2s)} = \frac{k_1}{(Js + B + k_2)s}$$

$$\frac{\theta(s)}{E_c(s)} = \frac{k_1}{s(B + k_2)\left[\frac{J}{B+k_2}s + 1\right]}$$

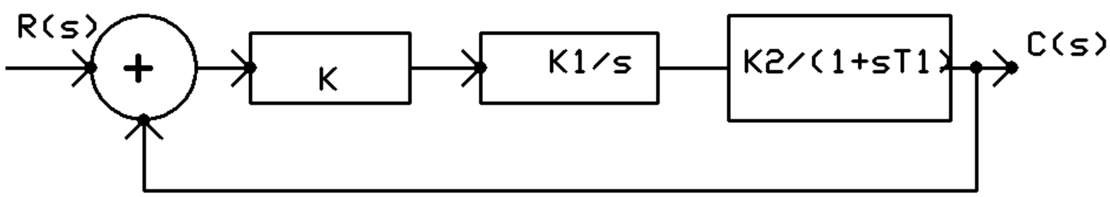
$$\frac{\theta(s)}{E_c(s)} = \frac{k_1/(B + k_2)}{s\left[\frac{J}{B+k_2}s + 1\right]} \quad \frac{\theta(s)}{E_c(s)} = \frac{k_m}{s(\tau_m s + 1)}$$

Where $k_m = \frac{k_1}{B+K_2}$ = Motor gain constant

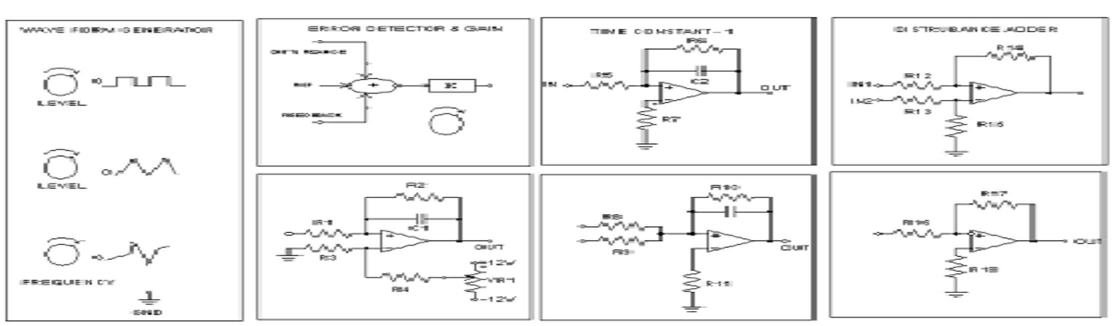
$\tau_m = \frac{J}{B+k_2}$ = Motor time constant

S. No.	Gain K	Peak percent Overshoot $\%M_P$	Rise time t_r (sec)	Peak Time t_p (sec)	Settling time t_s (sec)	Damping ratio ζ	Undamped Natural frequency ω_n (rad/sec)

Block diagram to obtain closed loop response of Type-1 second order system



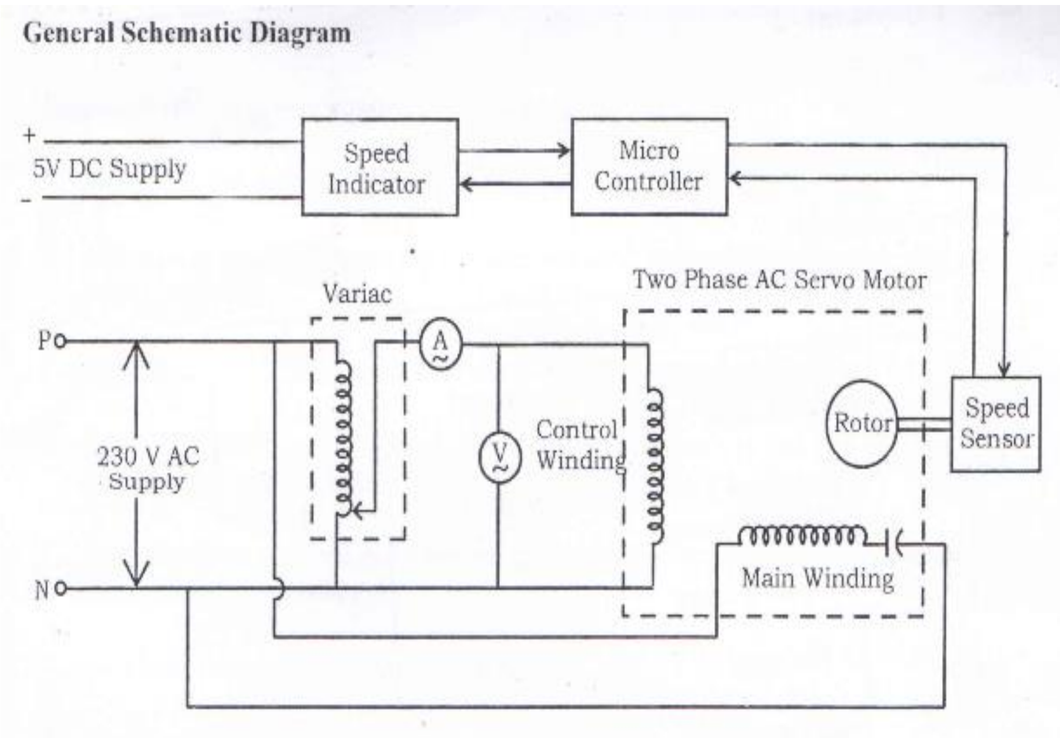
PATCHING DIAGRAM TO OBTAIN THE CLOSED LOOP RESPONSE OF TYPE – 1 SECOND ORDER SYSTEM



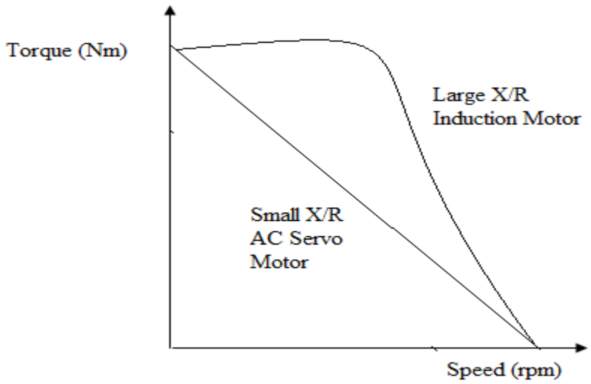
OBSERVATIONS:

S. No.	Gain K	Peak percent Overshoot $\%M_P$	Rise time t_r (sec)	Peak Time t_p (sec)	Settling time t_s (sec)	Damping ratio ζ	Undamped Natural frequency ω_n (rad/sec)

Full load speed - 900 rpm



Speed torque characteristics of Induction motor and AC servomotor:



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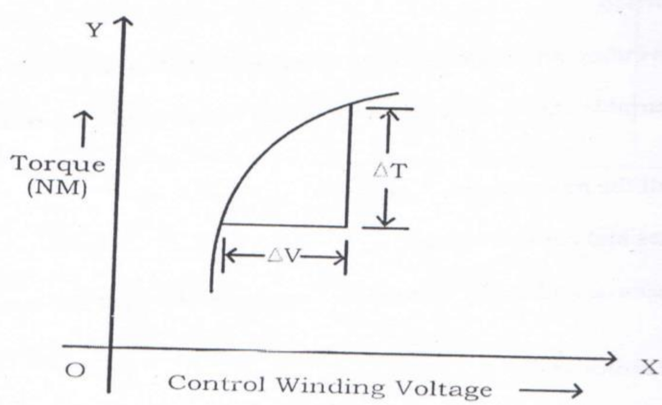
To find K_1 :

Tabulation

S. No.	Load (S)	Control Voltage (V)	Torque (T)
	Kg	Volt	Nm
	0		

Model graph



$$\text{Motor Constant } K1 = \frac{\Delta T}{\Delta V}$$

Connection Procedure:

1. Initially keep all the switches in OFF position
2. Connect the banana connector P_{out} to P_{in} and N_{out} to N_{in}
3. The banana connector P_{in} terminal is also connected with motor control winding P terminal and the banana connector N_{in} terminal is also connected with motor control winding N terminal.
4. Connect the 9 pin D connector from AC servomotor to module trainer kit.
5. Keep the variable AC source in minimum position.

Experimental Procedure to find K_1:

1. Apply 3-phase AC supply to 3-phase input banana connectors at the back side of the module.
2. Switch ON the power switch.
3. Switch ON the control winding and main winding switches S_1 and S_2 respectively.
4. Now slowly vary the variable AC source to the control winding till the motor reaches 300rpm.
5. Apply load one by one till the motor stops.
6. Note down the load values and control voltage.
7. Now again vary the AC source and apply voltage to control winding till the motor reaches 300 rpm.
8. Again apply loads till the motor stops.
9. Repeat the above steps and note down the values and tabulate it.
10. Calculate the torque of the motor.
11. Draw a graph between control voltage Vs torque.
12. From the graph find out the motor constant K_1.

Experimental Procedure to find K_2:

1. Switch ON the power supply.
2. Switch ON the main winding power supply S_2.
3. After giving the power supply to the main winding, switch ON the control winding power supply switch $S_{1.}$

4. Vary the control voltage to set a rated voltage of the control winding (180 V)
5. Apply the load in step by step upto the motor run at a zero rpm and note down the speed of the motor and applied load.
6. After taking the readings, fully remove the load from the motor and bring the variable AC source in minimum position.
7. Switch OFF the control winding switch S_1.
8. Finally switch OFF the main winding switch S_2 and power supply switch.
9. Tabulate the speed and load values and calculate torque.
10. Draw a graph of torque Vs speed and find motor constant K_2.

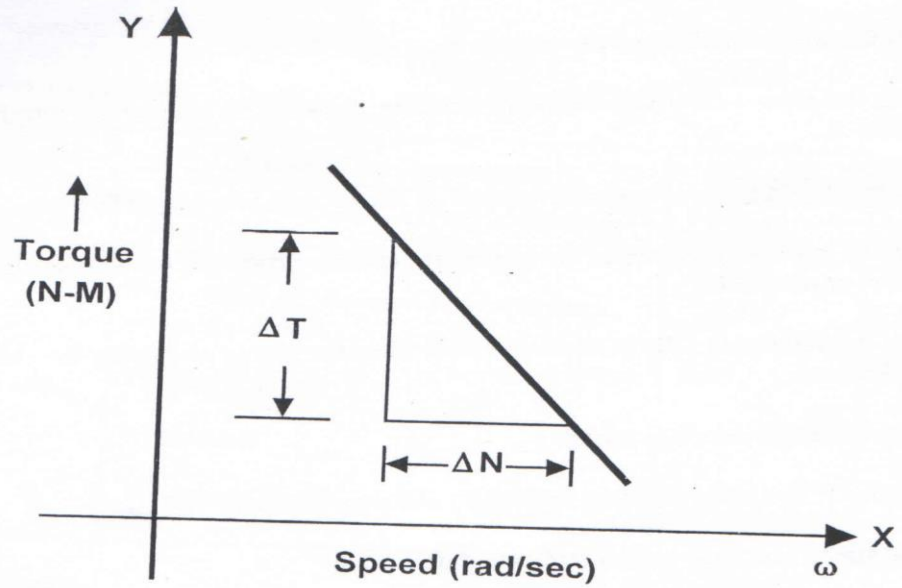
To find K_2 :

Tabulation

S. No.	Speed (N)	Load (S)	Torque (T)
	Rpm	Kg	N-M

$$\text{Motor Constant } K_2 = \frac{\Delta T}{\Delta N}$$

Model Graph



RESULT: