SRM VALLIAMMAI ENGINEERING COLLEGE

An Autonomous Institution

SRM Nagar, Kattankulathur – 603 203

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EI3469 - C O N T R O L SYSTEMS

LABORATORY MANUAL

(2023 REGULATION)

2025-2026 EVEN SEMESTER

Prepared by,

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EI3469 CONTROL SYSTEMS LABORATORY

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COURSE OBJECTIVES:

1. To make the students familiarize with various representations of systems.
2. To make the students analyze the stability of linear systems in the time domain and frequency domain.
3. To make the students design compensator based on the time and frequency domain specifications.
4. To develop linear models mainly state variable model and transfer function model.
5. To make the students to design a complete closed loop control system for the physical systems.

LIST OF EXPERIMENTS:

1. Simulation of Control Systems by Mathematical development tools.
2. Synchro Transmitter and Receiver Characteristics.
3. Mathematical modeling and simulation of physical systems in at least two fields.
    1. Mechanical
    2. Electrical
    3. Chemical process
4. Determination of Transfer function of Self and Separately excited DC Shunt Generator.
5. Determination of Transfer function of Armature and Field control DC Shunt Motor.
6. Stability analysis using Pole zero maps and Routh Hurwitz Criterion in simulation platform.
7. Root Locus based analysis in simulation platform.
8. Determination of transfer function of a physical system using frequency response and Bode's asymptotes.
9. Design of Lag, lead compensators and evaluation of closed loop performance.
10. Design of P, PI, PID controllers and evaluation of closed loop performance.
11. Study of DC Position control system.
12. Test of controllability and observability in continuous and discrete domain in simulation platform.

COURSE OUTCOMES:

At the end of this course, the students will demonstrate the ability

1. To model and analyze simple physical systems and simulate the performance in analog and digital platform.
2. To design and implement simple controllers in standard forms.
3. To design compensators based on time and frequency domain specifications.
4. To design a complete closed control loop and evaluate its performance for simple physical systems.
5. To analyze the stability of a physical system in both continuous and discrete domains.

LIST OF EXPERIMENTS:

1. Simulation of Control Systems by Mathematical development tools.
2. Synchro Transmitter and Receiver Characteristics.
3. Mathematical modeling and simulation of physical systems in at least two fields.
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    2. Electrical
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11. Study of DC Position control system
12. Test of controllability and observability in continuous and discrete domain in simulation platform

ADDITIONAL EXPERIMENTS

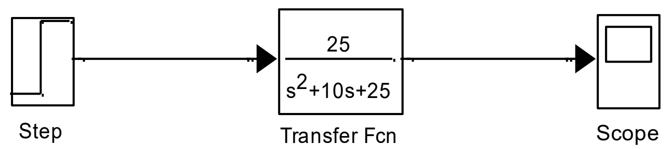
1. Analog simulation of Type – 0 and Type – 1 Systems.
2. Determination of transfer function of AC Servomotor.

INDEX

Sl. No.	Date of Expt.	Name of the Experiment	Page No.	Marks	Staff sign. with date

2. Second Order System

1. Critically Damped System



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SIMULATION OF CONTROL SYSTEMS BY MATHEMATICAL DEVELOPMENT TOOLS.

AIM:

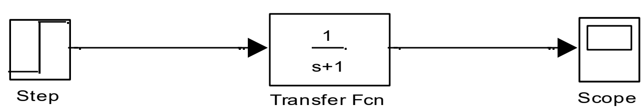
To check the simulation result with first order and second order system with the step input.

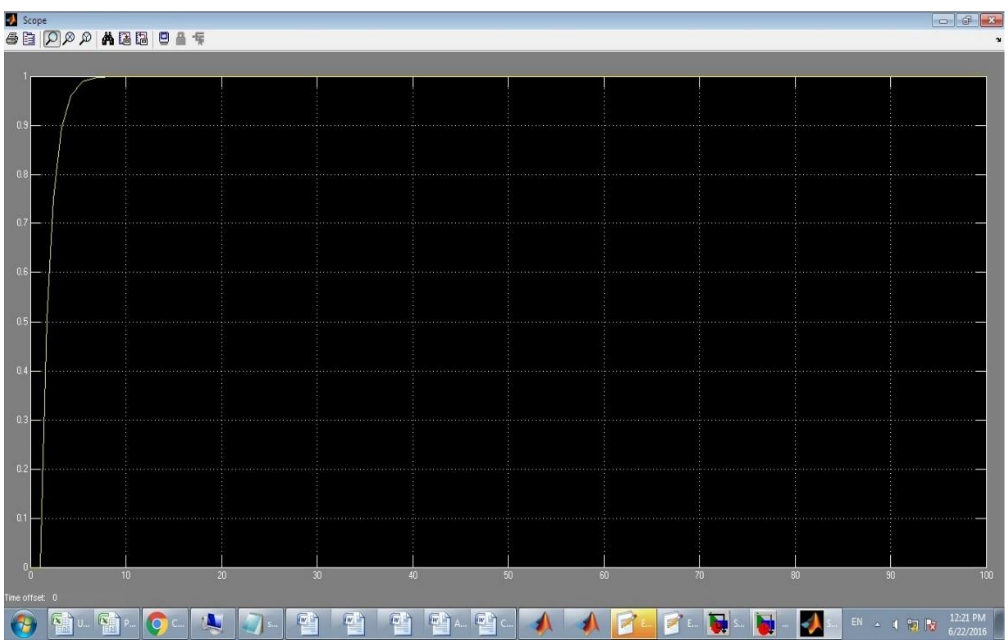
APPARATUS REQUIRED:

1. MATLAB Software.

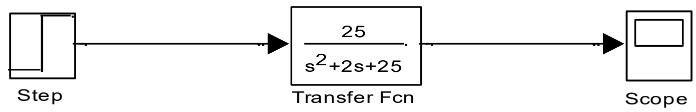
DESIGN OF SIMULINK BLOCK

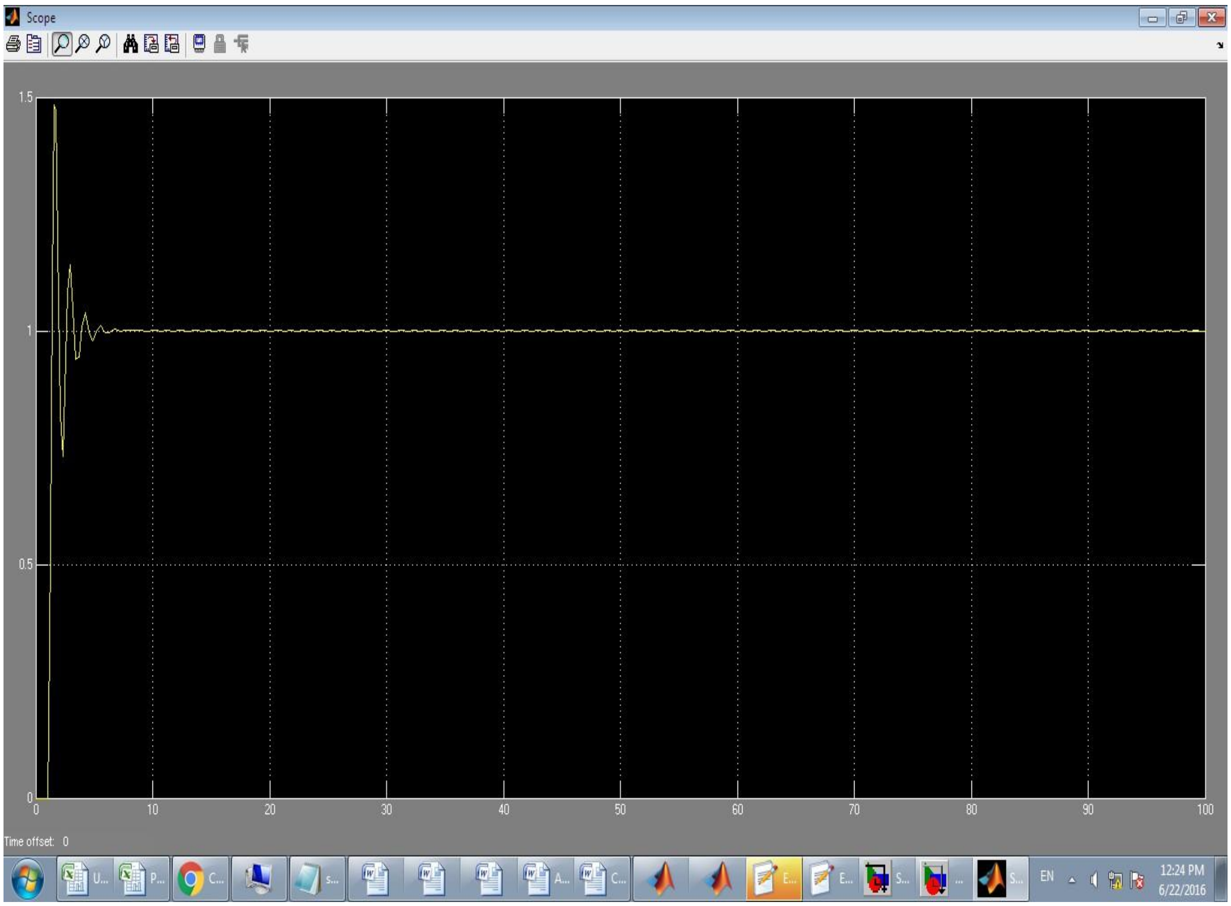
1.First Order System



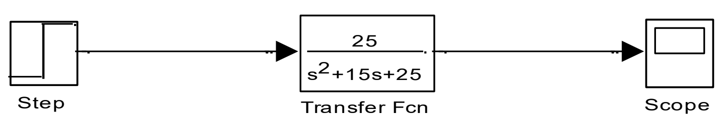


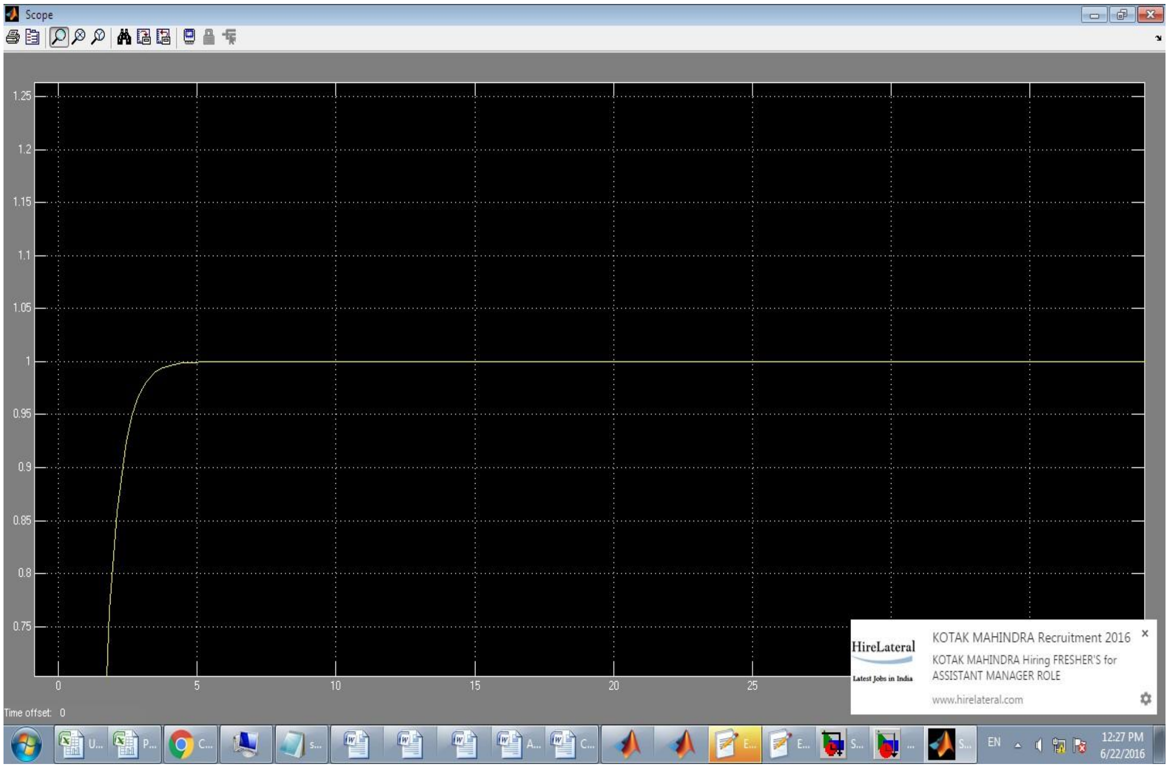
2. Under Damped System



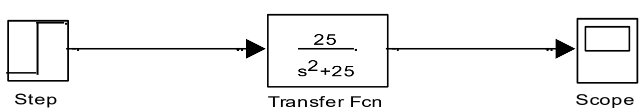


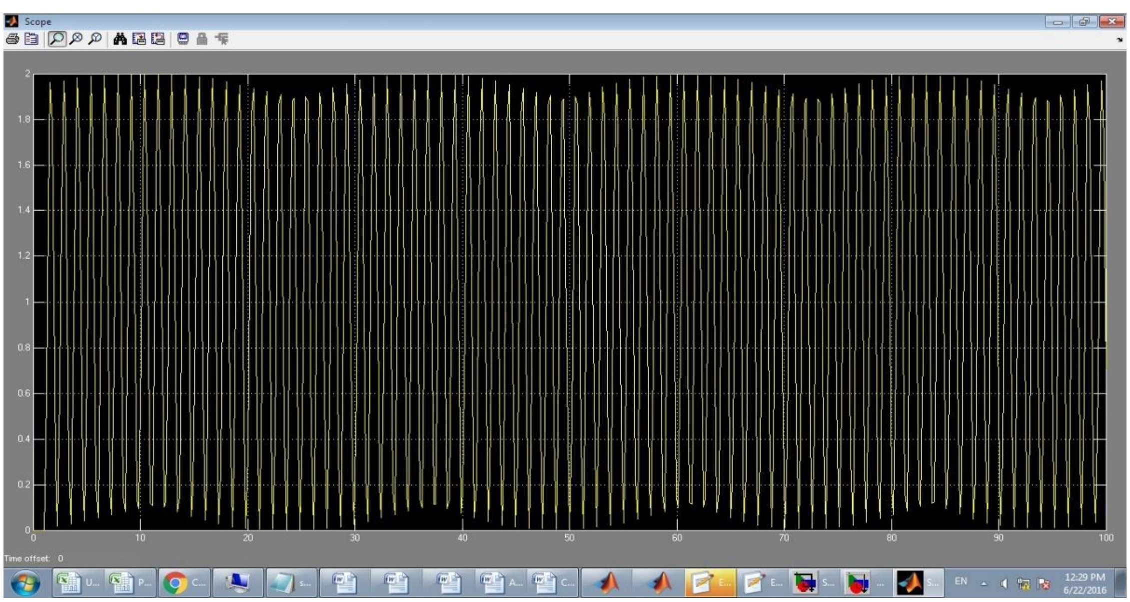
3. Over Damped System





4. UnDamped System



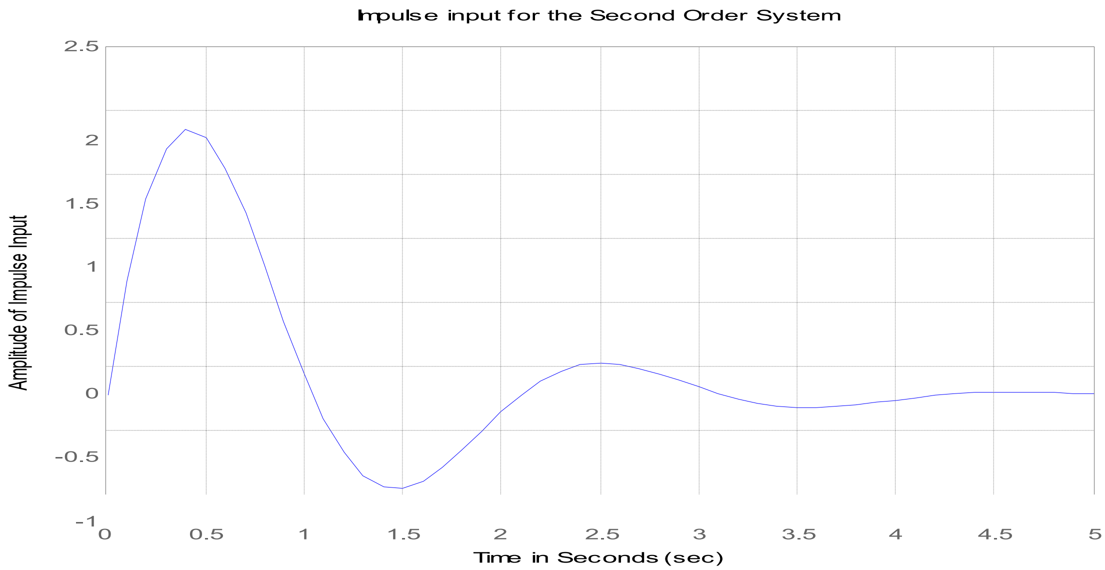


1. The Second order system has the transfer functions (i)Under Damped Second Order System G(s)=10/(s2+2s+10) (ii) Undamped Second Order system G(s)=10/(s2+10) (iii)Critically Damped Second Order System G(s)=10/(s2+7.32s+10) (iv)Over Damped Second Order System

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

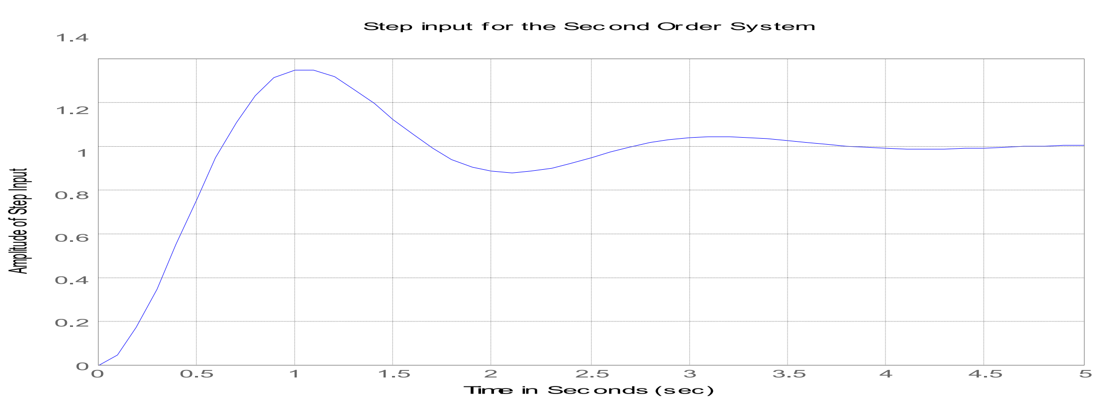
ANS

```
% 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];

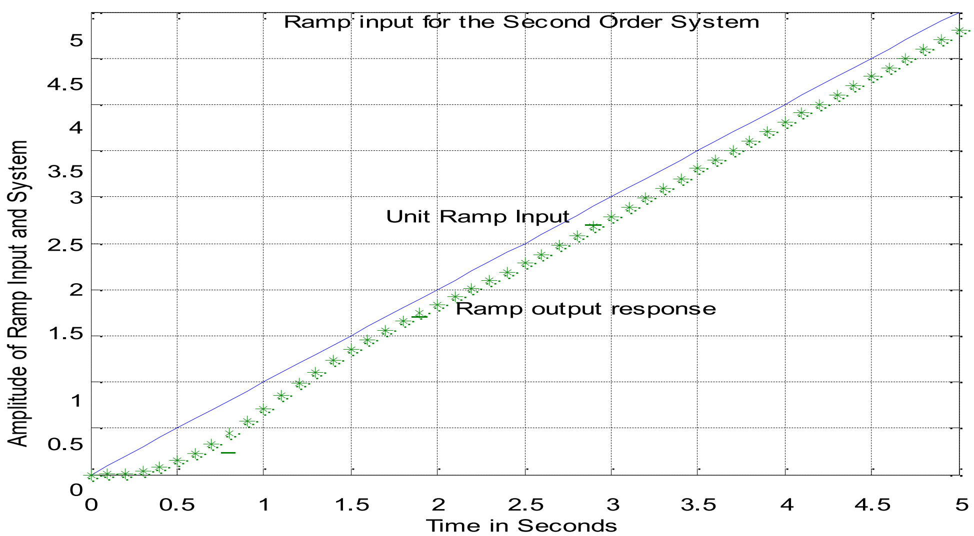
den3=[1 7.32 10];

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];

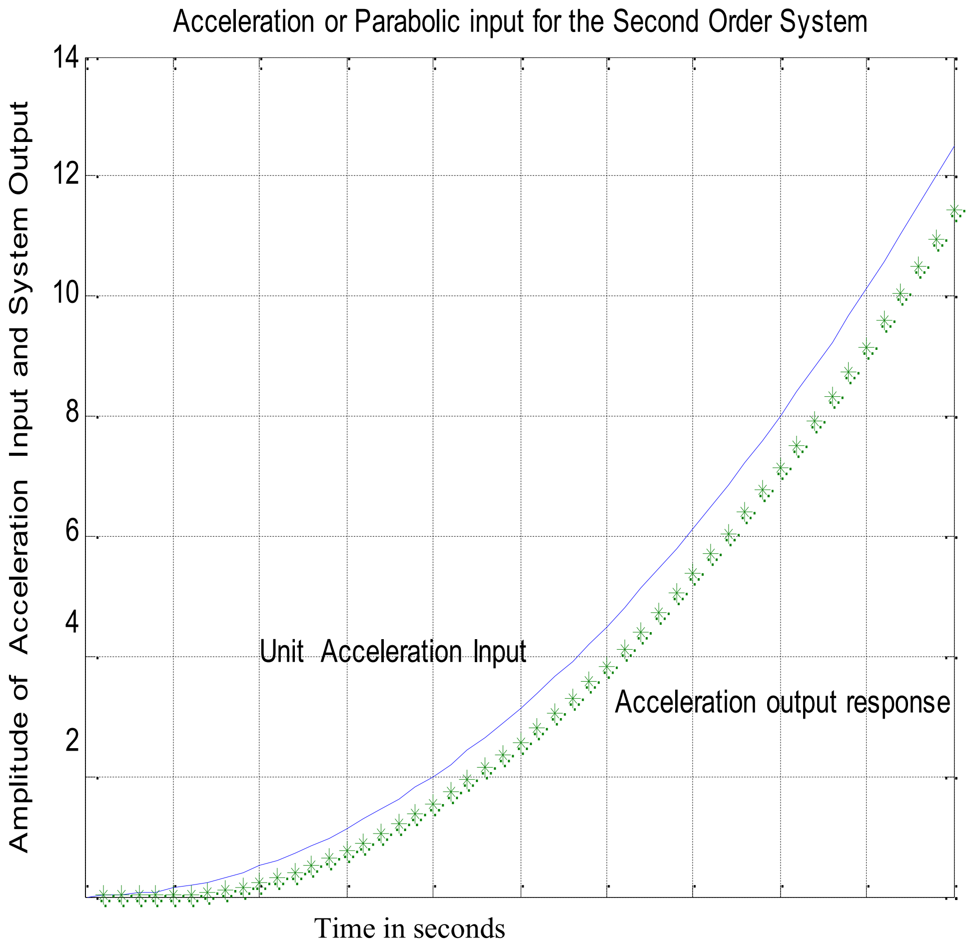
den4=[1 3 10];

figure(4);

step(num4,den4,t)

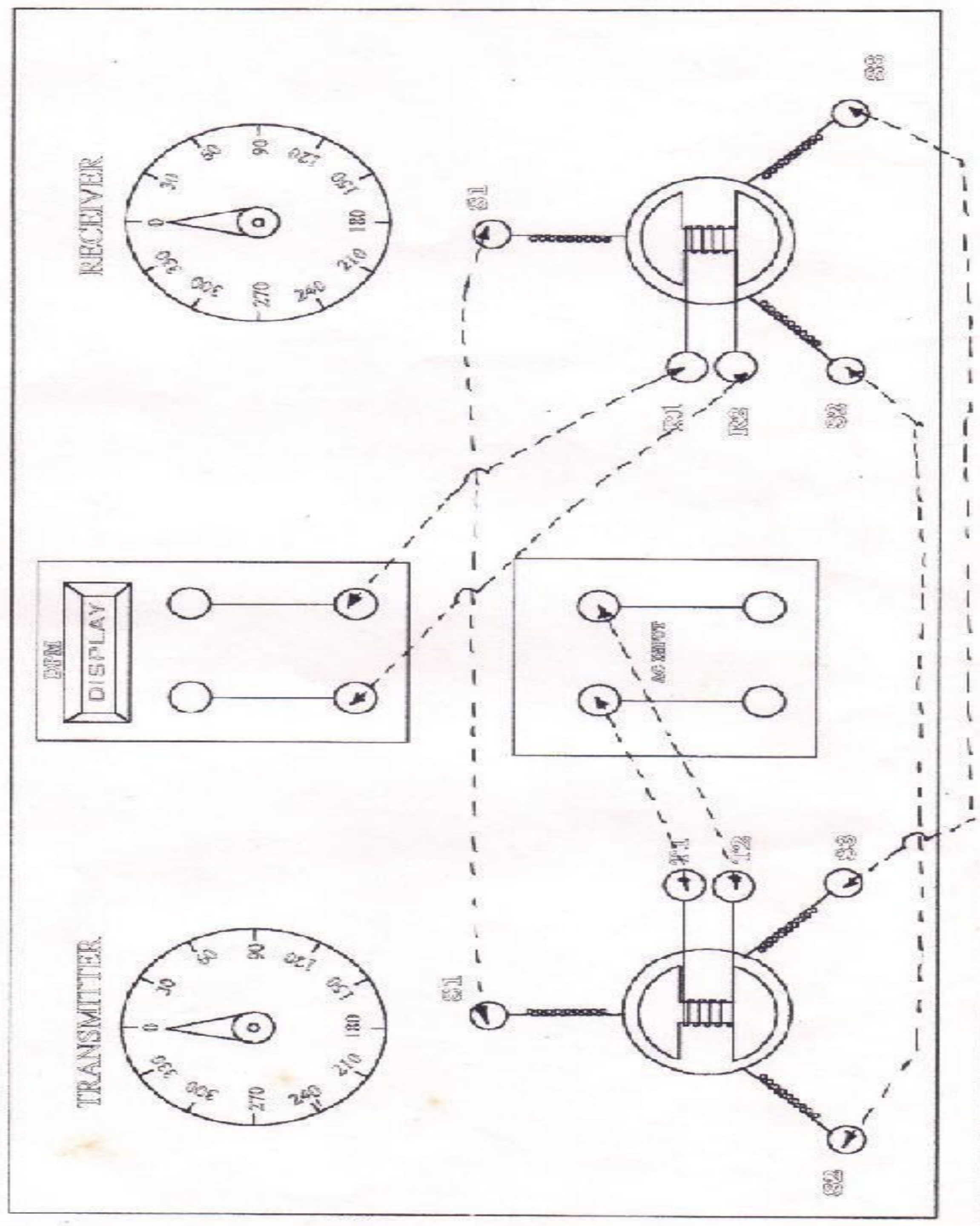
title('Over Damped Second Order System Response for Step Input');

grid;


Acceleration or Parabolic input for the Second Order System
14
12
10
8
6
4
2
Amplitude of Acceleration Input and System Output
Unit Acceleration Input
Acceleration output response
Time in seconds

RESULT :

Synchro transmitter and receiver angle difference Vs output error voltage



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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:

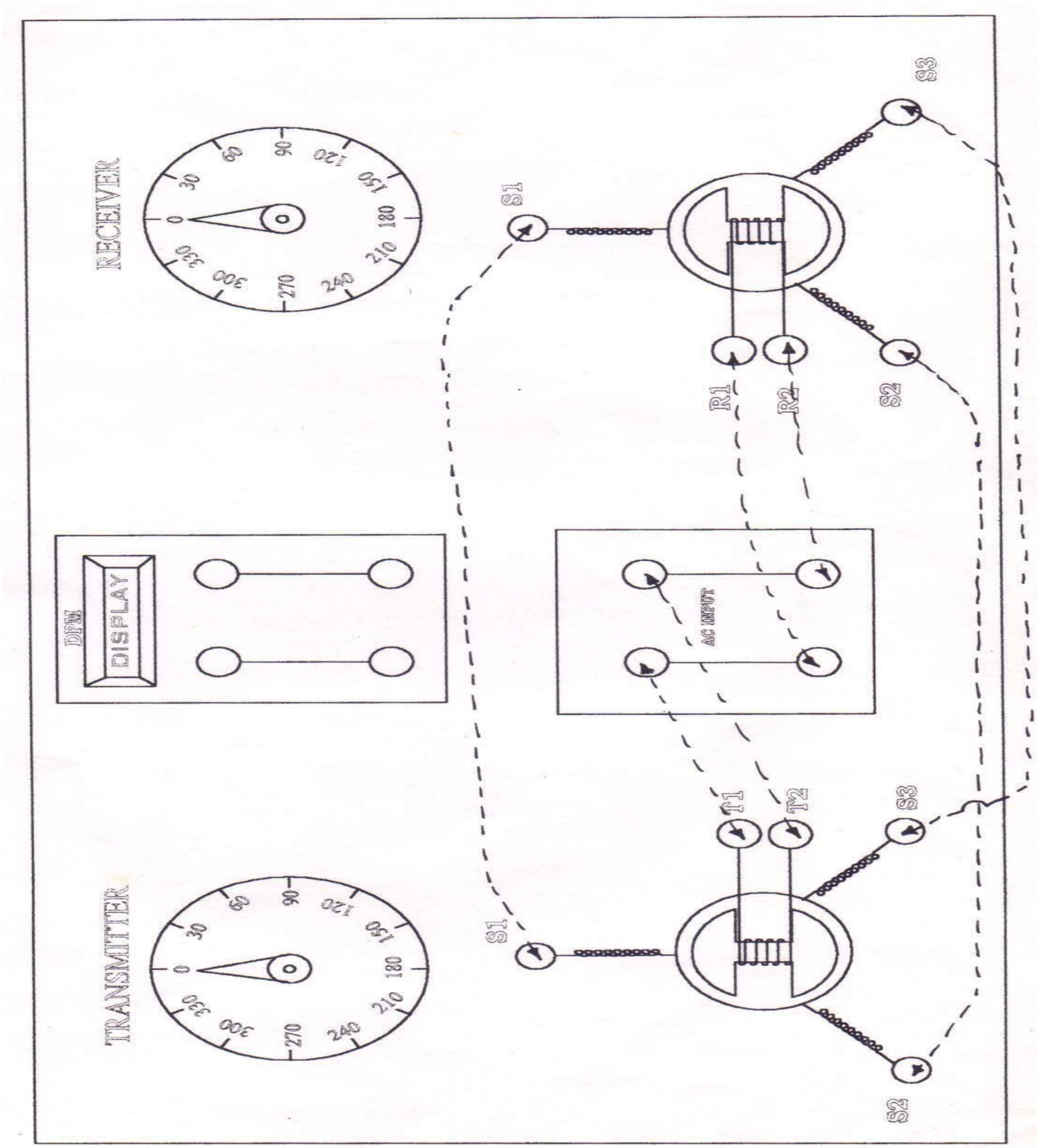
Synchro transmitter and receiver as an error detector

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.

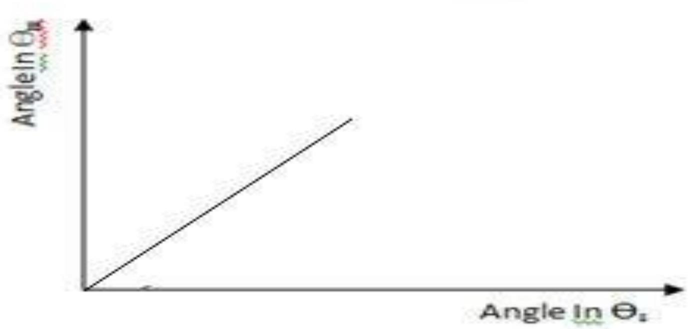
Synchro Transmitter stator angle Vs receiver rotor angle characteristics



Tabulation for rotor angle versus receiver angle:

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

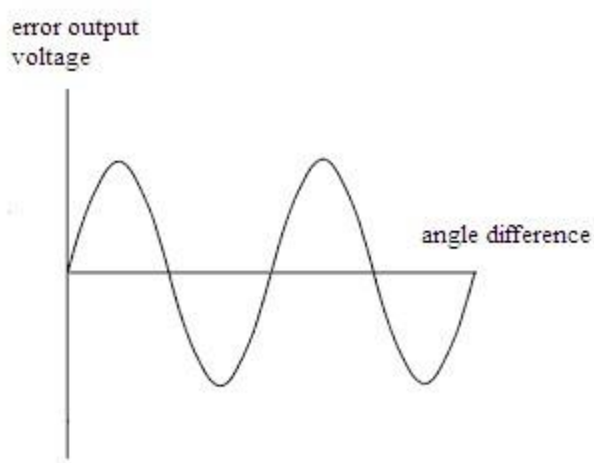
Model Graph:



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:

Ex. No:
Date:

MATHEMATICAL MODELING AND SIMULATION OF PHYSICAL SYSTEMS IN AT LEAST TWO FIELD

1.MECHANICAL
2.ELECTRICAL
3.CHEMICAL PROCESS

3.(a). STUDY OF DISPLACEMENT TRANSDUCER – LVDT

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

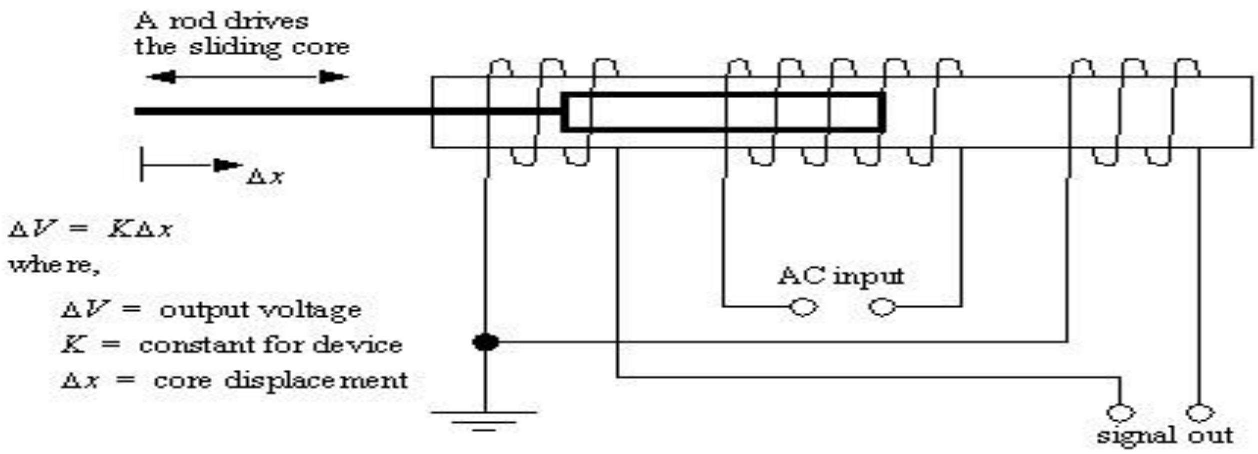
APPARATUS REQUIRED:

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

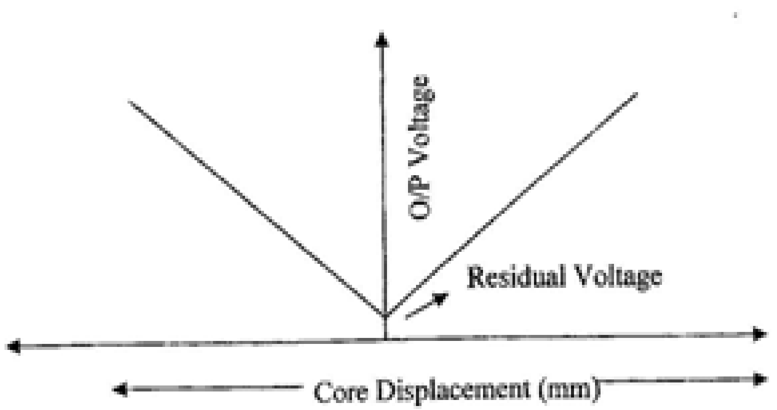
THEORY:
LVDT is the most commonly and extensively used transducer, for linear displacement measurement. The LVDT consists of three symmetrical spaced coils wound onto an insulated bobbin.

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

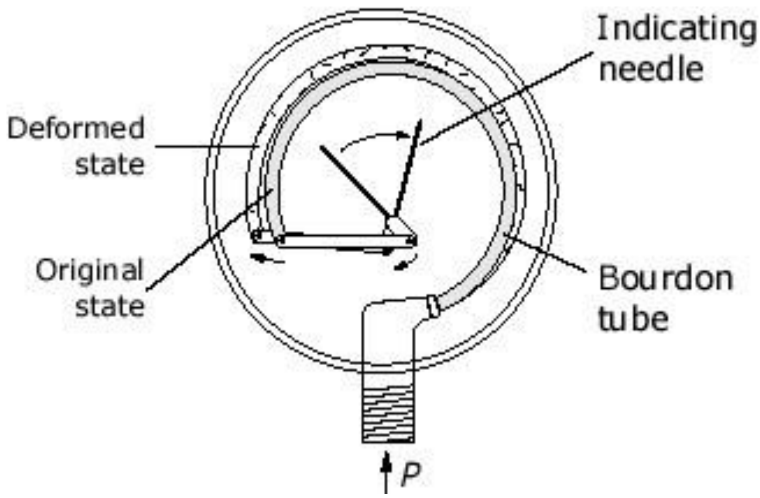
S. No.	Displacement (mm)	Output voltage (mV)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

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:

DIAGRAM:



PRESSURE TRANSDUCER – BOURDON TUBE

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.

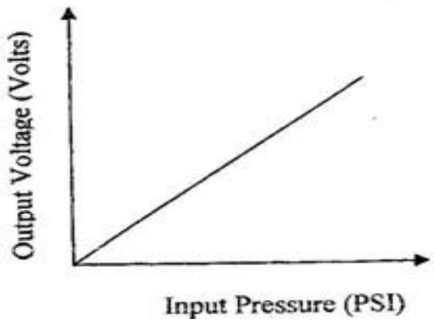
The bourdon transmitter consists of a pressure gauge with an outside diameter of 160 mm including a built-in remote transmission system. Pressure chamber consists or a pressure tank with a provision to connect manual pressure foot pump, slow-release valve for discharging the air from this pressure tank, 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

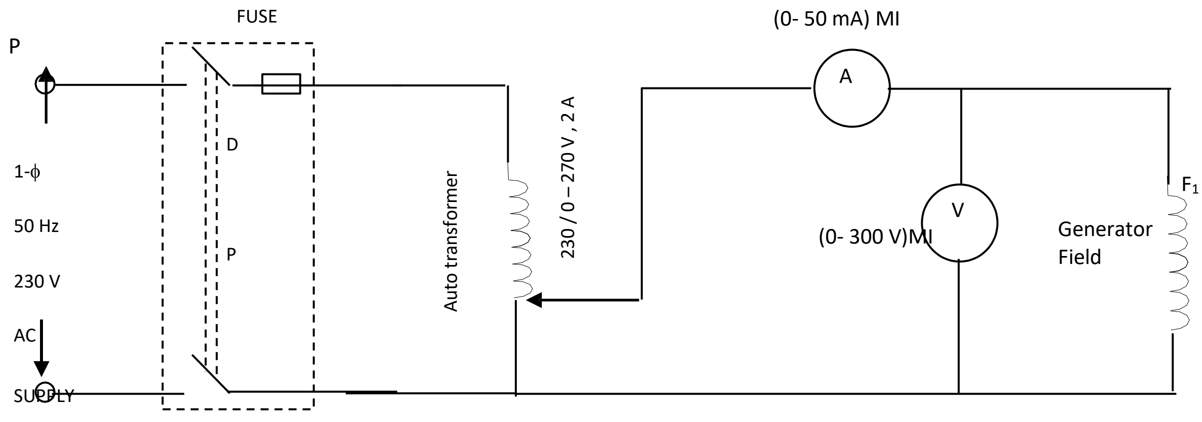


TABULATION

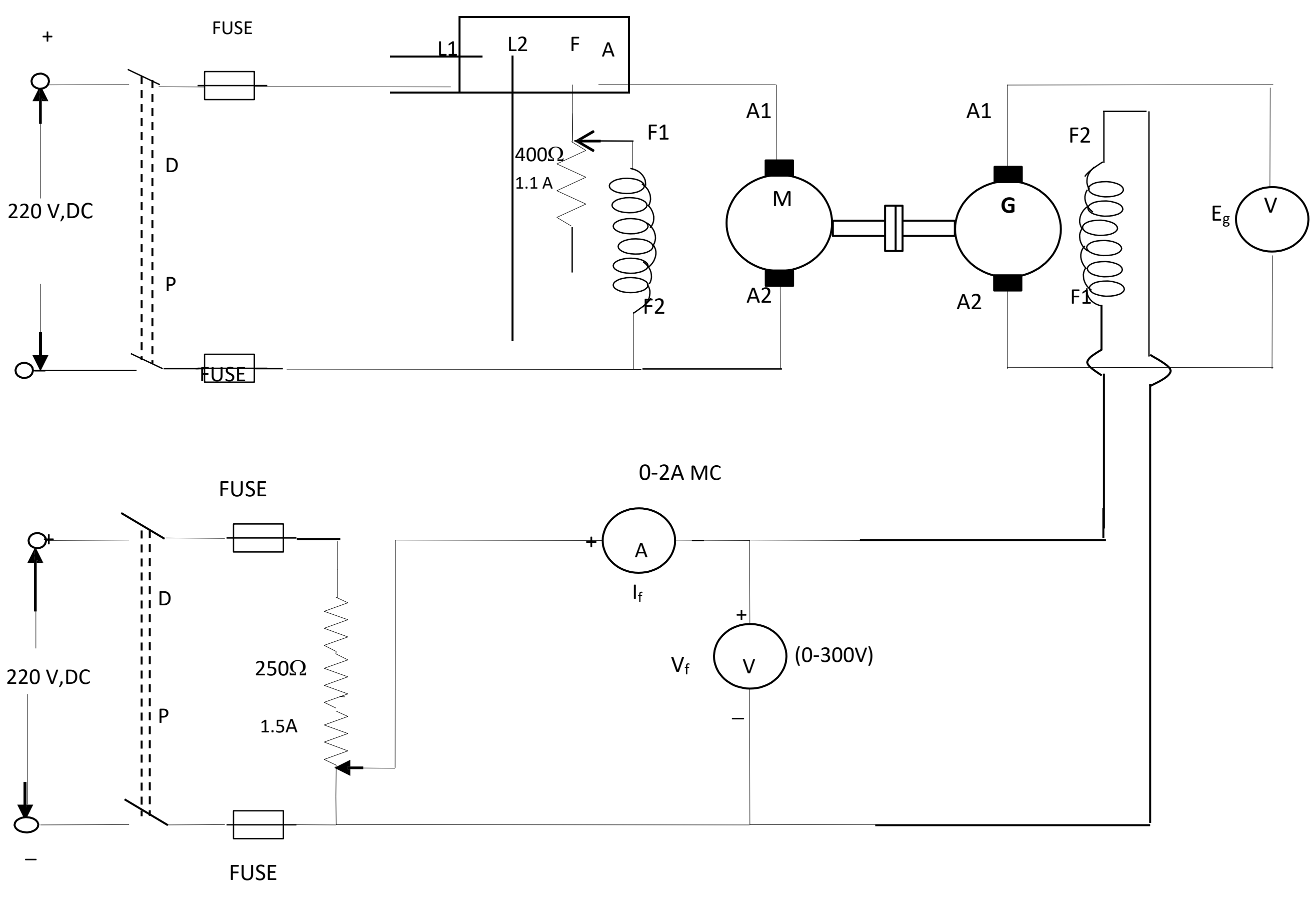
Sl. No.	Input Pressure (PSI)	Output Pressure (Kg/ cm^2)	Output Voltage mV
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

RESULT:

CIRCUIT DIAGRAM:



Circuit diagram to find L_f



Circuit diagram to find k_g and R_f

Ex. No:
Date:

DETERMINATION OF TRANSFER FUNCTION OF DC GENERATOR

AIM:

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

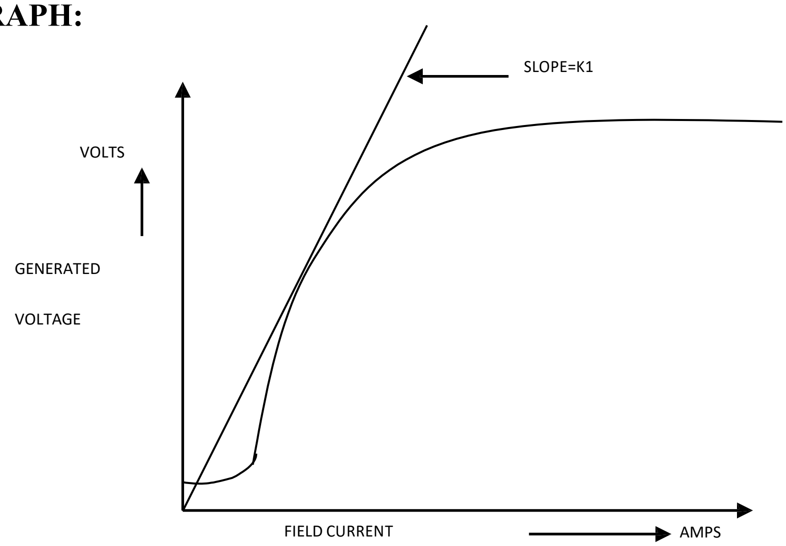
APPARATUS REQUIRED:

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	0 - 1500 rpm	1
6.	Starter	4 point, 10 A	
7.	Connecting Wires	-	

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:

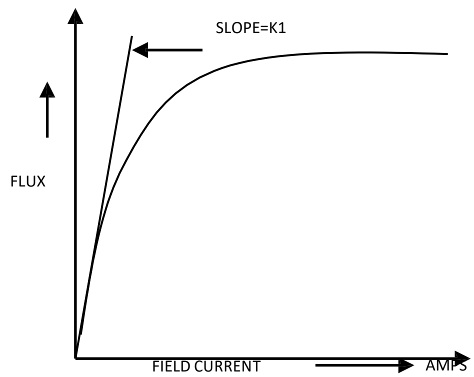


Field current VS Generated voltage

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.

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

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:

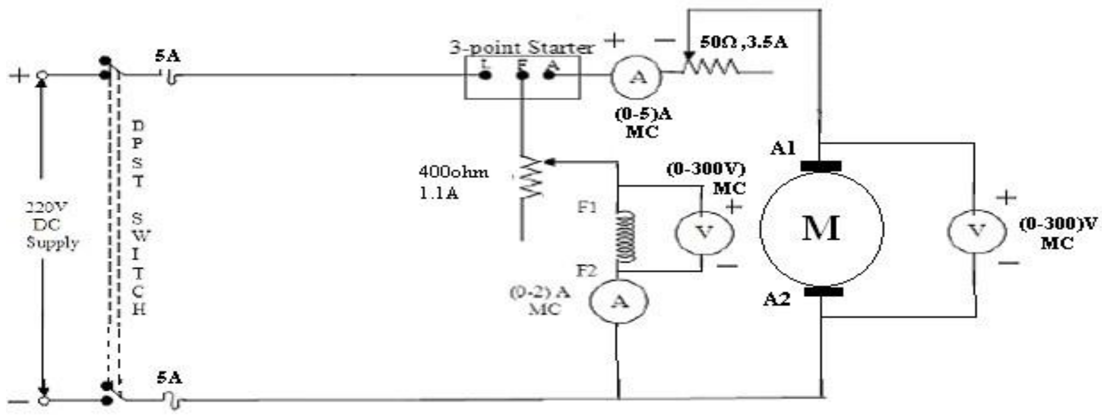
Sl.No.	Ammeter Reading I (amps)	Voltmeter Reading V (volts)	Armature Impedance Z_a (ohms)	X_a (Ohms)	L_a (Henry)

MODEL CALCULATION:

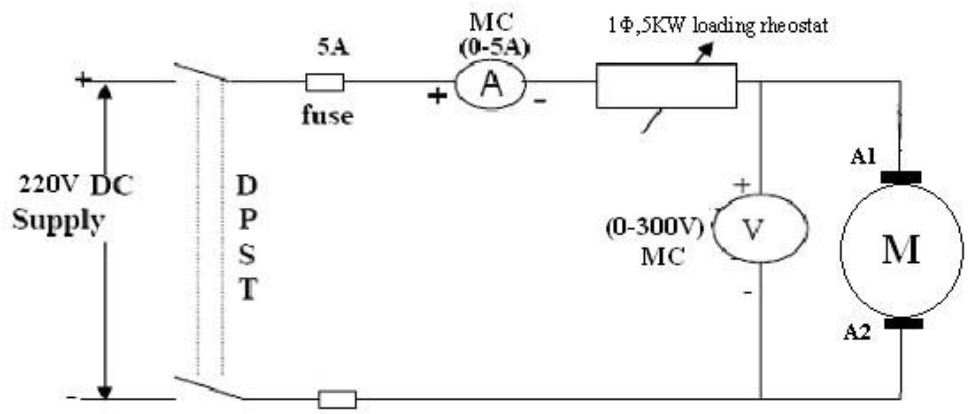
RESULT:

CIRCUIT DIAGRAM:

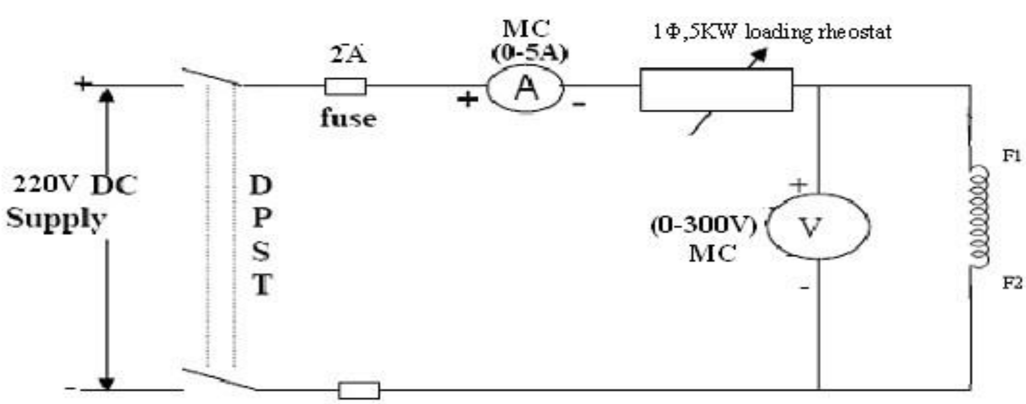
ARMATURE AND FIELD CONTROLLED DC MOTOR:



TO MEASURE ARMATURE RESISTANCE R_a:



TO MEASURE FIELD RESISTANCE R_f:



Ex. No:

Date:

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 a 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

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

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

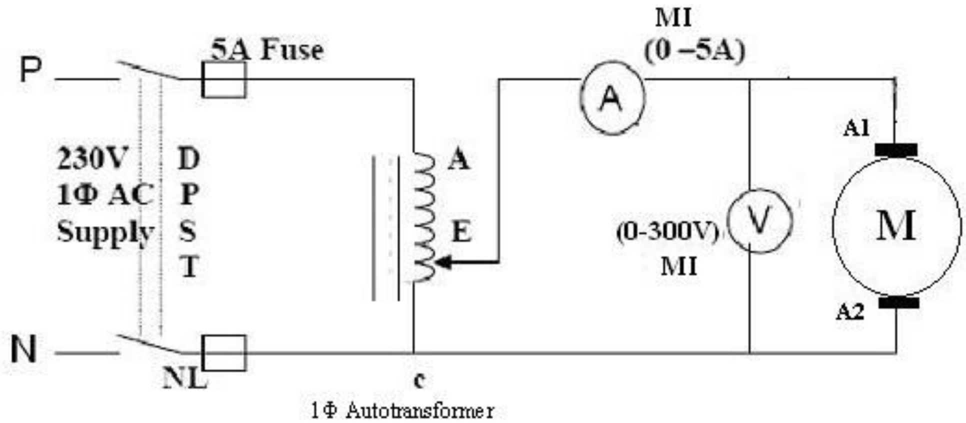
$$T = J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt} \quad (3)$$

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

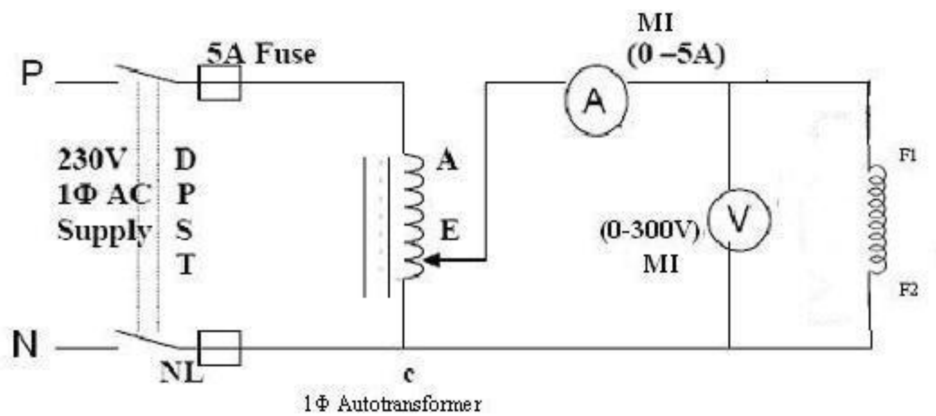
On taking Laplace transform of the system differential equations with zero initial conditions we get

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

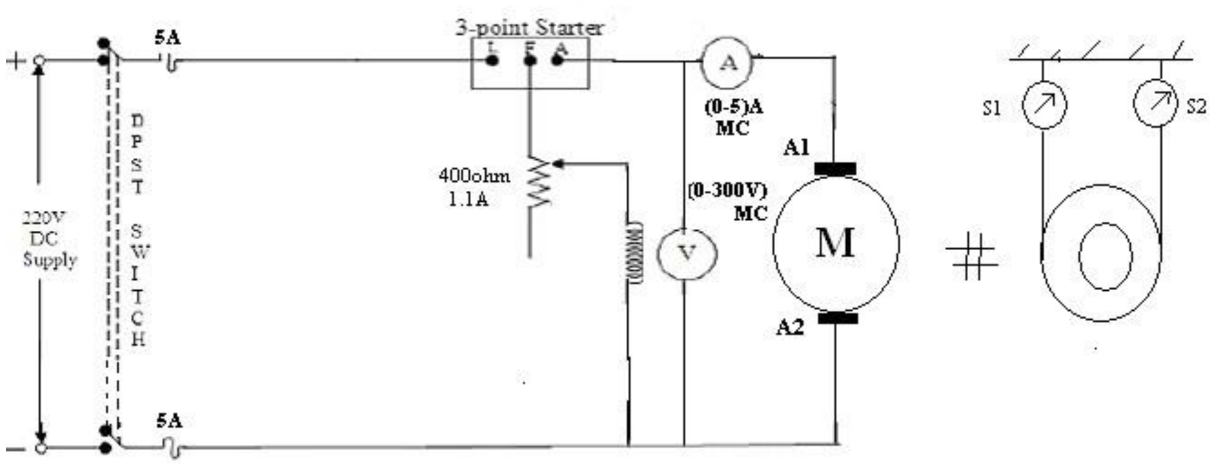
TO MEASURE ARMATURE INDUCTANCE(La):



TO MEASURE FIELD INDUCTANCE(L_F):



TO MEASURE Ka



$$T(s) = K_t\, I_a(s) \tag{6}$$

$$T(s) = Js^2\theta(s) + Bs\theta(s) \tag{7}$$

$$E_b(s) = K_b s\theta(s) \tag{8}$$

on equating equation (6) and (7)

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

Equation (5) can be written as

$$V_a(s) = (R_a + sL_a)I_a(s) + E_b(s) \tag{10}$$

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

<u>TRANSFER FUNCTION OF FIELD CONTROLLED DC MOTOR</u>

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

$$V_f = R_f\, I_f + L_f \frac{di_f}{dt} \tag{11}$$

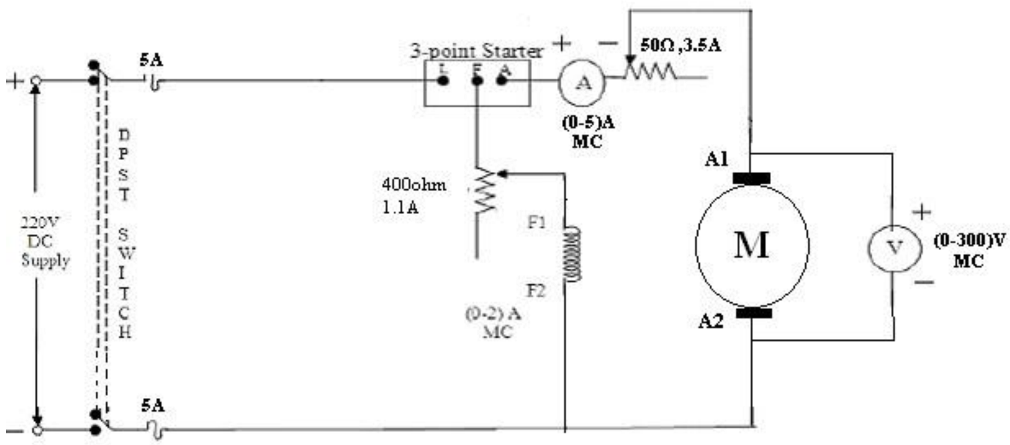
$$T(s) = K_{t_f} I_f(s) \tag{12}$$

$$T(s) = Js^2\theta(s) + Bs\theta(s) \tag{13}$$

Equation (12) and (13)

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

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

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

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

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

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

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

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.

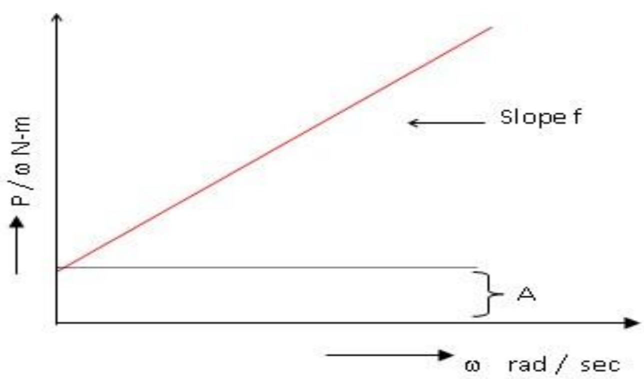
To find k_b:

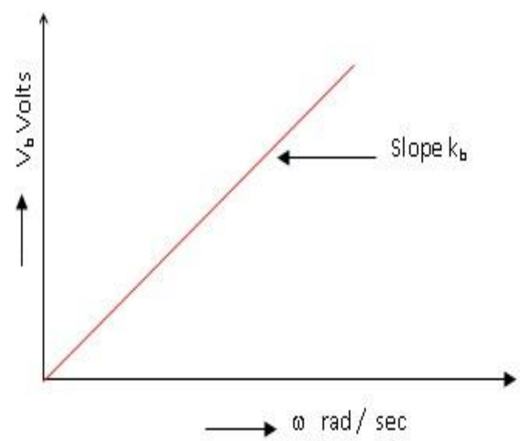
1. Connections are made as per the circuit diagram.
2. By observing the precautions switch on the supply.
3. Note down the current and speed values.
4. Calculate E_b and $\boldsymbol{\omega}$.

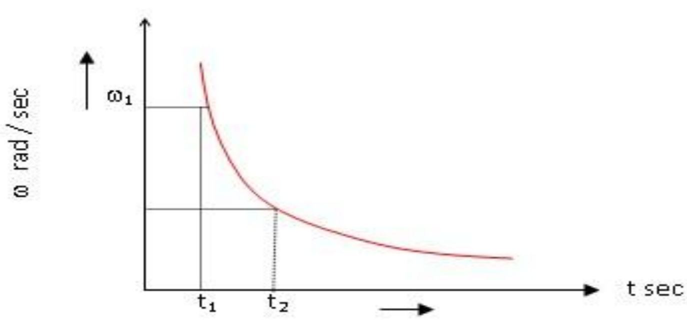
FIELD CONTROLLED DC MOTOR:

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:







RESULT:

Ex.No:
Date:

STABILITY ANALYSIS USING POLE ZERO MAPS AND ROUTH HURWITZ CRITERION IN SIMULATION PLATFORM

AIM:

To plot the pole-zero configuration in s-plane for the given transfer function using MATLAB.

APPARATUS REQUIRED:

MATLAB with Control System toolbox

Program:

Plot the pole-zero configuration in s-plane for the given transfer function

G(s)= (5s^2 + 15s + 10)/(2s^4 + 7s^3 + 20s^2 + 24s).

```
clc
n=[5 15 10];                      %Numerator array of Transfer Function
%n=input('Enter the numerator vector:')
d=[2 7 20 24 0];                 %Denominator array of Transfer Function
%d=input('Enter the denominator vector:')
Transfer_Function=tf(n,d)        %Determining the Transfer Function
G=zpk(Transfer_Function)        %Converts the Transfer Function into
                                  %the format showing in pole, zero and gain
                                  %form
[z,p,k]=tf2zp(n,d)          %Provides the values of Zeros(z),
%Poles(p) and Gain constant for
                                  % Transfer Function
[n1,d1]=zp2tf(z,p,k)          %Provides the Numerator and
                                  % Denominator arrays of Transfer
                                  %Function from the values of
                                  % Zeros(z), Poles(p) and Gain constant
pzmap(n,d)                        %Plot the poles and zeros on s-plane
ltiview(G)
```

Results:

n= 5 15 10

d= 2 7 20 24 0

Transfer function:

5 s^2 + 15 s + 10

----

2 s^4 + 7 s^3 + 20 s^2 + 24 s

Zero/pole/gain:

2.5 (s+2) (s+1)

----

s (s+1.73) (s^2 + 1.77s + 6.938)

z =

-2

-1

p =

0

-0.8852 + 2.4808i

-0.8852 - 2.4808i

-1.7296

```
k =

   2.5000

n1 =

        0         0    2.5000    7.5000    5.0000

d1 =

   1.0000    3.5000   10.0000   12.0000         0
```

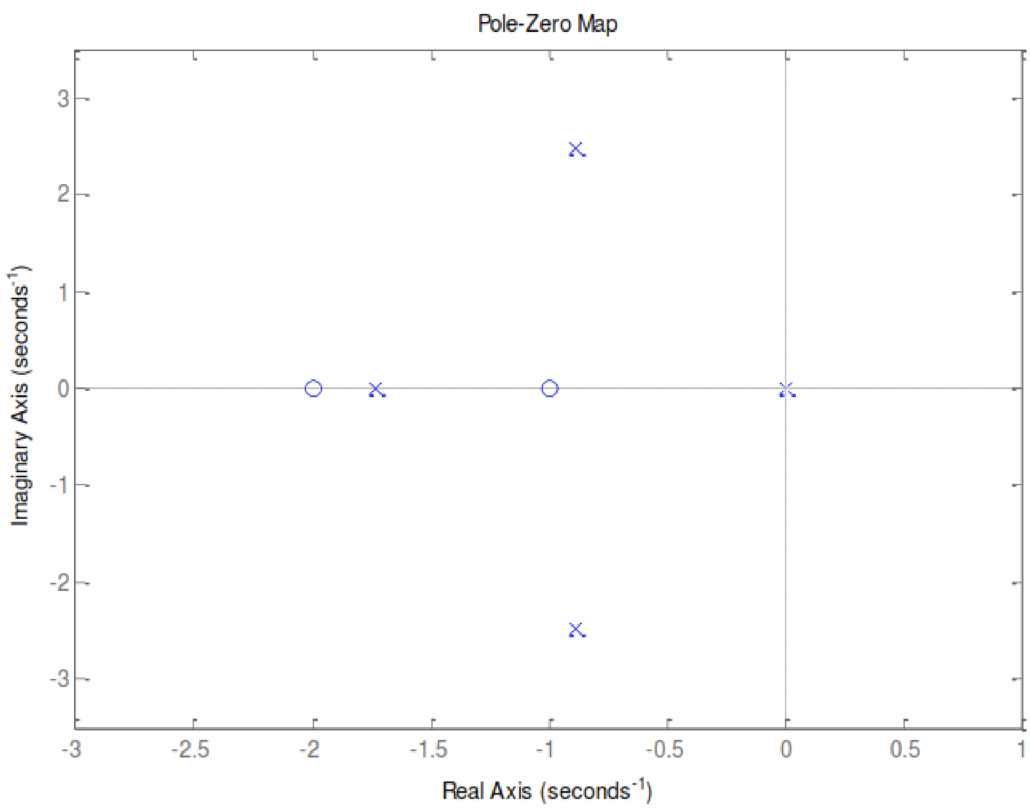


Figure 3.1: Pole-Zero Plot for the given transfer function

Result

AIM OF THE EXPERIMENT:

To determine the stability of a system using Routh Hurwitz method.

APPARATUS REQUIRED:

MATLAB software.

Computer.

THEORY:

The theory of network synthesis states that any pole of the system lies on the right hand side of the origin of the s plane, it makes the system unstable. On the basis of this condition A. Hurwitz and E.J.Routh started investigating the necessary and sufficient conditions of stability of a system. We will discuss two criteria for stability of the system. A first criterion is given by A. Hurwitz and this criterion is also known as **Hurwitz Criterion for stability** or **Routh Hurwitz Stability Criterion**. With the help of characteristic equation, we will make a number of Hurwitz determinants in order to find out the stability of the system. We define characteristic equation of the system as:

$$a_0 s^n + a_1 s^{n-1} + a_2 s^{n-2} + \cdots\cdots\cdots\cdots\cdots a_{n-1} s^1 + a_n$$

where n determinants for n^{th} order characteristic equation.

PROCEDURE:

- Enter the program in the editor window.
- Execute the program.
- Enter the coefficients of characteristic equation in the command window.
- Finally save the program and run it.
- The Routh matrix is obtained in the command window.

Program:

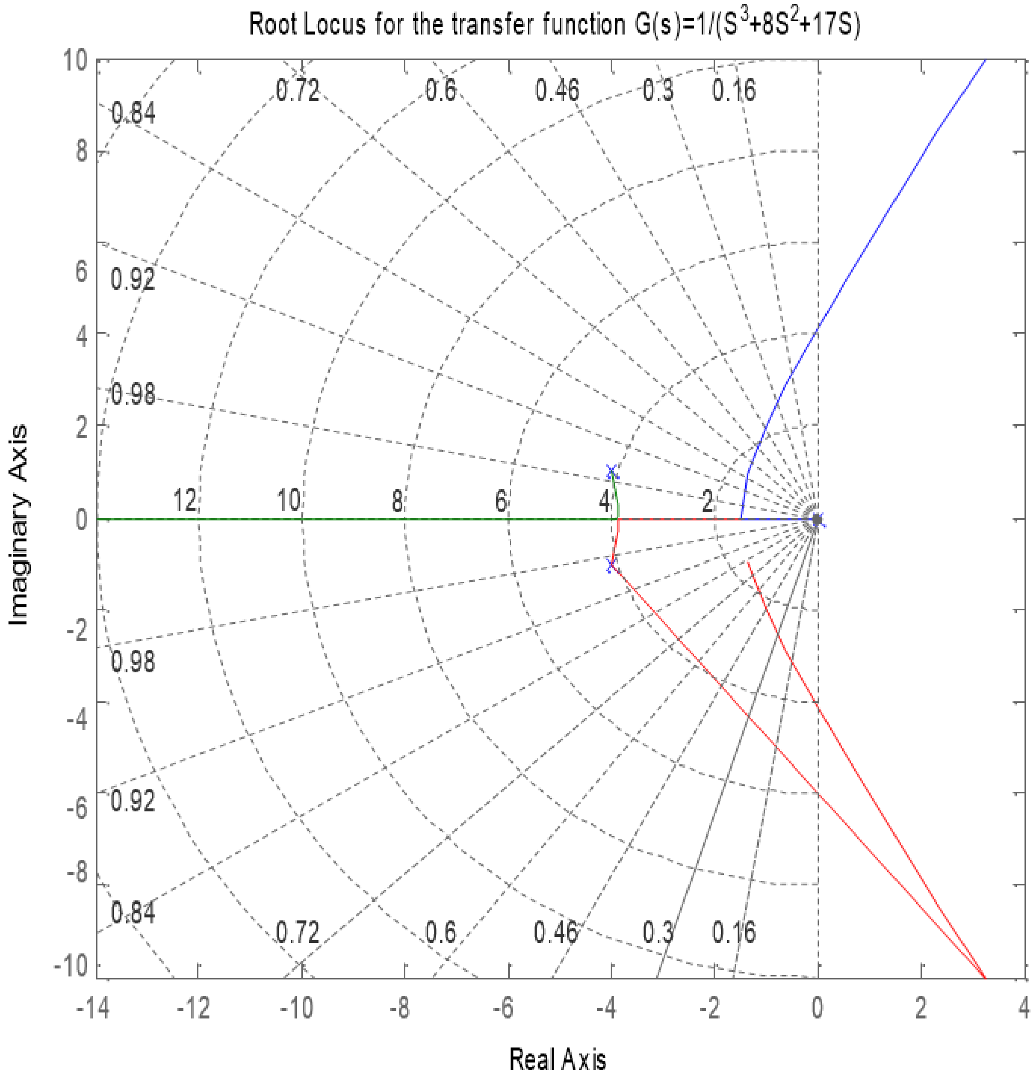
```
clear clc
%% firstly it is required to get first two row of routh
matrix e=input('enter the coefficients of characteristic
equation: ');
disp('-------------------------------------------------------------------------')
l=length(e);
m=mod(l,2); if
m==0
  a=rand(1,(l/2));
  b=rand(1,(l/2));   for
  i=1:(l/2)
    a(i)=e((2*i)-1);
    b(i)=e(2*i);
```

```
   end else
   e1=[e 0];
   a=rand(1,((l+1)/2));
   b=[rand(1,((l-1)/2)),0]; for
   i=1:((l+1)/2)
      a(i)=e1((2*i)-1);
      b(i)=e1(2*i);
   end end
%% now we genrate the remaining rows of routh
matrix l1=length(a);
c=zeros(l,l1);
c(1,:)=a; c(2,:)=b;
for m=3:l
   for n=1:l1-1
      c(m,n)=-(1/c(m-1,1))*det([c((m-2),1) c((m-2),(n+1));c((m-1),1) c((m-1),(n+1))]);
   end end
disp('the routh matrix:')
disp(c)
%% now we check the stablity of system
if c(:,1)>0
   disp('System is Stable')
else
   disp('System is Unstable');
end
```

OUTPUT:

```
enter the coefficients of characteristic equation: [1 1 3 1 6]
---------------------------------------------------------------------- the
routh matrix:
    1     3     6
    1     1     0
    2     6     0
   -2     0     0
    6     0     0

System is Unstable
```

Result:


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

Ex. No:
Date:

ROOT LOCUS BASED ANALYSIS IN SIMULATION PLATFORM

AIM:-

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

APPARATUS REQUIRED

1. MATLAB Software

DESIGN PROCEDURE :

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;
```

Result:

Ex. No:
Date:

DETERMINATION OF TRANSFER FUNCTION OF A PHYSICAL SYSTEM USING FREQUENCY RESPONSE AND BODE'S ASYMPTOTES

AIM:-

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

APPARATUS REQUIRED

1. MATLAB Software

BODE PLOT : The open loop transfer function of a unity feedback system G(s)=K/s(s2+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)

```
%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

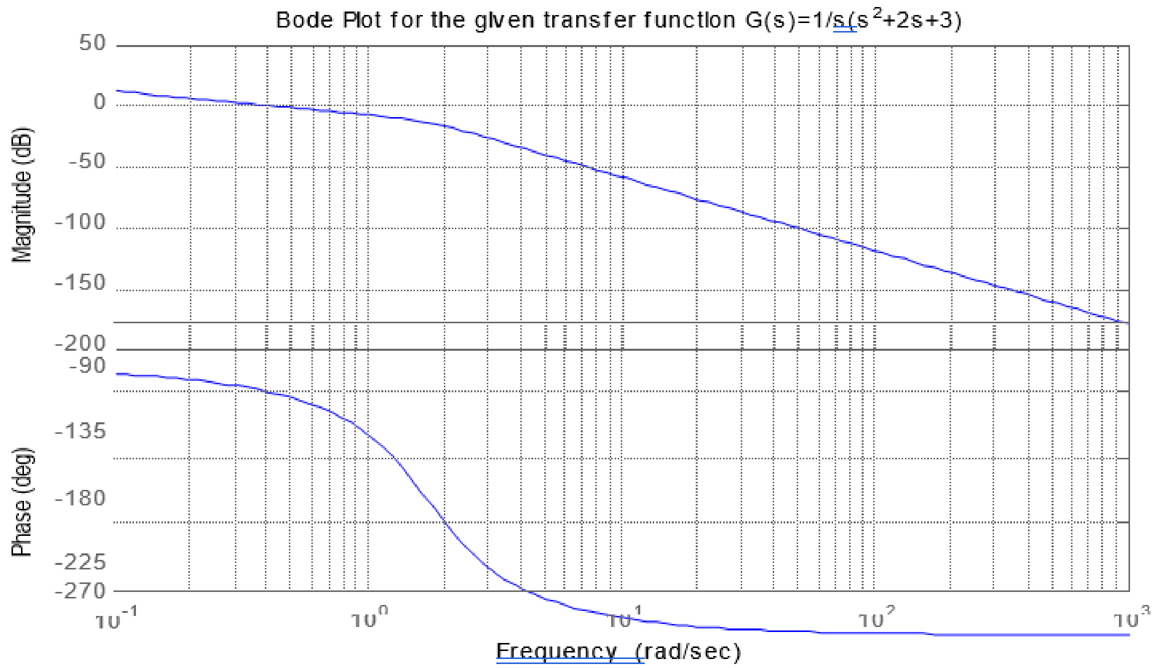
Gaincrossover_Frequency = 0.3374

Phasecrossover_Frequency= 1.7321

Resonant_PeakdB = 10.4672

Resonant_Frequency = 0.1000

Bandwidth = 0.5356



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;
```

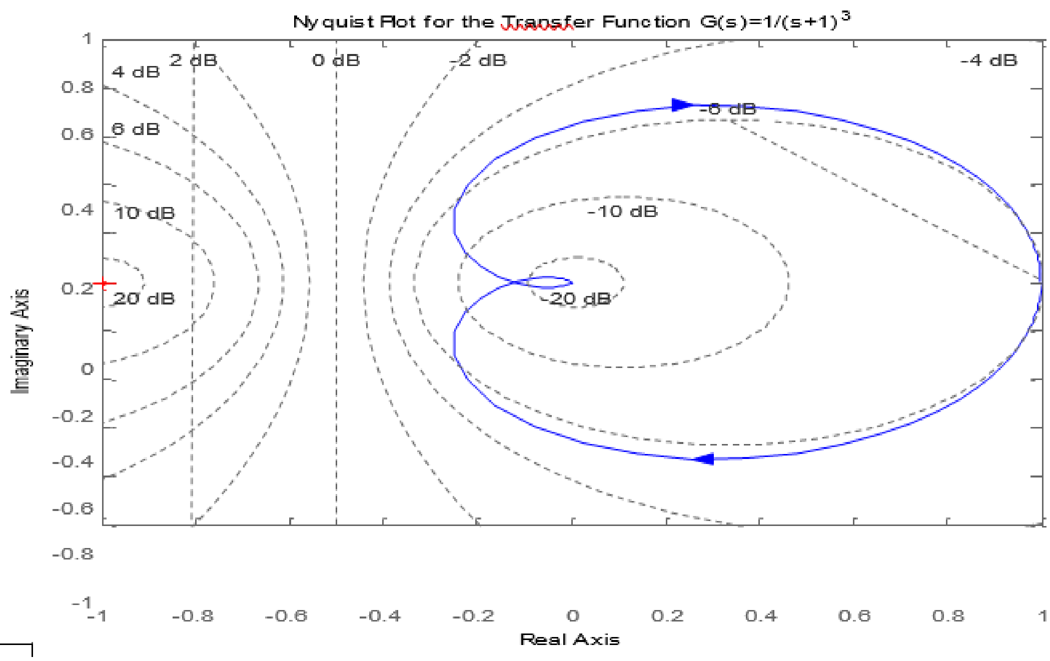
[Gm,Pm,Wcg,Wcp] =margin(num,den);

Gain_Margin=Gm

Phase_Margin=Pm

PhaseCrossover_Frequency=Wcg

GainCrossover_Frequency=Wcp



Answer

Gain_Margin = 8.0011

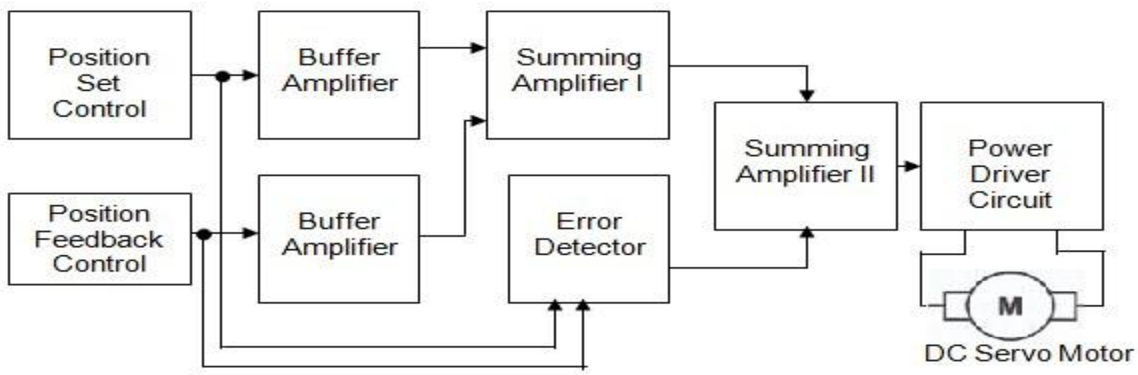
Phase_Margin = -180

PhaseCrossover_Frequency = 1.7322

GainCrossover_Frequency = 0

Result:

BLOCK DIAGRAM:



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:

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.

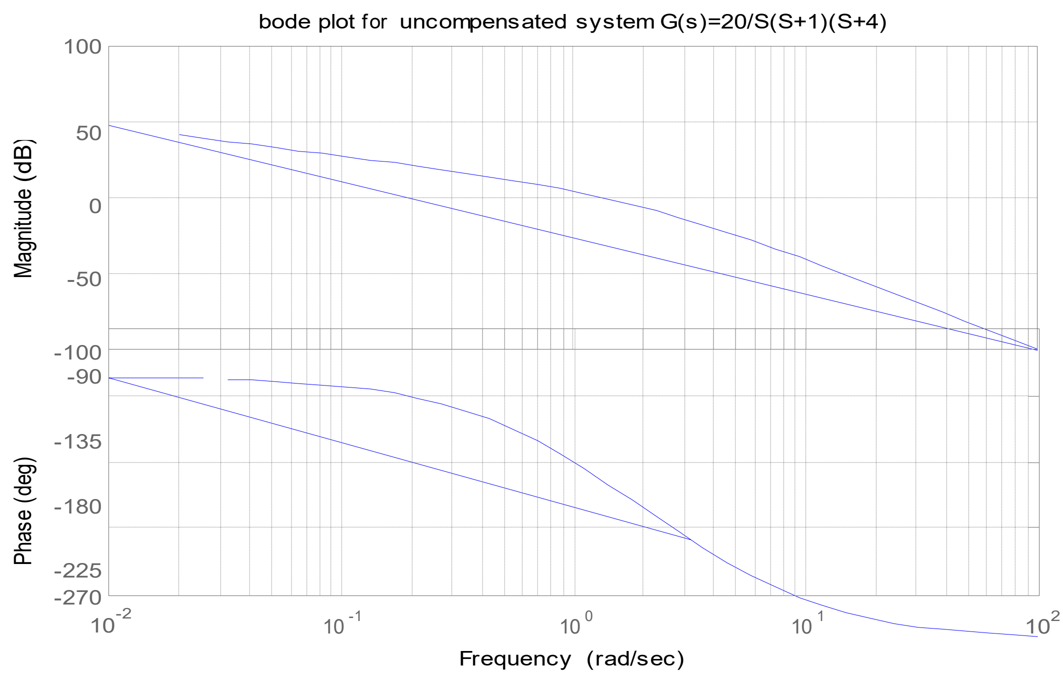
DESIGN PROCEDURE

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.

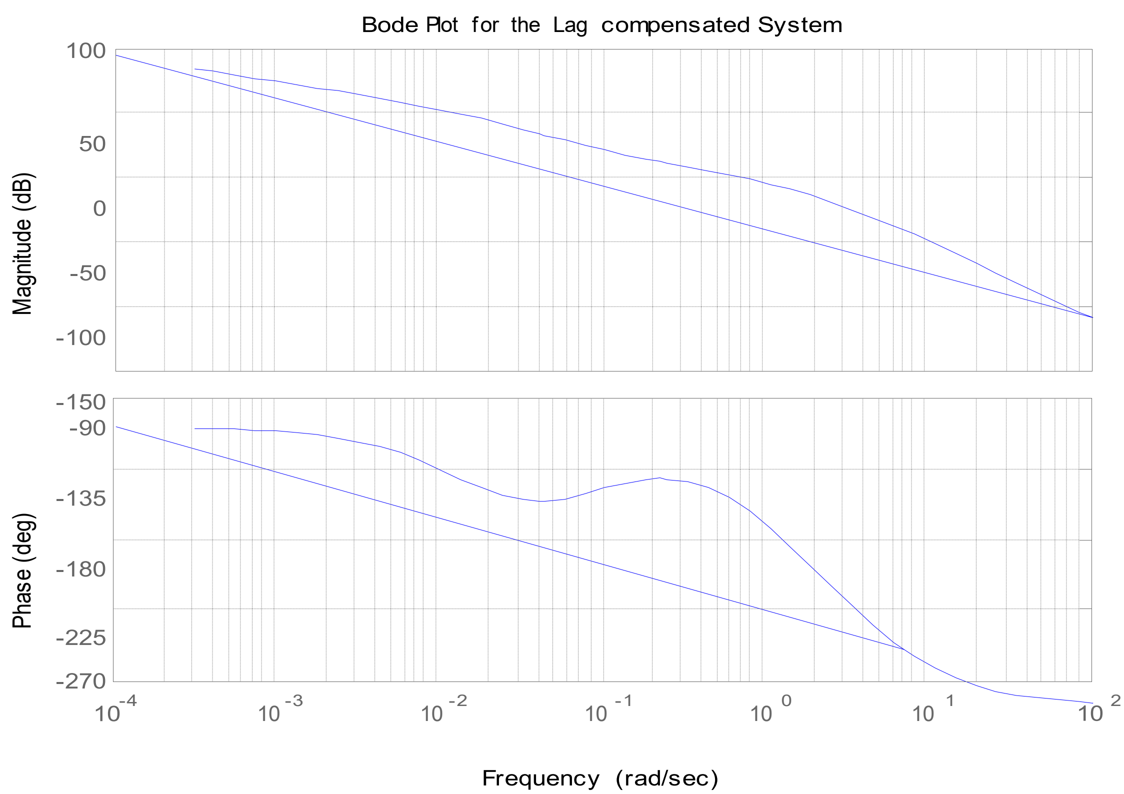
Solution

```
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)
100
50
0
-50
-100
Magnitude (dB)
-90
-135
-180
-225
-270
Phase (deg)
10 -2
10 -1
10 0
10 1
10 2
Frequency (rad/sec)

`


Bode Plot for the Lag compensated System
100
50
0
-50
-100
Magnitude (dB)
-150
-90
-135
-180
-225
-270
Phase (deg)
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
```

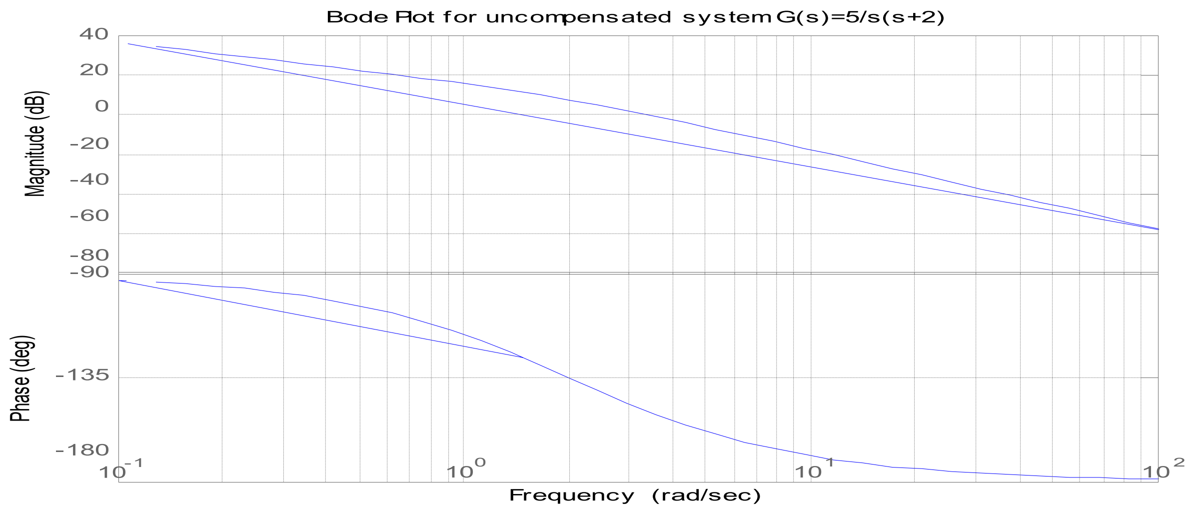
0.398 s^3 + 1.796 s^2 + 2 s

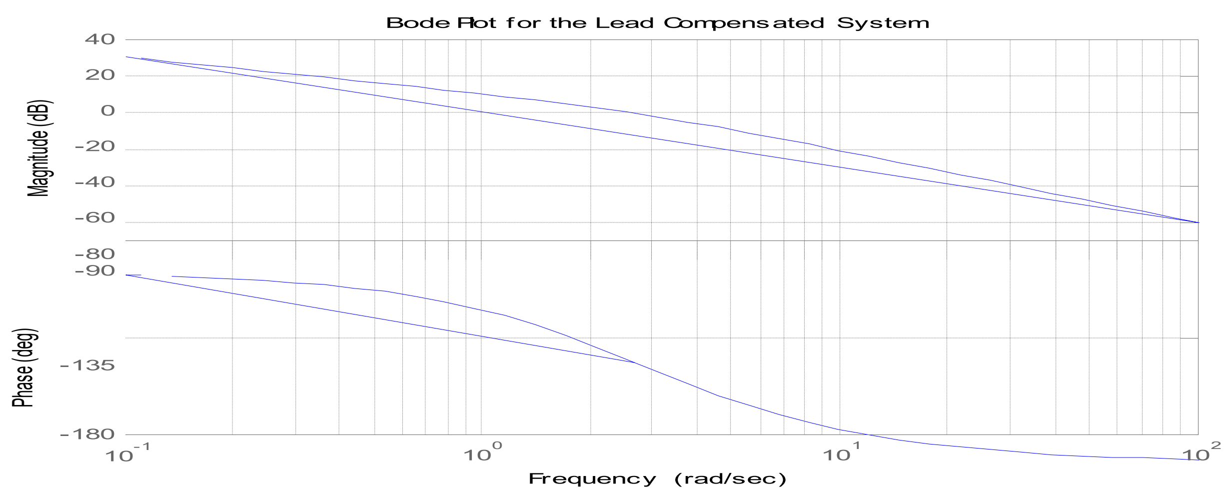
Gm1 =   Inf

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
```

----

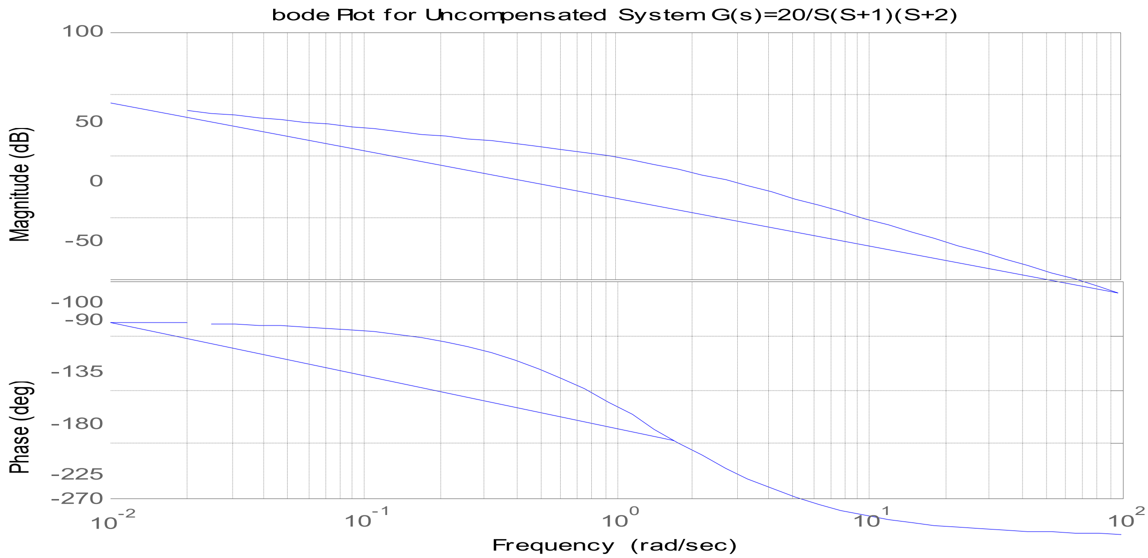
158 s^5 + 873.9 s^4 + 1516 s^3 + 802.6 s^2 + 2 s

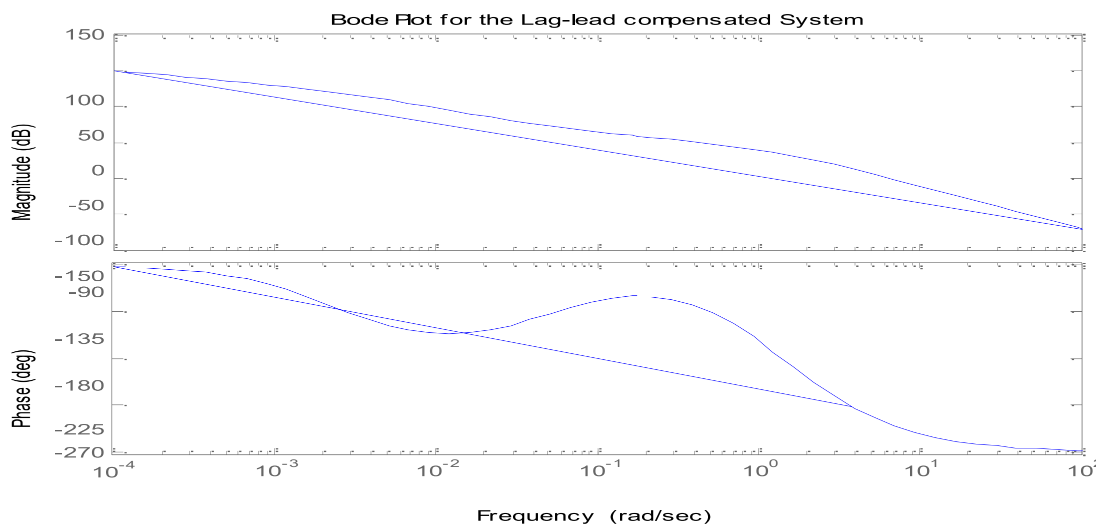
Gm1 = 6.1202

Pm1 = 48.5839

Wcg1 = 1.3976

Wcp1 = 0.4279





RESULT

Ex. No:
Date:

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:

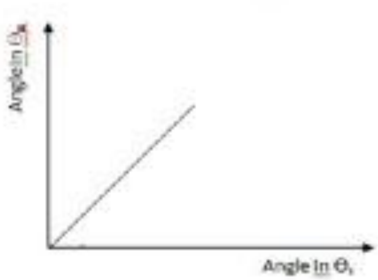
A 1 K Ω servo potentiometer is used in this stage. A + 5 V power supply is connected to this potentiometer. The feed point of this potentiometer is connected to the buffer amplifiers. A same value of another servo potentiometer is provided for position feedback control circuit. This potentiometer is 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.

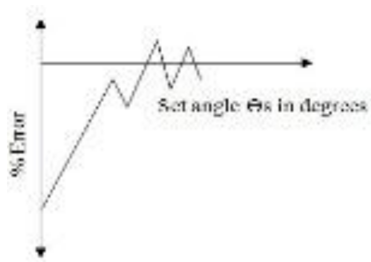
Buffer amplifier for transmitter and receiver and summing amplifier are constructed in one quad operational amplifier. The error detector is constructed in a single opamp IC LM 310. And another quad operational amplifier constructs other buffer stages.

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 % $[(\Theta_s - \Theta_m) / \Theta_s] \times 100$

MODEL GRAPH:





PROCEDURE:

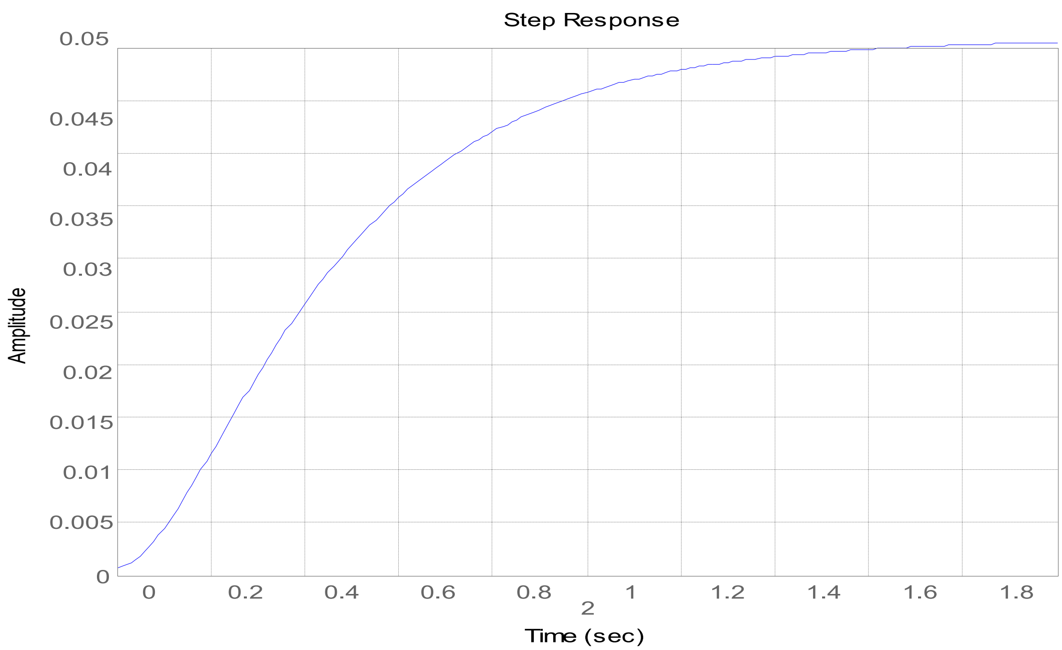
1. Connect the trainer kit with motor setup through 9 pin D connector.
2. Switch ON the trainer kit.
3. Set the angle in the transmitter by adjusting the position set control as Θ_s.
4. Now, the motor will start to rotate and stop at a particular angle which is tabulated as Θ_m.
5. Tabulate Θ_m for different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

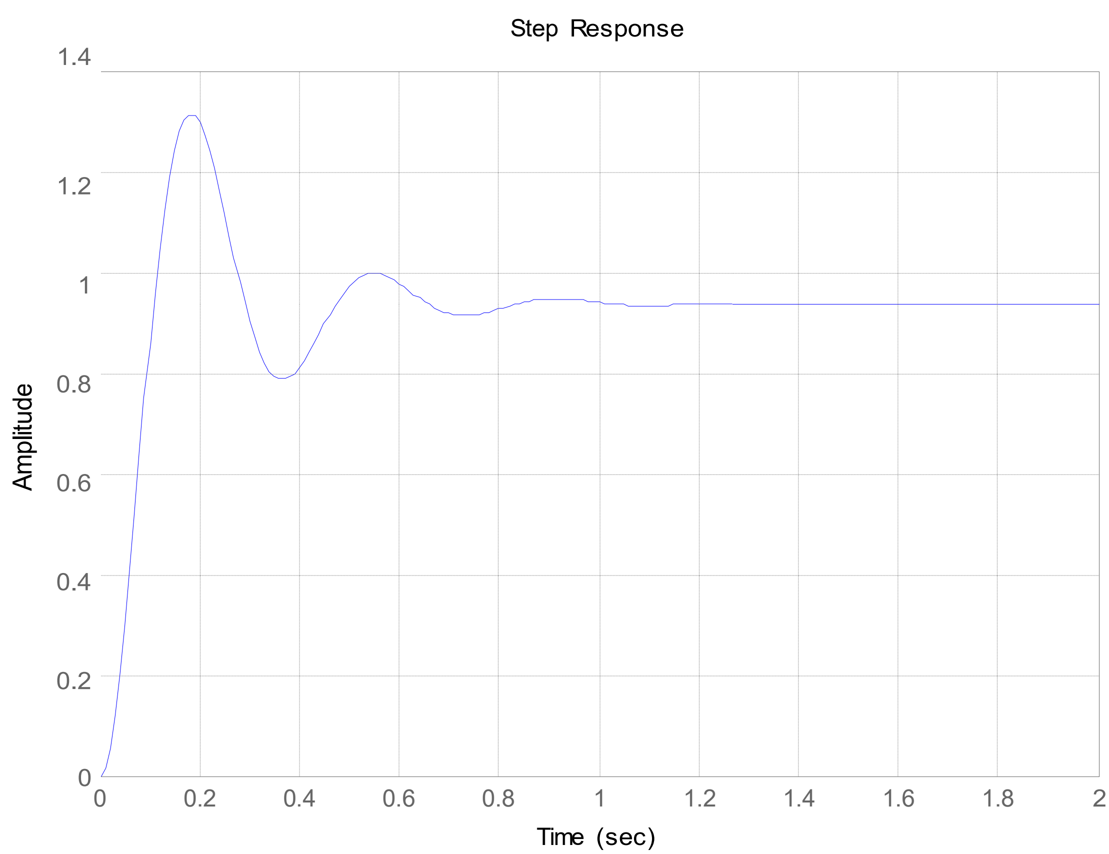
FORMULA USED:

Error in degree $= \Theta_s - \Theta_m$

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

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 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 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2

Ex. No:
Date:

DESIGN OF P, PI, PID CONTROLLERS AND EVALUATION OF CLOSED LOOP PERFORMANCE

AIM

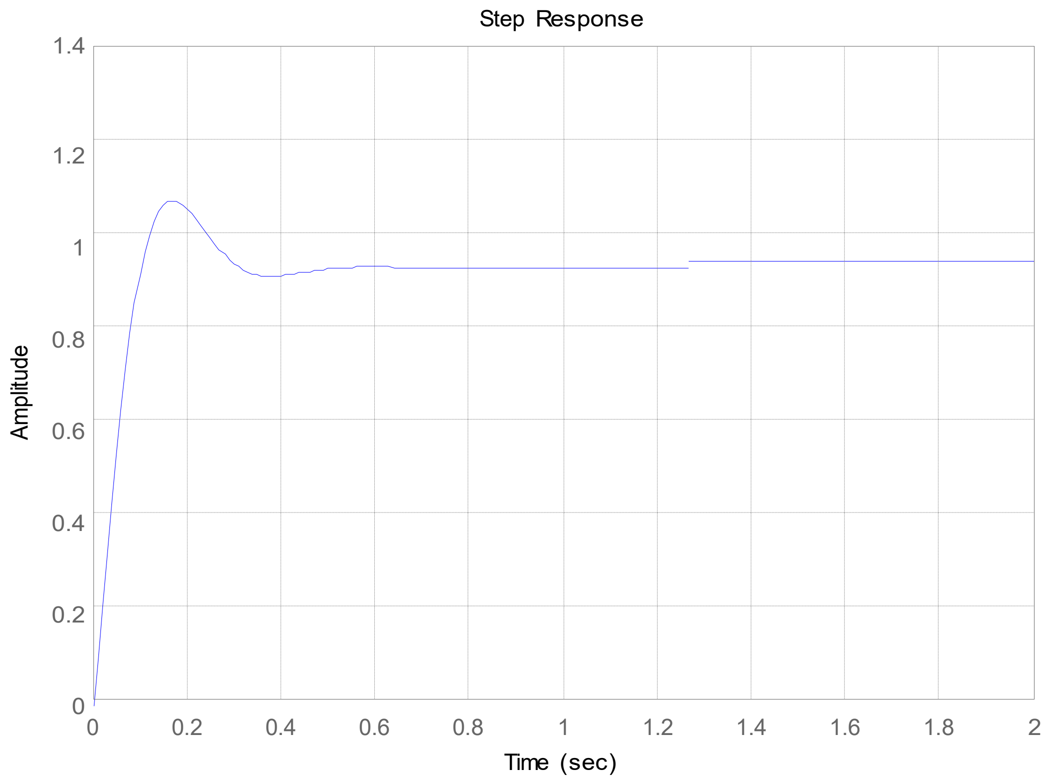
To obtain the response of the P, PI, PD, PID controller using MATLAB software.

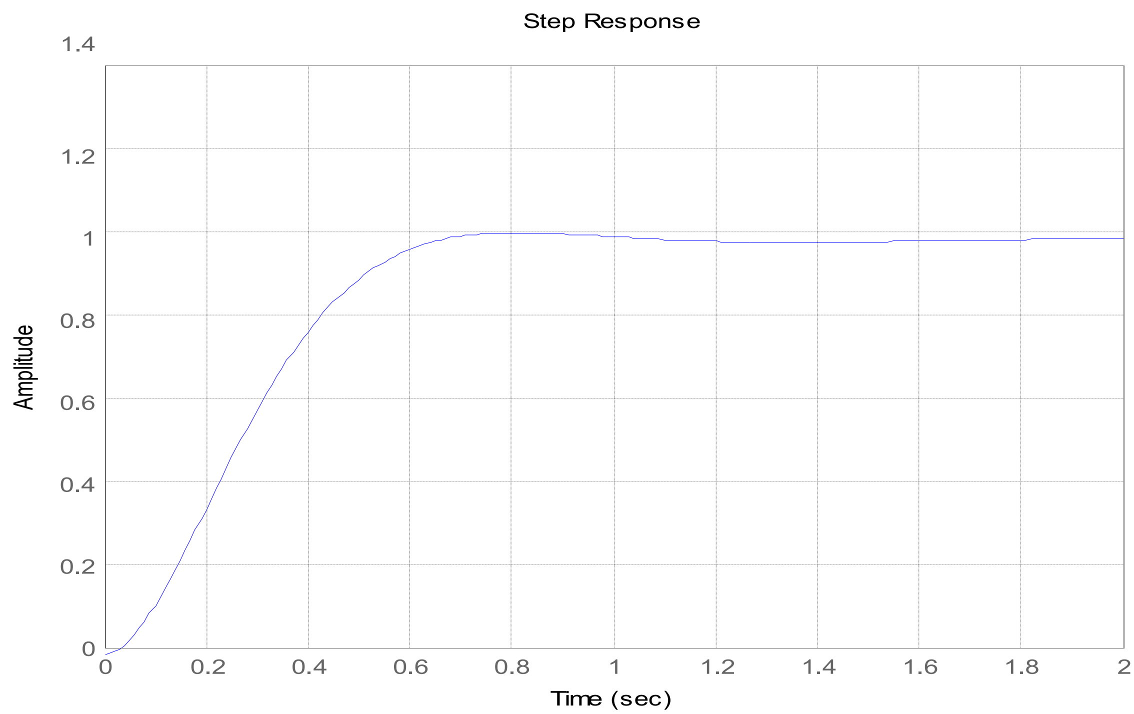
APPARATUS REQUIRED

1. MATLAB Software

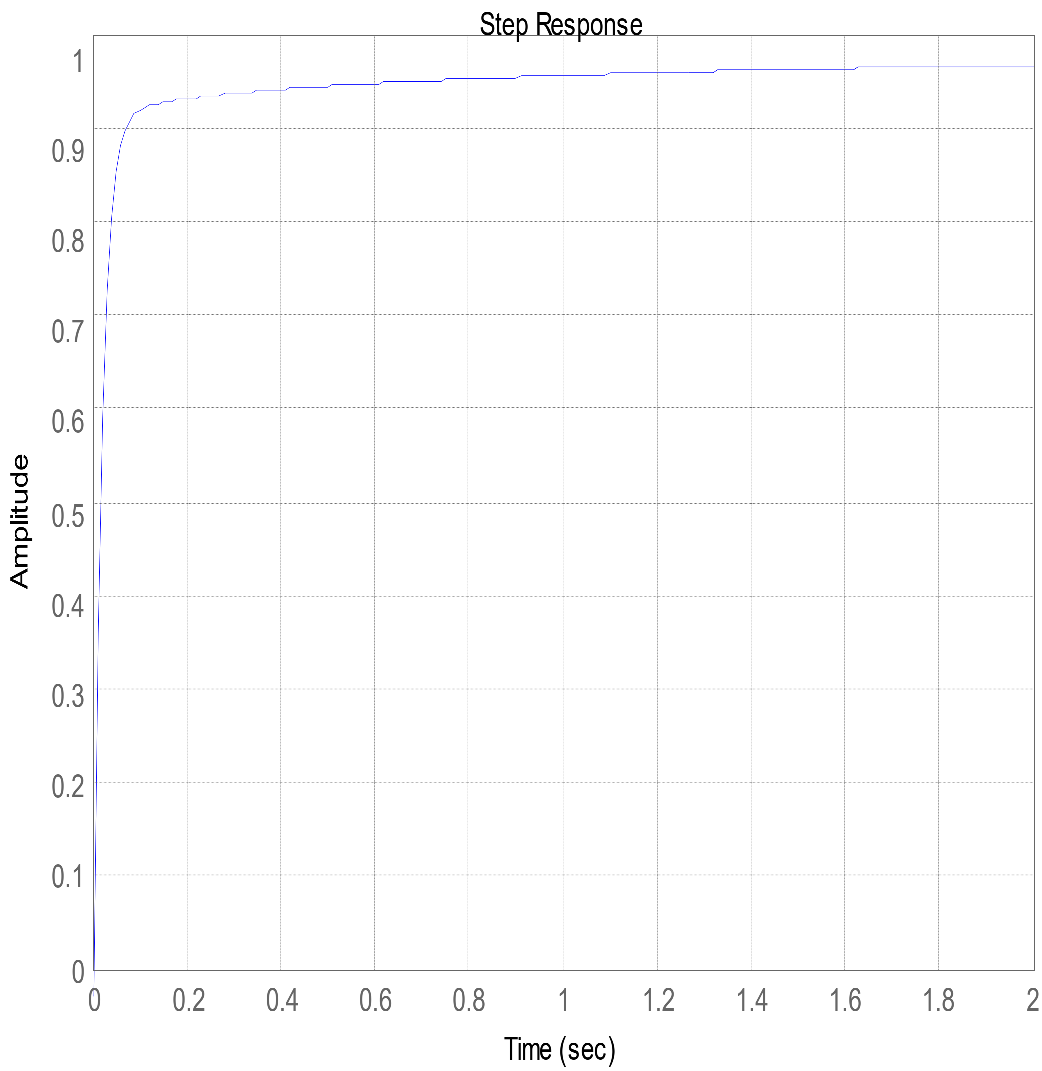
PROGRAM

```
% 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
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
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;
```



%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

Ex. No.
Date:

TEST OF CONTROLLABILITY AND OBSERVABILITY IN CONTINUOUS AND DISCRETE DOMAIN IN SIMULATION PLATFORM.

AIM:

To do the test of controllability and observability in simulation platform.

APPARATUS :

MATLAB

THEORY:

Controllability & Observability test on a control system using Matlab.

In state space analysis in Control system, sometimes we come across controllability and observability test on a control system. In this post I want to share with you an elementary Matlab program demonstrating the results of whether the system is observable and controllable or not using the well known Kalman's Test algorithm.

In this program, I have used the state space analysis approach using a 3x3 matrix for A, 3x1 matrix for B and 1x3 matrix for C as per the equation:

X= Ax + Bu

Y= Cx + Du

PROGRAM:

```
%{
Kalmans test for controllability and observability
 x* = Ax + Bu
 y  = Cx + Du
controllability condition Q = [B AB A2B]
Observability condition T=[CT ATCT (AT)2CT]
%}
clc
clear all
```

```
A=[0 0 1; -2 -3 0; 0 2 -3]
B=[0; 2; 0]
C=[1 0 0]
D=0
Q=horzcat(B,A*B,(A^2)*B)
t1=transpose(C);
t2=transpose(A);
T=horzcat(t1,t2*t1,((t2)^2)*t1)
if rank(Q)==3
    fprintf('Controllable\n')
else
    fprintf('Not controllable\n')
end
if rank(T)==3
    fprintf('Observable\n')
else
    fprintf('Not Observable\n')
end
```

Output:

RESULT:

BEYOND THE SYLLABUS EXPERIMENTS:

Ex. No. **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

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.
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.

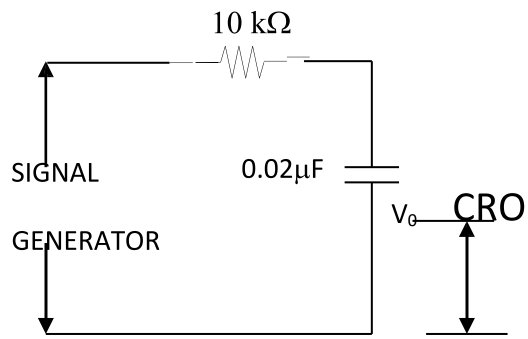
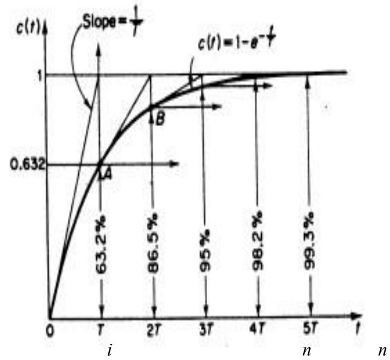


Figure: Circuit diagram for study of first order system

MODEL GRAPHS:

Time (Step) response of the first order



+ 2ζ ( ) ( )

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.

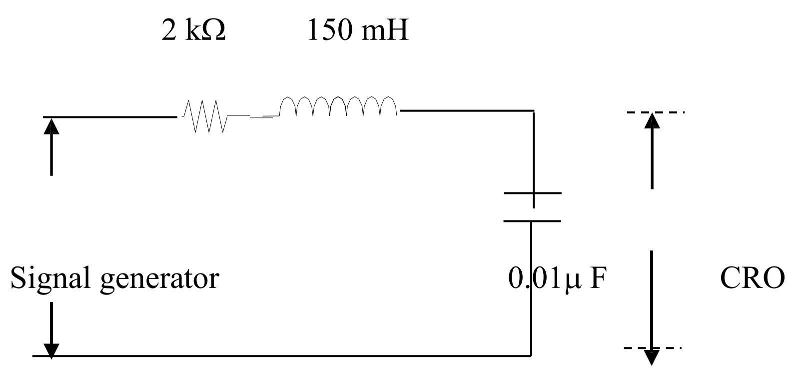


Figure: Circuit diagram for Study of Second order system

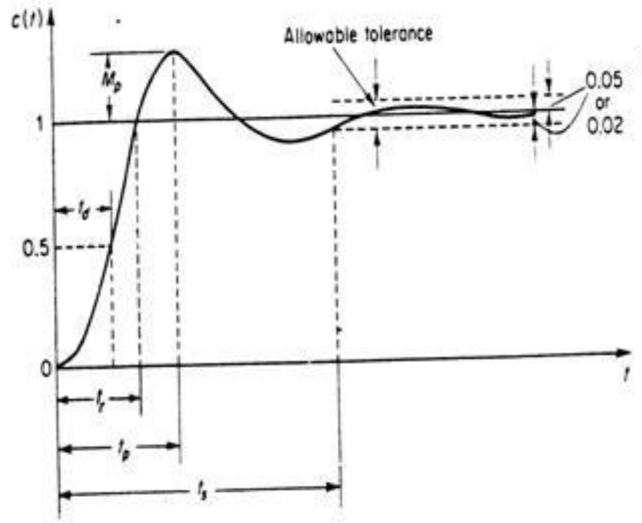
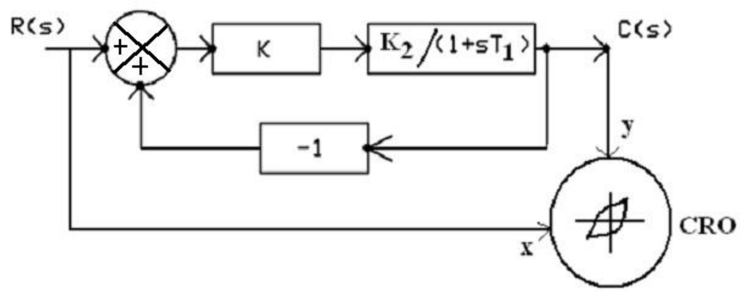


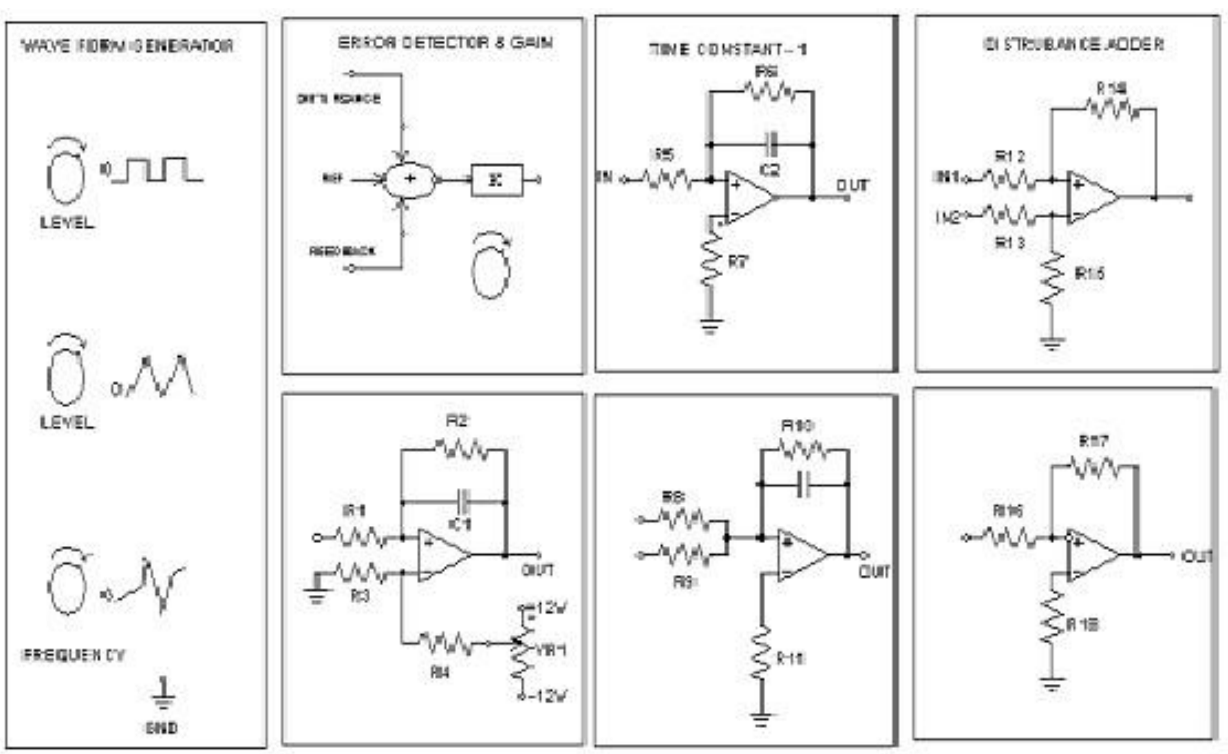
Figure: Response of second order system for unit step input

Block diagram of Type-0 first order system

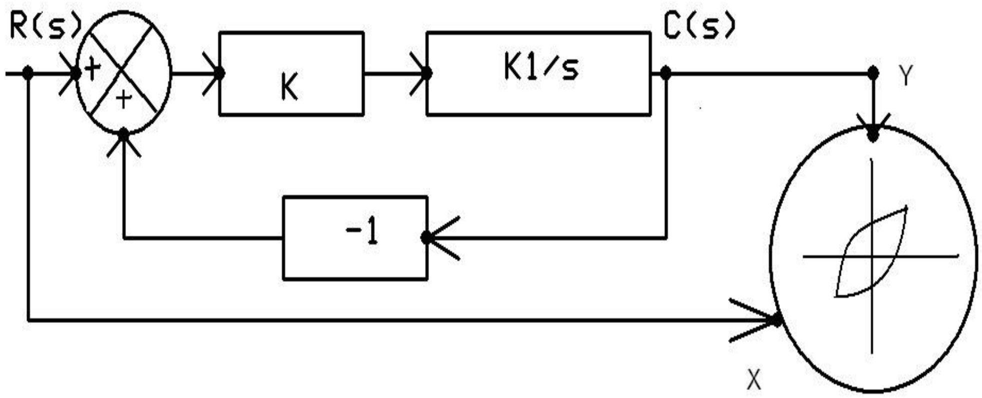


PATCHING DIAGRAM TO OBTAIN THE STEADY STATE ERROR OF

TYPE – 0 FIRST ORDER SYSTEM



Block diagram of Type- 1 First order system

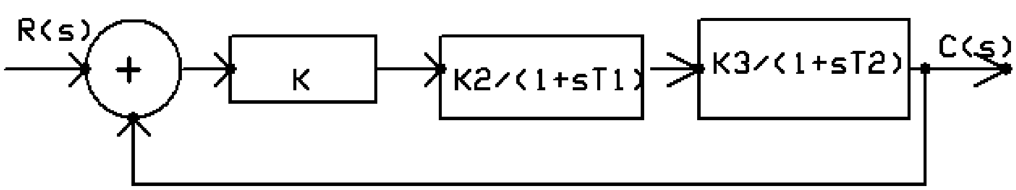


PATCHING DIAGRAM TO OBTAIN THE STEADY STATE ERROR OF TYPE – 1 FIRST ORDER SYSTEM

OBSERVATIONS:

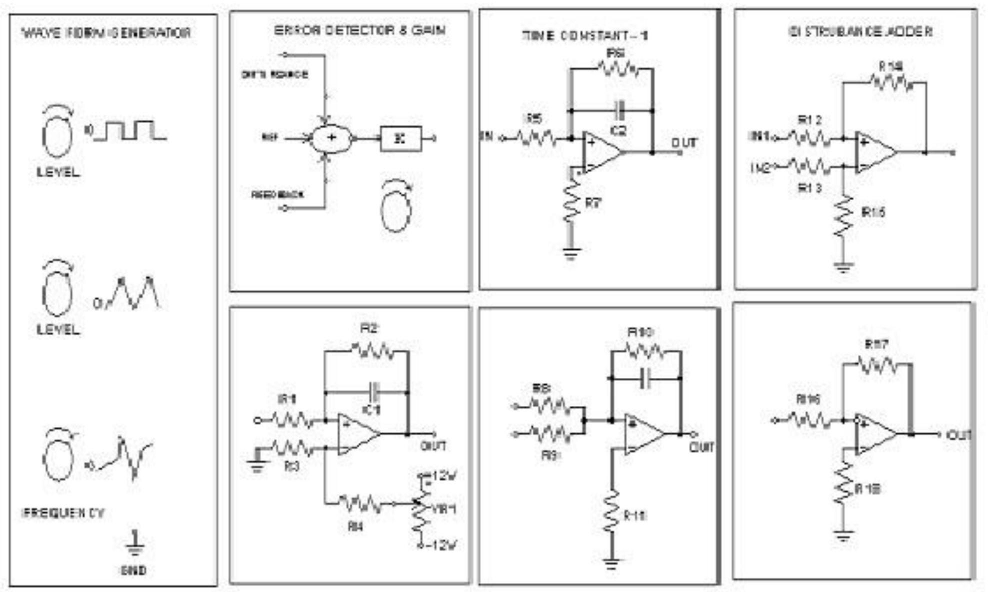
S. No.	Gain, K	Steady state error, e_{ss}
1		
2		
3		

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:

RESULT:

Ex. No. **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) - 0.85×10^{-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.

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

$$Js^2\theta(S) + Bs\theta(S) = k_1 E_c(S) - k_2 s\theta(S)$$

$$(Js^2 + Bs + k_2 s)\theta(S) = k_1 E_c(S)$$

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

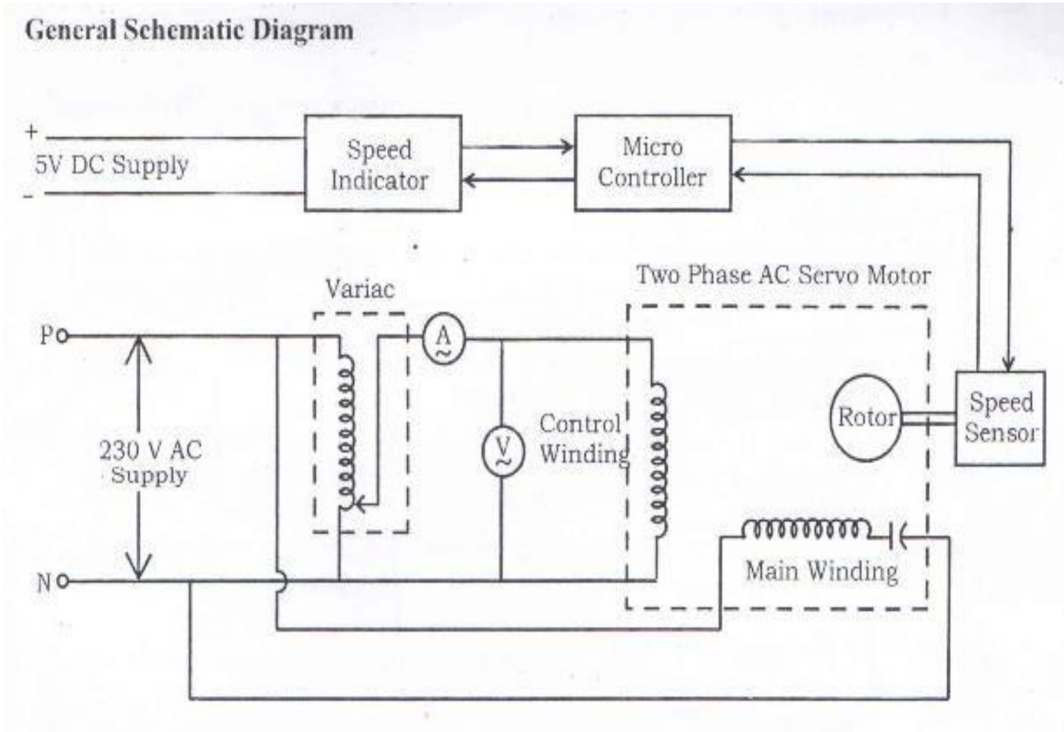
$$\frac{\theta(s)}{E_c(s)} = \frac{k_1}{s(B + k_2)\left[\frac{J}{B+k_2}s + 1\right]}$$

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

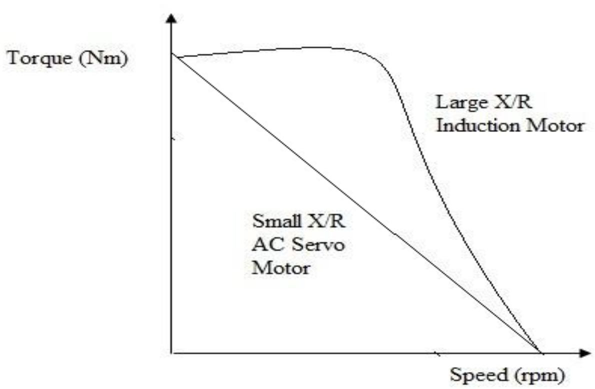
Where $k_m = \frac{k_1}{B + K_2}$ = Motor gain constant

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

Full load speed - 900 rpm



Speed torque characteristics of Induction motor and AC servomotor:



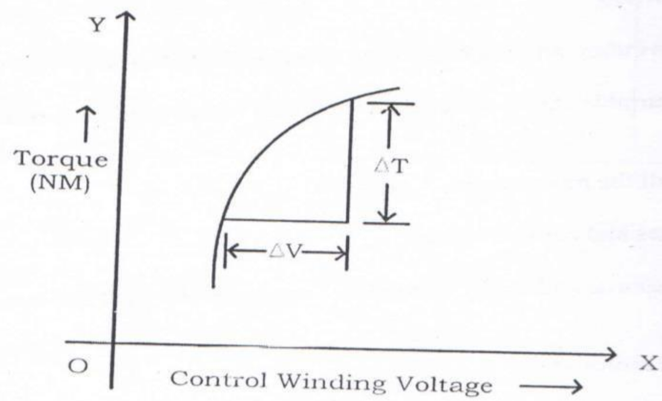
\

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.

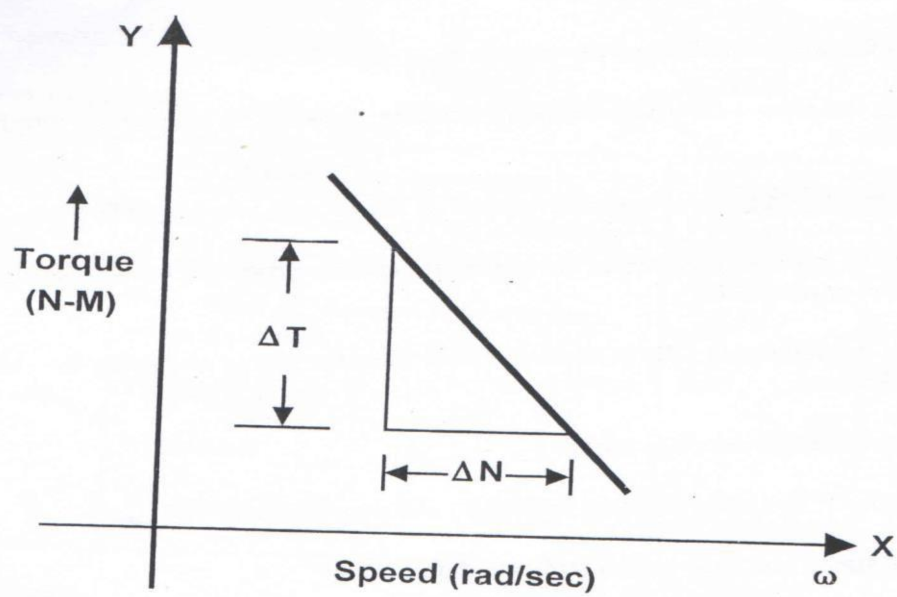
To find K_2 :

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: