Channabasaveshwara Institute of Technology
(Affiliated to VTU, Belgaum & Approved by AICTE, New Delhi)
(NAAC Accredited & ISO 9001:2015 Certified Institution)
NH 206 (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka

Department of Electrical & Electronics Engineering

LAB MANUAL

(2022-2023)

CONTROL SYSTEMS LABORATORY - 18EEL66

B.E. - VI Semester

Name: _____

USN: _____

Batch:_____Section: _____

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Department of Electrical & Electronics Engineering

CONTROL SYSTEMS LABORATORY - 18EEL66

B.E. - VI Semester

Version 3.0

April 2023

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OUR VISION

To create centers of excellence in education and to serve the society by enhancing the quality of life through value based professional leadership.

OUR MISSION

- To provide high quality technical and professionally relevant education in a diverse learning environment.

- To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a global society.

- To prepare the next generation of skilled professionals to successfully compete in the diverse global market.

- To promote a campus environment that welcomes and honors women and men of all races, creeds and cultures, values and intellectual curiosity, pursuit of knowledge and academic integrity and freedom.

- To offer a wide variety of off-campus education and training programmes to individuals and groups.

- To stimulate collaborative efforts with industry, universities, government and professional societies.

- To facilitate public understanding of technical issues and achieve excellence inthe operations of the institute.

QUALITY POLICY

Our organization delights customers (students, parents and society) by providing value added quality education to meet the national and international requirements. We also provide necessary steps to train the students for placement and continue to improve our methods of education to the students through effective quality management system, quality policy and quality objectives.

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

VISION:

To be a department of excellence in electrical and electronics Engineering education and Research, thereby to provide technically competent and ethical professionals to serve the society.

MISSION:

- To provide high quality technical and professionally relevant education in the field of electrical engineering.

- To prepare the next generation of electrically skilled professionals to successfully compete in the diverse global market.

- To nurture their creative ideas through research activities.

- To promote research and development in electrical technology and management for the benefit of the society.

To provide right ambience and opportunities for the students to develop into creative, talented and globally competent professionals in electrical sector.

Course Learning Objectives:

- ·To determine the time and frequency domain reposes of a given second order system using software package or discrete components.
- To design and analyze Lead, Lag and Lag – Lead compensators for given specifications.
- To draw the performance characteristics of ac and DC servomotors and synchro-transmitter receiver pair.
- To study the DC position & feedback control system and to study the effect of P, PI, PD and PID controller and Lead compensator on the step response of the system.
- To write a script files to plot root locus, bode plot, to study the stability of the system using matlab

Course Outcomes:

At the end of the course the student will be able to:

- Utilize software package and discrete components in assessing the time and frequency domain response of a given second order system.
- Design, analyze and simulate Lead, Lag and Lag – Lead compensators for given specifications.
- Determine the performance characteristics of ac and DC servomotors and synchro-transmitter receiver pair used in control systems.
- Simulate the DC position and feedback control system to study the effect of P, PI, PD and PID controller and Lead compensator on the step response of the system.
- Develop a script files to plot Root locus, Bode plot and Nyquist plot to study the stability of system

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18EEL66 : Control systems Lab

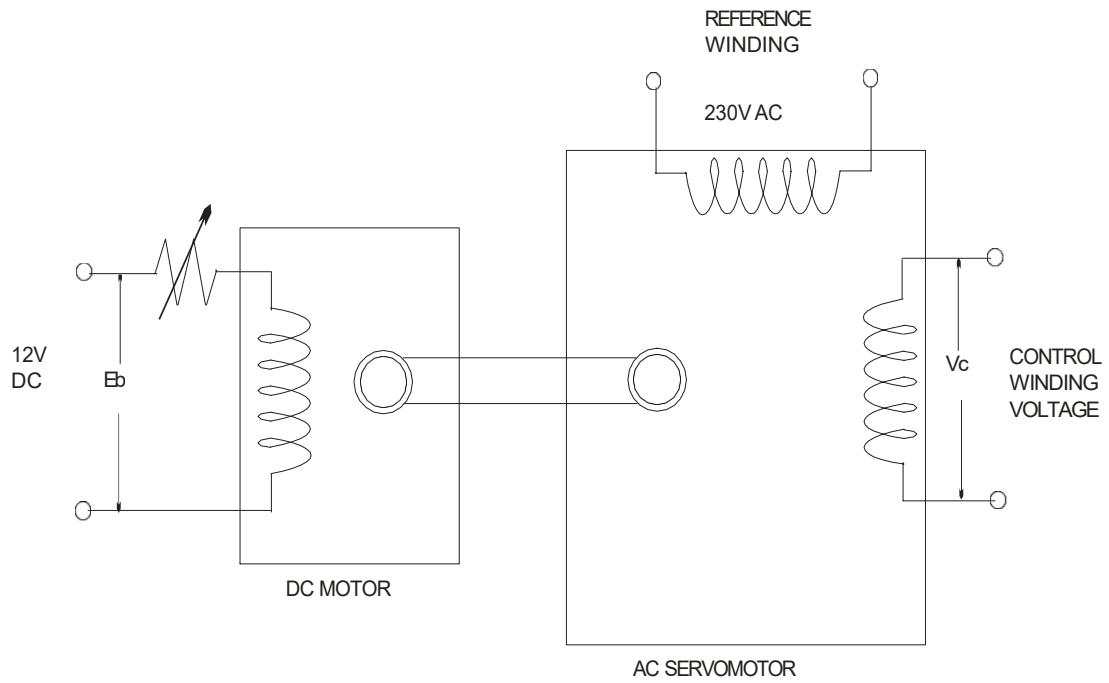| Sl.No	Name of the Experiment	Date			Observation Marks (Max (20)	Record Marks (Max. 05)	Signature (Student)	Signature (Faculty)
		Conduction	Repetition	Submission of Record				
01								
02								
03								
04								
05								
06								
07								
08								
09								
10								
11								
	Average							

Note: If the student fails to attend the regular lab, the experiment has to be completed in the same week. Then the observation and record will be evaluated for 50% of maximum marks.
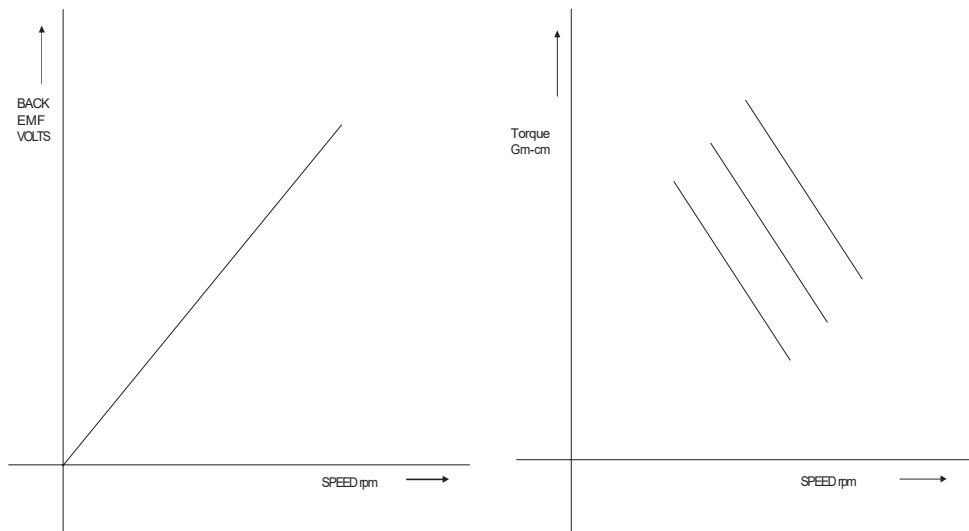
Syllabus

Experiments
1 Experiment to draw the speed torque characteristics of (i) AC servo motor (ii) DC servo motor
2 Experiment to draw synchro pair characteristics
3 Experiment to determine frequency response of a second order system
4 (a) To design a passive RC lead compensating network for the given specifications, viz, the Maximum phase lead and the frequency at which it occurs and to obtain the frequency response.
5   (b) To determine experimentally the transfer function of the lag compensating network
6 Experiment to draw the frequency response characteristics of the lag – lead compensator network and determination of its transfer function.
7 To study a second order system and verify the effect of (a) P, (b) PI, (c) PD and (d) PID controller on the step response.
8 (a) To simulate a typical second order system and determine step response and evaluate time response specifications.
(b) To evaluate the effect of adding poles and zeros on time response of second order system.
(c) To evaluate the effect of pole location on stability
9 (a) To simulate a D.C. Position control system and obtain its step response.
(b) To verify the effect of input waveform, loop gain and system type on steady state errors.
(c) To perform trade-off study for lead compensator.
(d) To design PI controller and study its effect on steady state error.
10 (a) To examine the relationship between open-loop frequency response and stability, open-loop frequency and closed loop transient response
(b) To study the effect of open loop gain on transient response of closed loop system using root locus.
11 (a) To study the effect of open loop poles and zeros on root locus contour
(b) Comparative study of Bode, Nyquist and root locus with respect to stability.

Circuit Diagram:

REFERENCE
WINDING

230V AC

12V
DC   Eb

Vc   CONTROL
WINDING
VOLTAGE

DC MOTOR

AC SERVOMOTOR

Graph:

BACK
EMF
VOLTS

SPEED rpm

Torque
Gm-cm

SPEED rpm

Exp: 1.   **Date:**_____

SPEED TORQUE CHARACTERISTICS OF AC & DC SERVO MOTOR

(i) AC SERVO MOTOR

Aim: To draw the speed torque characteristics of AC servomotor.

Apparatus:

Sl.No.	Apparatus	Nos.
1.	AC servomotor Unit	1
2.	multimeter	1

Procedure:

1) Keep load control switch & AC servo meter supply switch at OFF position.

2) Keep load Potentiometer & control voltage at minimum position.

3) Switch ON the main supply to the unit & also AC servomotor supply switch.

4) Vary the control winding voltage by varying the speed Potentiometer (speed proportional to voltage). Now the servomotor starts rotating & the speed will be indicated by the tachometer on the front panel.

5) With load switch in OFF position, vary the speed Potentiometer in steps & note down the speed & back emf generated by dc machine.

6) Set the control winding voltage for maximum value (230V,AC). Now switch on the load switch & start loading AC servomotor by varying the load Potentiometer slowly & note down the values of armature current I_a & speed of servomotor.

7) Bring the load potentiometer to zero position & switch off the load switch.

8) Repeat steps 6 & 7 for 70%, 50% & 30% of rated control winding voltage(or speed).

9) Reduce the control voltage to zero & switch OFF AC servomotor supply switch & main supply switch.
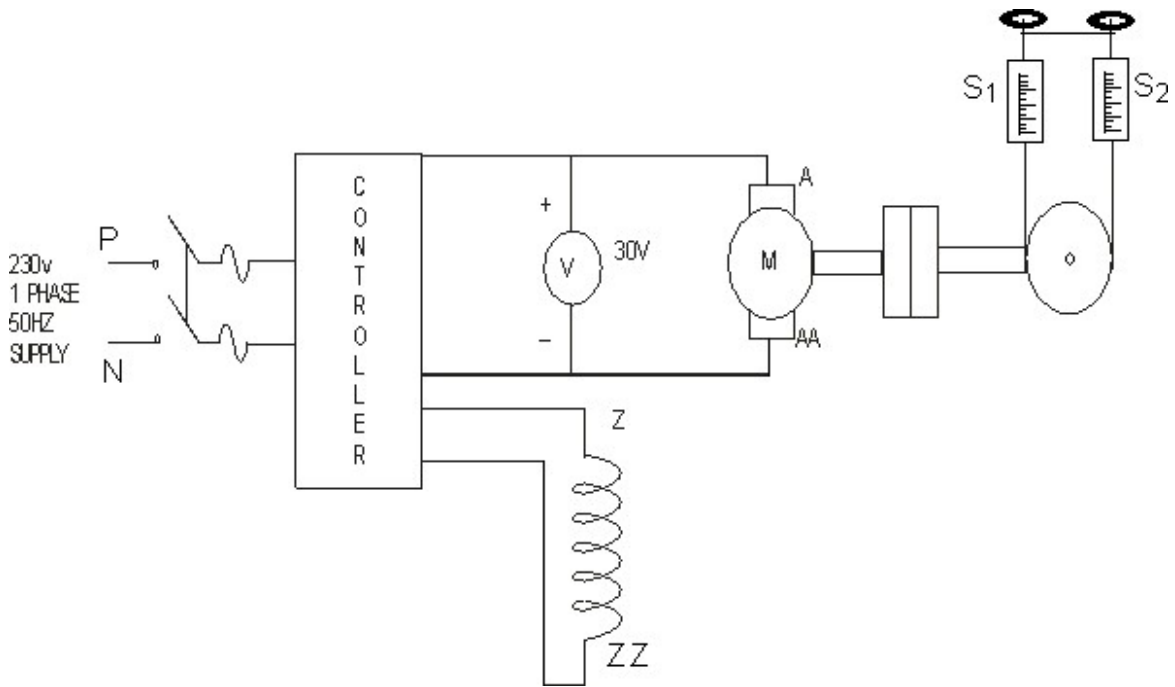
Tabular Column:

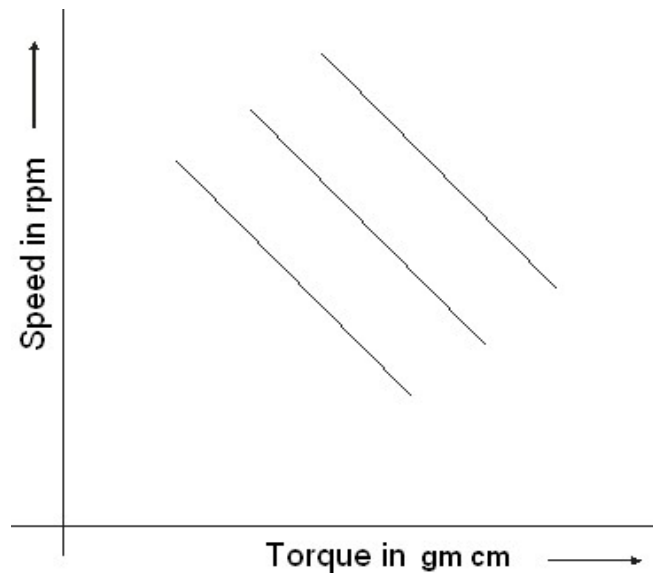**Speed V/S back emf on no load:**

Sl.No	Speed rpm	Bacf emf Volts

Torque V/S speed on Load:

% of Voltage	Speed(N) rpm	Bacf emf (E$_b$) Volts	Current (I$_a$) Amps	Torque = {E$_b$*I$_a$*60*(1.019*10^4)} /{2*π*N} gm-cm
100% (230V)				
70% of 230 V				
50% of 230 V				

Result:

Circuit Diagram:

Graph:

(ii) DC SERVO MOTOR

Aim: To draw the speed torque characteristics of DC servomotor.

Apparatus:

Sl.No.	Apparatus	Nos.
1.	DC servomotor Unit	1
2.	Multimeter	1

Procedure:

1) Remove the load on the brake drum and connect a 30V voltmeter across the motor armature.

2) Switch on the main supply to the unit. Now both tachometer and ammeter reads zero.

3) Switch on the servomotor switch. Now the motor starts rotating.

4) Set the voltage of the motor to maximum value at 24volts using speed variation knob. Note down the no load readings.

5) Now apply the load in steps and note down the speed and spring balance readings till the rated current of motor.

6) Remove the load on the brake drum.

7) Repeat steps 4,5 & 6 for 60%& 40% of armature rated voltage also.

8) Reduce the voltage of the motor to zero and switch off the servomotor switch and the main switch to the unit.

9) Draw the graph of speed V/S torque for all the 3 cases.
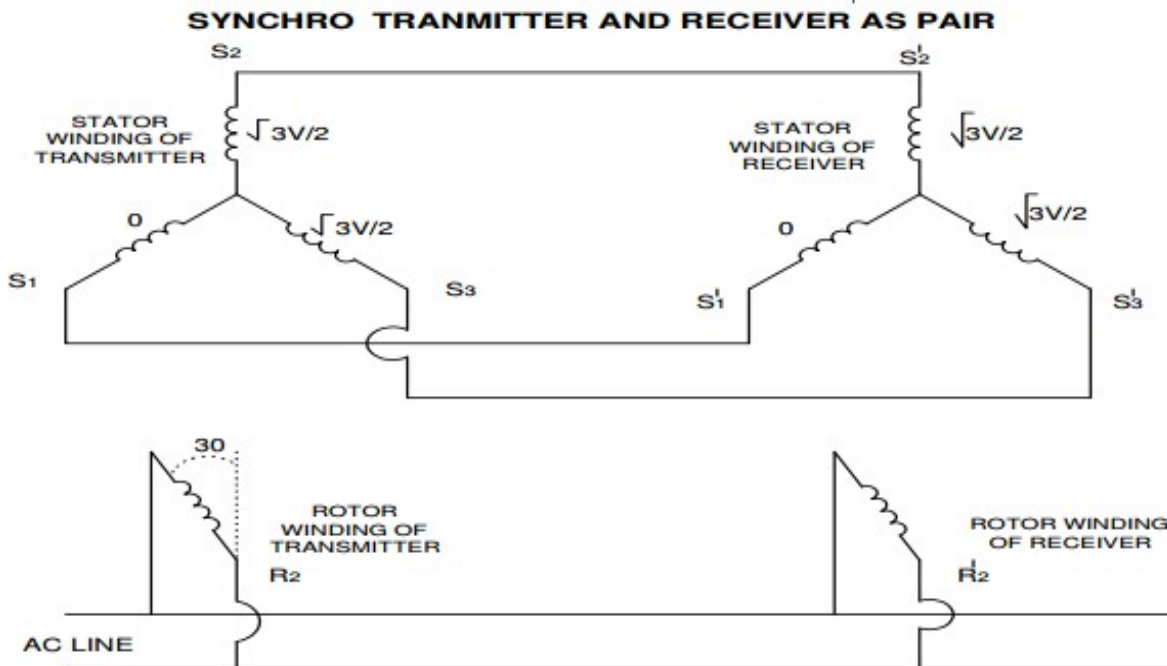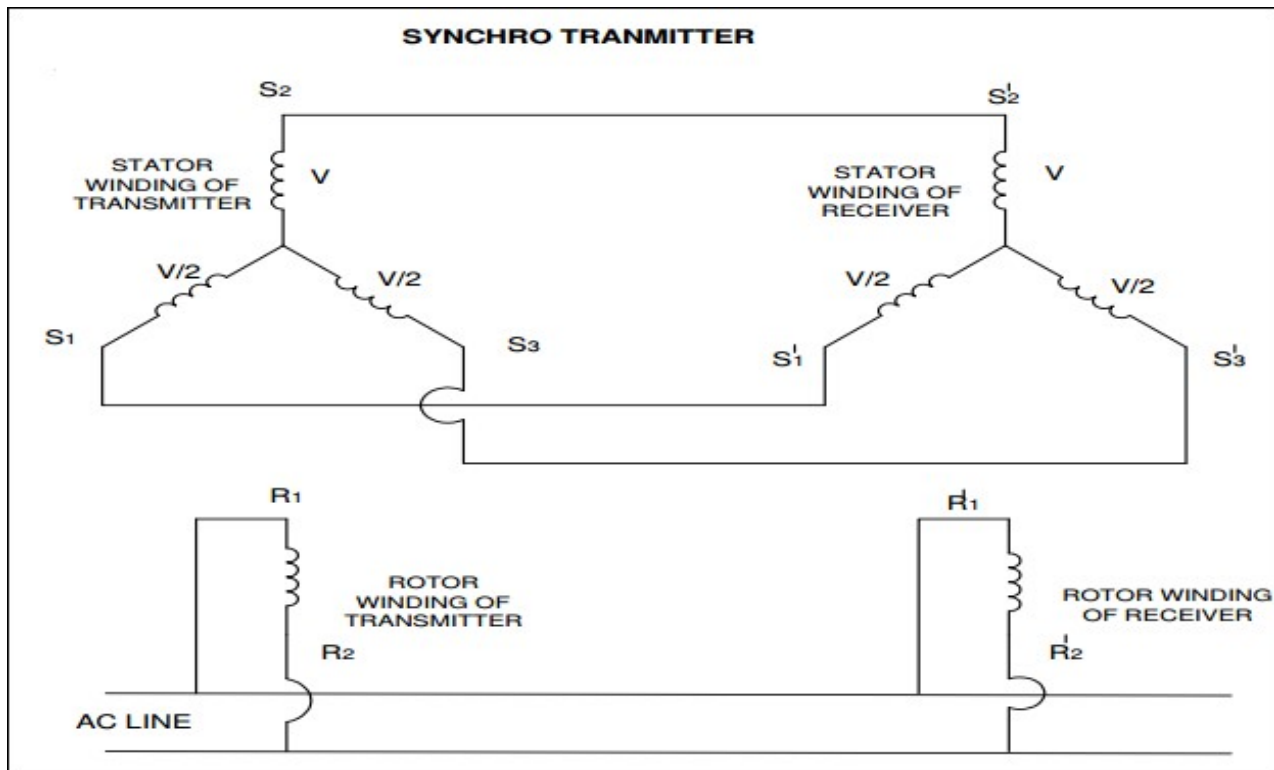
Name plate details:

Speed -   4400rpm

Voltage - 24Volts

Current - 2 amps

Torque - 400gm-cm

Radius of brake drum(r) - 2.75cm

Tabular Column

% of Voltage	Speed (N) rpm	S_1 gms	S_2 gms	$(S_1 \approx S_2)$ gms	$T=(S_1 \approx S_2)r$ gm-cm
100% (24V)					
60% of 24V					
40% of 24V					

Result:

Circuit Diagram:

SYNCHRO TRANMITTER

SYNCHRO TRANMITTER AND RECEIVER AS PAIR
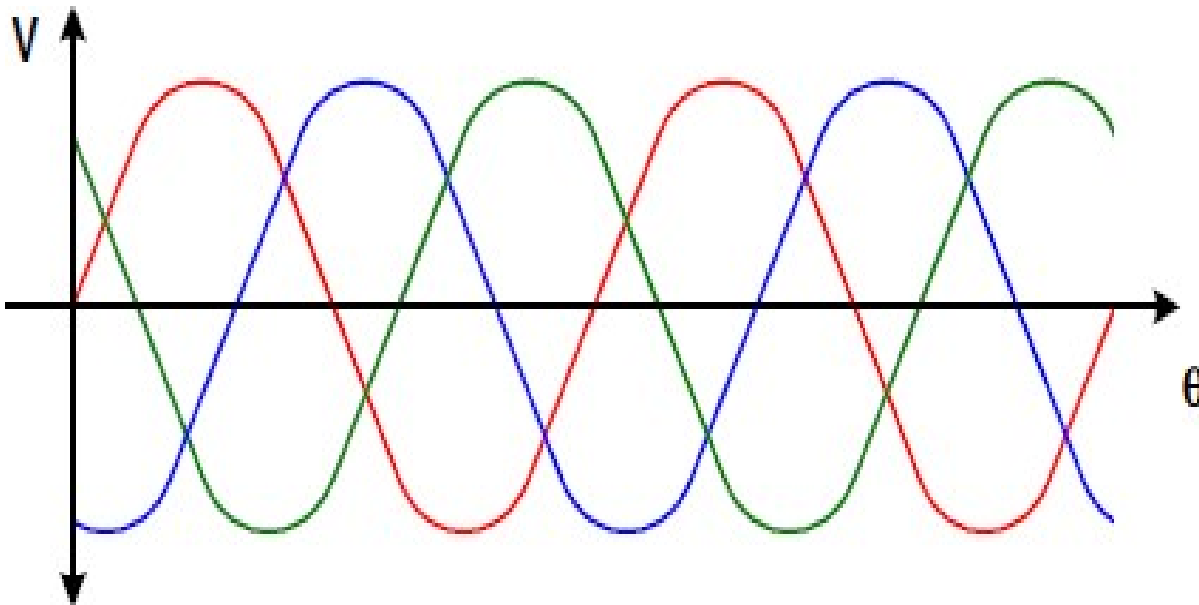
Exp: 2   **Date:**_____

SYNCRO PAIR CHARACTERISTICS

Aim: To study synchro transmitter and receiver.

Apparatus:

Sl.No.	Apparatus	Nos.
1.	Synchro transmitter and receiver unit	1
2.	Patch cards	few

Procedure:

Rotor position verses stator voltages:

1. Connect the main supply to the system with help of cable provided.
2. Connect 60V AC supply to R_1 & R_2 of the transmitter.
3. Starting from zero position note down the voltage between stator winding terminals V_{S1S2}, V_{S2S3} and V_{S3S1} in a sequence manner i.e in the interval of 30 degrees. Enter the reading in a tabular column & plot graph of angular position of rotor verses stator voltages for all three phases.
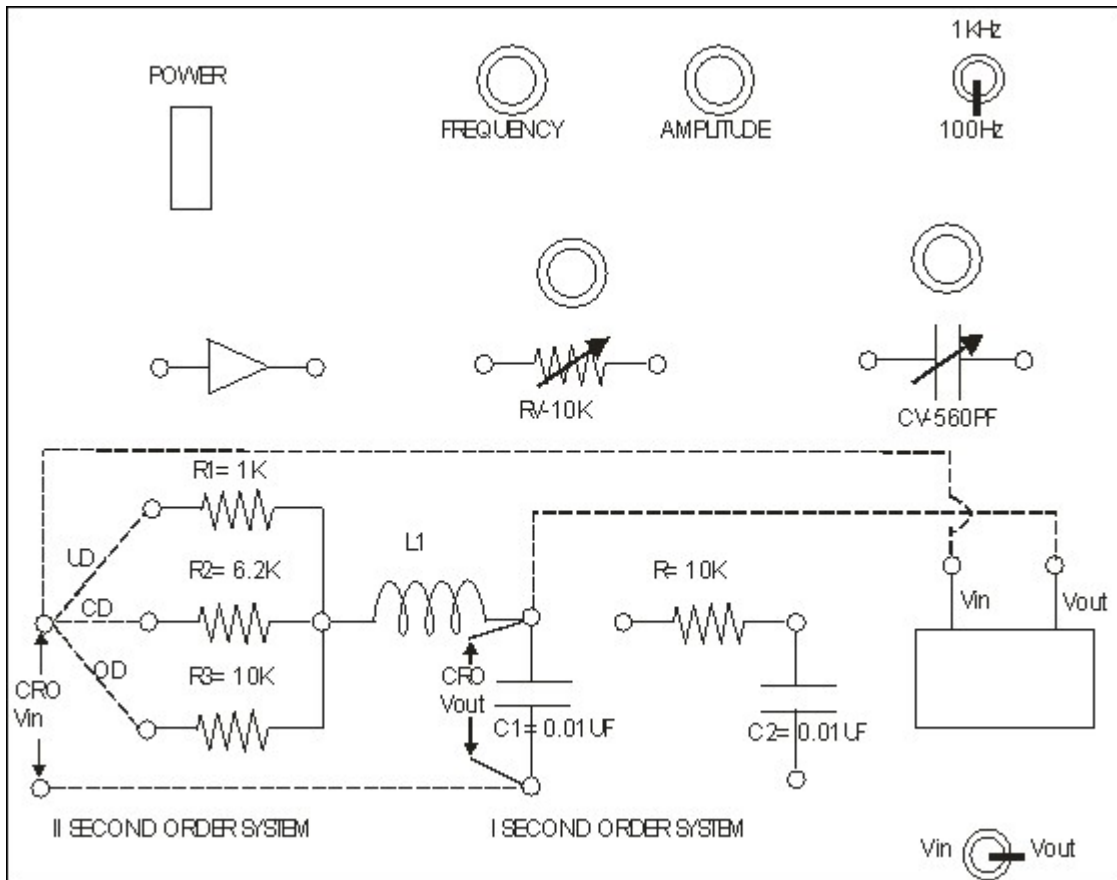
Graph:

TRANSMITTER

RECEIIVER

V
AC

AC V

S1   S1

R1   S2   S2   R1   0   60V

R2   S3   S3   R2   AC

POWER   S1   S2   S3   S1   S2   S3

TRANSMITTER   RECEIVER
WINDING   WINDING
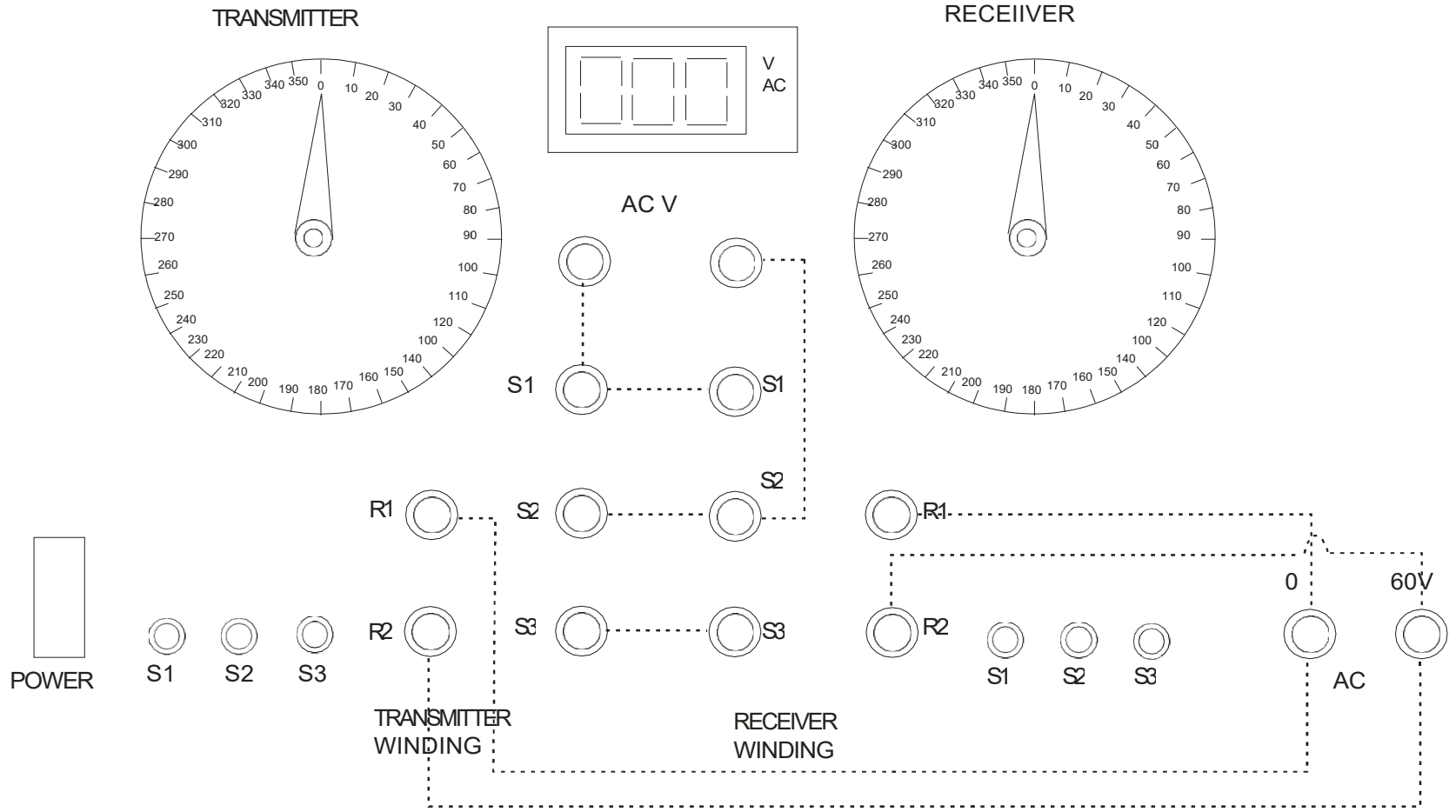
Tabular Column:

Sl.no.	Rotor position	Stator terminal voltages		
		V_{S1S2}	V_{S2S3}	V_{S3S1}
1	0°			
2	30°			
3	60°			
4	90°			
5	120°			
6	150°			
7	180°			
8	210°			
9	240°			
10	280°			
11	300°			
12	330°			
13	360°			

Result:

Circuit Diagram:

Graph:
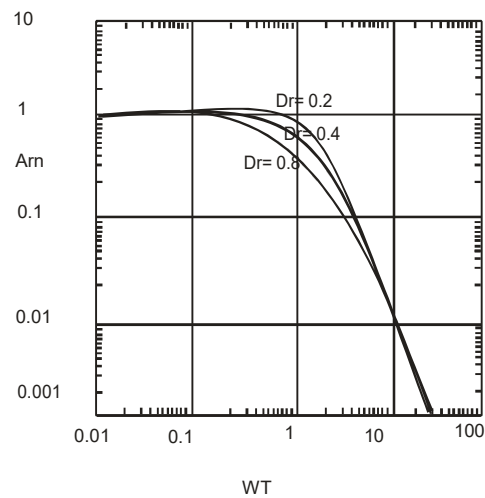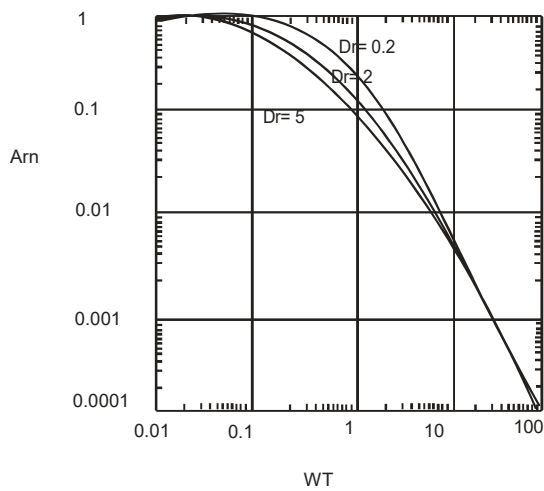
Exp: 3   **Date:**_____

FREQUENCY RESPONSE CHARACTERISTICS OF SECOND ORDER SYSTEM

Aim: To plot frequency response/bode plot for a given second order system and
to find various parameter.

Apparatus:

Sl.No.	Apparatus	Nos.
1.	Second order system unit	1
2.	Patch cards	few

Procedure:

1) Connections are made as shown in circuit diagram.

2) Switch on the apparatus.

3) Set the signal generator to sine output. Adjust the amplitude of the sine signal to suitable voltage.

4) Enter various readings in the table for the frequency from 100Hz to 10KHz in steps.

5) Plot a graph of Gain v/s $\omega\tau$.

Note: For under damped system, $0 < \delta < 1$, Choose $R=R_1$

For Critically damped system, $\delta = 1$, Choose $R=R_2$

For Over damped system, $\delta > 1$, Choose $R=R_3$
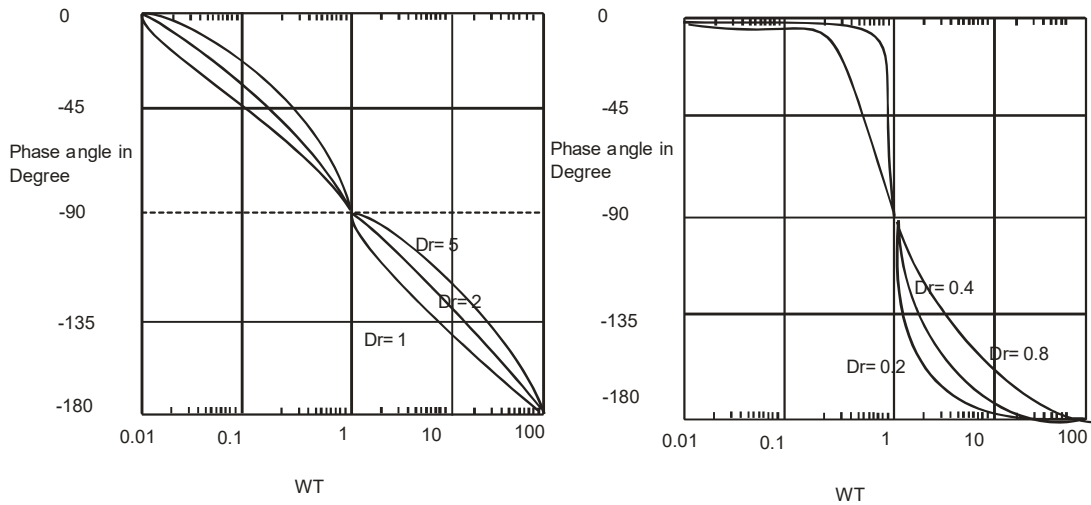
Design:

$R_1 = 1K\Omega$

$R_2 = 6.23K\Omega$

$R_3 = 10K\Omega$

$L = 100mH$

$C = 0.01\mu F$

$\tau = \sqrt{LC}$

Tabular Column:

Frequency Hz	$\omega = 2\pi f$	$\omega\tau$ *radians*	$\delta=0.158$(underdamped)			
			V_i	V_o	Gain= 20 log(V_o/ V_i)	Phase angle Φ
100						
200						
400						
600						
800						
1K						
2K						
4K						
4.5K						
5K						
6K						
8K						

$$R = \frac{2\delta}{\sqrt{\dfrac{C}{L}}}$$

$$AR_N = \frac{1}{\sqrt{(1-\omega^2\tau^2)^2 + (2\omega\tau\delta)^2}}$$

$$\phi = \tan^{-1}\left[\frac{-2\omega\tau\delta}{1-\omega^2\tau^2}\right]$$

At ω=0, Φ=0

At ω=∞, Φ=-180°

Front Panel Details:

- Power   : Mains ON/OFF switch with built-in indicator.
- AC output   : Sine/ square wave output w.r.t GND for the experiment.
- Frequency   : Varies from 10Hz to 100KHz.
- Amplitude   : Varies up to 5V.
- R_1 : 1KΩ
- R_2 : 6.23KΩ
- R_3 : 10KΩ
- L   : 100mH
- C   : 0.01µF

Frequency	$\omega = 2\pi f$	$\omega\tau$	δ=1(Critically damped)			
Hz		*radians*	V_i	V_o	Gain= 20 log(V_o/ V_i)	Phase angle Φ
100						
200						
400						
600						
800						
1K						
2K						
4K						
4.5K						
5K						
6K						
8K						

Frequency	$\omega = 2\pi f$	$\omega\tau$	δ=1.58(over damped)			
Hz		*radians*	V_i	V_o	Gain= 20 log(V_o/ V_i)	Phase angle Φ
100						
200						
400						
600						
800						
1K						
2K						
4K						
4.5K						
5K						
6K						
8K						

Resonant Peak $\_ M_r = \dfrac{1}{2\xi\sqrt{(1-\xi^2)}}$

Resonant Frequency $\_ \omega_r = \omega_n\sqrt{(1-\xi^2)}$

Bandwidth $\_ \omega_b = \omega_b\sqrt{(1-\xi^2)+\sqrt{4\xi^4-4\xi^2+1}}$

Result:

Circuit Diagram:
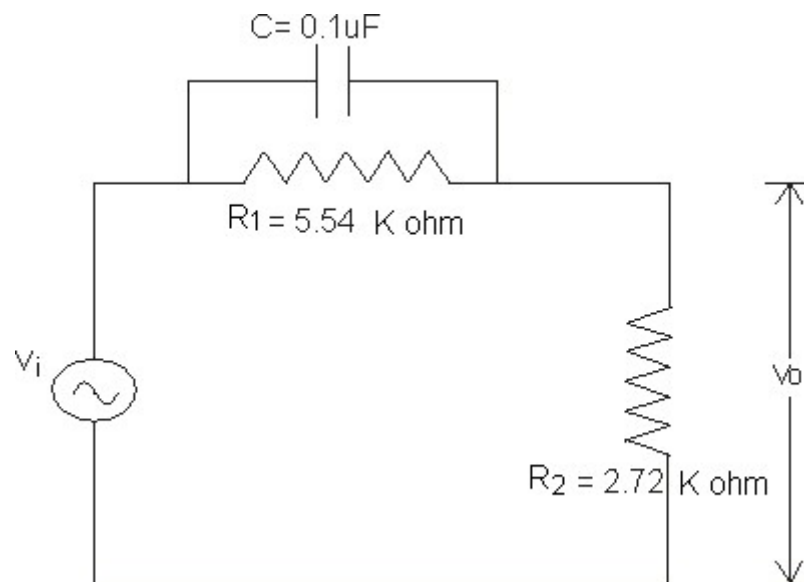
Graph:
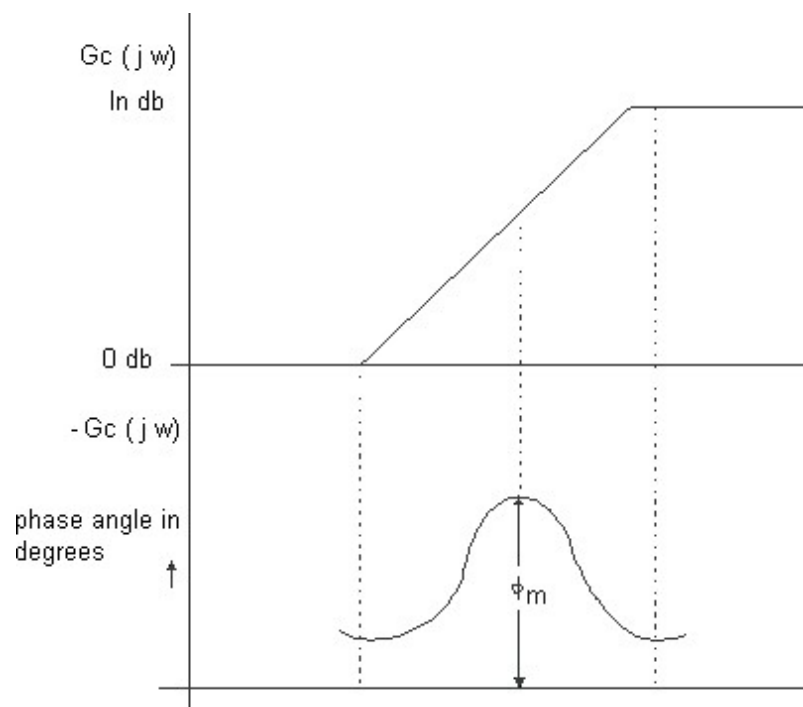
Exp: 4   Date:_____

DESIGN, DETERMINATION OF TRANSFER FUNCTION & FREQUENCY RESPONSE FOR LEAD NETWORK

Aim: a) To design a passive RC Lead compensating network for the given specifications, viz, the maximum phase lead and the frequency at which it occurs and to obtain its frequency response.

b) To determine experimentally the transfer function of the lead Compensating network.

Apparatus:

Sl. No	Apparatus	Range	Nos.
1	Resistor	5.54KΩ,2.7 or 2KΩ	1 each
2	Capacitor	0.1µF	1
3	Signal generator		1
4	CRO		1
5	Probe		3
6	Wires		few

Procedure:

1) Connection is made as shown in circuit diagram.

2) The output voltage of the sine generator is set to 10V peak.

3) Input frequency is varied in steps (in the range of 1 to 1MHz) and at each step the output voltage and phase angle are noted down using CRO.

4) All the readings are tabulated and the gain characteristic & phase characteristics are plotted on semi log sheet.

Lissajous figure:-

fig (a)   fig (b)
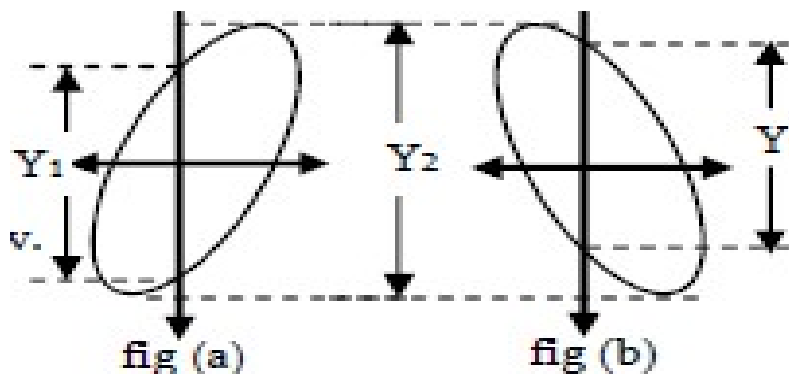
Design:

The general transfer function of the lead compensator is

$$G_C(s) = \frac{s+(1/T)}{s+(1/\alpha T)}, \alpha < 1, T > 0 \;-------------------------->A$$

Where $\alpha = \dfrac{R_2}{R_1 + R_2}$

Time constant T= $R_1 C$ ....$\rightarrow$1

The corner frequencies are 1/T and 1/ α T ------------------------------- $\rightarrow$2

The maximum phase lead $\varphi_m = \sin^{-1}(\dfrac{[1-\alpha]}{[1+\alpha]}) \;-------------->3$

Or $\quad \alpha = \dfrac{1-\sin\phi_m}{1+\sin\phi_m}$

and ω_m is the frequency at with ϕ_m occurs

$$\omega_m = \sqrt{1/T * 1\alpha T} = \frac{1}{\sqrt{\alpha}} * \frac{1}{T} \;----------------------------------\rightarrow 4$$

(1) For a given system phase lead φ_m find the α using equation (3)

(2) Assuming R_1, find R_2 from equation (1)

(3) For a given ω_m or time constant T, find C using equation (4) and or (2)

(4) Find the corner frequencies $\omega_1 = \dfrac{1}{T}$, $f_1 = \dfrac{\omega_1}{2\pi}$ Hz .

$\omega 2 = \dfrac{1}{\alpha T}, f_2 = \dfrac{\omega_2}{2\pi}$ and also $\omega_m = \dfrac{1}{\sqrt{\alpha}} * \dfrac{1}{T} \quad f_m = \dfrac{\omega_m}{2\pi}$ Hz

Example:

    Design a phase lead compensator which provides a maximum phase angle of 30°at 500Hz.

    Given: $\Phi_m = 30^o$ $\omega_m = 2\pi f$ f=500Hz

    $\omega_m = 2\pi f = 2\pi * 500$=3141.59rad/sec.

    $\omega_m = \dfrac{1}{\sqrt{\alpha T}}$ $\alpha = \dfrac{R_2}{R_1 + R_2}$ $T=R_1C$

    $\alpha = \dfrac{1 - Sin\phi_m}{1 + Sin\phi_m}$

    $\alpha = 0.33$

    $3141.56 = \dfrac{1}{\sqrt{0.33T}}$

    $T = 6.54 * 10^{-4}$ sec

    $T=R_1C$

    Assume C=0.1µf

    R₁=5.54KΩ

    $\alpha = \dfrac{R_2}{R_1 + R_2}$

    R₂=2.72KΩ

Tabular Column:

Sl. No.	Frequency (Hz)	V_i (volts)	V_0 (volts)	Amplified o/p $V_0' = (V_0/\alpha)$ (volts)	Magnitude in dB $=20\log\left(\dfrac{V_0'}{V_i}\right)$	Phase angle (degrees)

Result:

Circuit Diagram:
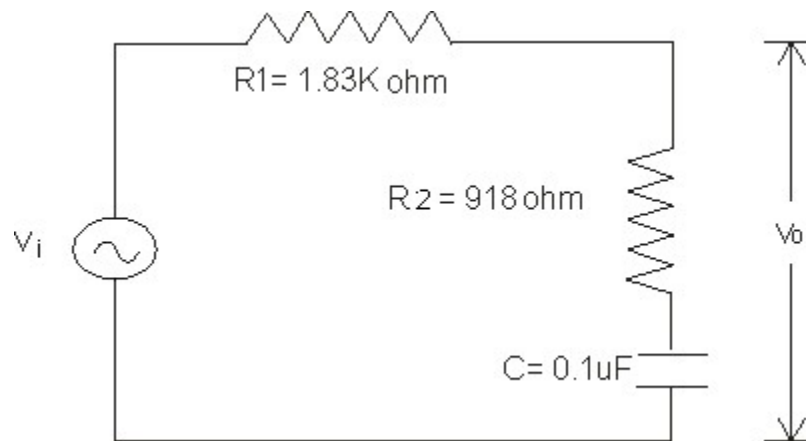
Graph:
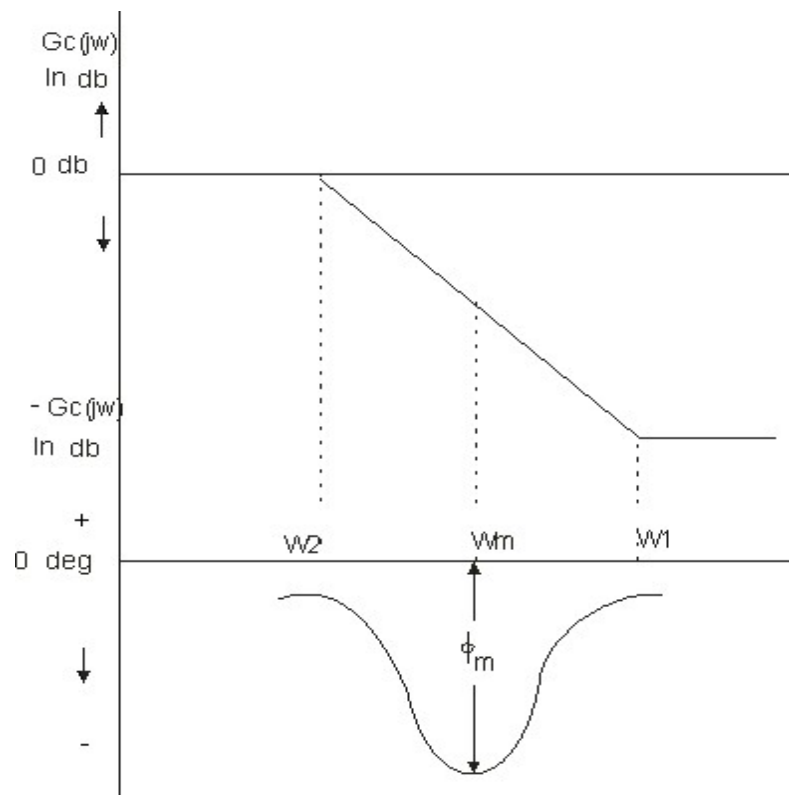
Exp: 5   **Date:_____**

DESIGN, DETERMINATION OF TRANSFER FUNCTION & FREQUENCY RESPONSE FOR LAG NETWORK

Aim: 1) To design a passive RC Lag compensating network for the given specifications,viz, the maximum phase lag and the frequency at which it occurs and to obtain its frequency response.

2)To determine experimentally the transfer function of the lag compensating network.

Apparatus:

Sl.No.	Apparatus	Range	No.s
1.	Resistor	1.83KΩ,918Ω	2
2.	Capacitor	0.1µF	1
3.	Signal generator		1
4.	CRO		1
5.	Probes		3
6.	Wires		few

Procedure:

1) Connection are made as shown in circuit diagram.
2) The output voltage of the sine generator is set to 10V peak.
3) Input frequency is varied in steps (in the range of 1 to 1MHz) and at each step the output voltage and phase angle are noted down using CRO.
4) All the readings are tabulated and the gain characteristic & phase characteristics are plotted on semi log sheet.

Design:

The general transfer function of the lead compensator is

$$G_C(s) = \frac{s + (1/T)}{s + (1/\beta T)}, \beta < 1, T > 0 \,-------------------------- > A$$

Where $\beta = \dfrac{R_1 + R_2}{R_2}$ ---------------------------------- $\rightarrow 1$

Time constant T= R_1 C .... $\rightarrow 2$

The corner frequencies are $\omega_1 = 1/T$ and $\omega_2 = 1/\beta T$

The maximum phase lag

$$C == \sin^{-1}(\frac{[1-\beta]}{[1+\beta]}) \,---------------------------------- > 3$$

and ω_m is the frequency at with ϕ_m occurs.

ω_m is the geometric mean of two frequencies.

$$\omega_m = \sqrt{1/T * 1\beta T} = \frac{1}{\sqrt{\beta}} * \frac{1}{T} \,-------------------------------- \rightarrow 4$$

Example:

    Design a phase Lag compensator which provides a maximum phase angle of 30°at 500Hz.

Given: $\Phi_m = 30^o$ $\omega_m = 2\pi f$ f=50Hz

$\omega_m = 2\pi f = 2\pi * 500$=3141.59rad/sec.

$\omega_m = \dfrac{1}{\sqrt{\beta T}}$ $\beta = \dfrac{R_1 + R_2}{R_2}$ T=$R_1 C$

$Sin\phi_m = \dfrac{\beta - 1}{\beta + 1}$

$0.5 = \dfrac{\beta - 1}{\beta + 1}$

$\beta = 3$

$3141.56 = \dfrac{1}{\sqrt{3T}}$

$T = 1.837 * 10^{-4}$ sec

T=$R_1 C$

Assume C=0.1μf

R₁=1.83KΩ

$\beta = \dfrac{R_1 + R_2}{R_2}$

R₂=918Ω

Tabular Column:

Sl.No	Frequency (Hz)	V_i (Volt)	V_o (Volt)	Magnitude in dB= $20\log \dfrac{V_o}{V_i}$	Phase angle (degree)

Transfer Function:

Result:

Circuit Diagram:

$C_1 = 0.1uF$

$R1 = 1.83K \text{ ohm}$

$R_2 = 918 \text{ ohm}$

V_i

V_o

$C_2 = 0.1uF$

Graph:

S-PLANE

I_m

$-\dfrac{1}{T_1}$ $-\dfrac{1}{\beta T_2}$

$\times$—$\bigcirc$—$\bigcirc$—$\times$ R_E

$-\dfrac{1}{\alpha T_1}$ $-\dfrac{1}{T_2}$

LEAD   LAG

180

-180

PHASE PLOT

$\dfrac{1}{\beta T_2}$ $\dfrac{1}{T_2}$ $\dfrac{1}{T_1}$ $\dfrac{1}{\alpha T_1}$

0 dB

MAGINITUDE PLOT
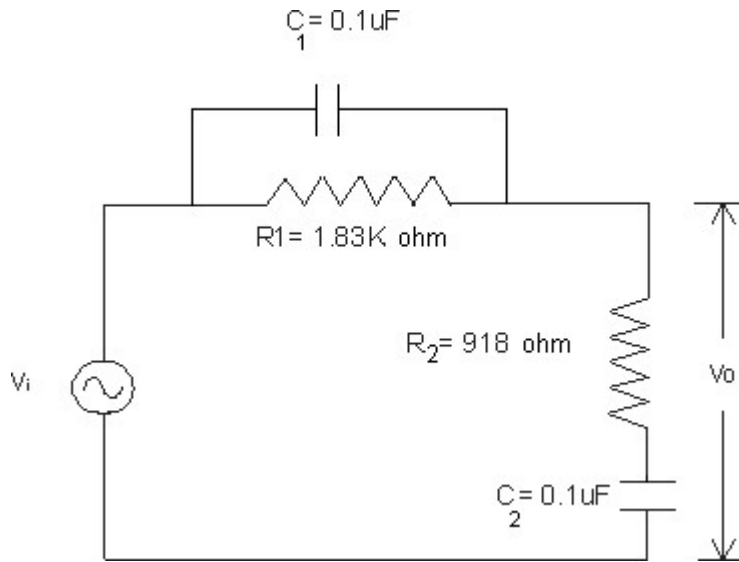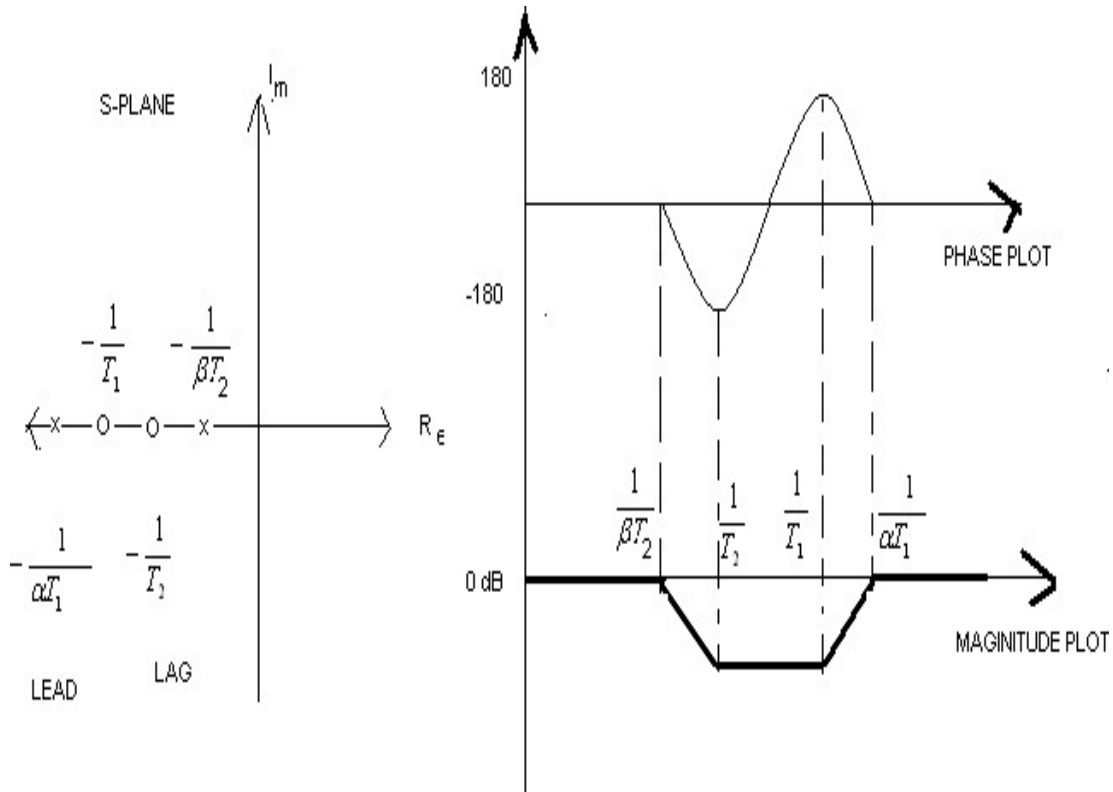
Exp: 6   Date:_____

DESIGN, DETERMINATION OF TRANSFER FUNCTION & FREQUENCY RESPONSE FOR LAG-LEAD NETWORK

Aim: To design a passive Lag-Lead compensating network for the given

Specifications and its frequency response characteristics.

Apparatus:

Sl.No.	Apparatus	Range	Nos.
1.	Resistor	5.5KΩ, 918Ω	2
2.	Capacitor	0.1µF	2
3.	Signal generator		1
4.	CRO		1
5.	Probe		3
6.	Wire		1set

Procedure:

5) Connection are made as shown in circuit diagram.

6) The output voltage of the sine generator is set to 10V peak.

7) Input frequency is varied in steps (in the range of 1 to 1MHz) and at each step the output voltage and phase angle are noted down using CRO.

8) All the readings are tabulated and the gain characteristic & phase characteristics are plotted on semi log sheet.

Design:

The general transfer function of the lag-lead compensator is

$$G_C(s) = \frac{(S + \dfrac{1}{T_1}) * (S + \dfrac{1}{T_2})}{(S + \dfrac{1}{\beta T_1}) * (S + \dfrac{1}{\beta T_2})}, \beta > 1$$

$$\qquad\qquad \text{LAG} \qquad \text{LEAD}$$

The corner frequencies are

$$\omega_1 = \frac{1}{T_1}, \omega_2 = \frac{1}{\beta T_1}, \omega_3 = \frac{1}{T_2} \ \& \ \omega_4 = \frac{\beta}{T_2}$$

Where

$T_1 = R_1 C_1$

$T_2 = R_2 C_2$

$\beta = (R_1 + R_2) / R_2$

The frequency at which the phase angle is zero is $\omega_1 = \dfrac{1}{\sqrt{T_1 T_2}}$

Tabular Column:

Sl.No	Frequency (Hz)	V_i (Volt)	V_o (Volt)	Gain=20log $\dfrac{V_o}{V_i}$	Phase angle (degree)

Result:

Date: _____   **Signature of Faculty**

MATLAB INTRODUCTION:

What Is MATLAB?

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

Typical uses include Maths and computation Algorithm development, Data acquisition Modeling, simulation, prototyping Data analysis, exploration, visualization Scientific and engineering graphics, Application development including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non interactive language such as C or FORTRAN.

The name MATLAB stands for **matrix laboratory**. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects.

Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation. MATLAB has evolved over a period of years with input from many users.

In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering and science. In industry, MATLAB is the tool of choice for high-productivity research, development and analysis.

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB. Toolboxes allow you to learn and apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions **(M-files)** that extend the MATLAB environment to solve particular classes of problems.

Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

The MATLAB system consists of five main parts:

1. **Development Environment:** This is the set of tools and facilities that help you use MATLAB functions and files. Many of these tools are graphical user interfaces. It includes the MATLAB desktop and Command Window, a command history, an editor and debugger, and browsers for viewing help, the workspace, files and the search path.

2. **The MATLAB Mathematical Function Library:** This is a vast collection of computational algorithms ranging from elementary functions, like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigen values, Bessel functions and fast Fourier transforms.

3. **The MATLAB Language:** This is a high-level matrix/array language with control flow statements, functions, data structures, input/output, and object-oriented programming features. It allows both "programming in the small" to rapidly create quick and dirty throw-away programs, and "programming in the large" to create large and complex application programs.
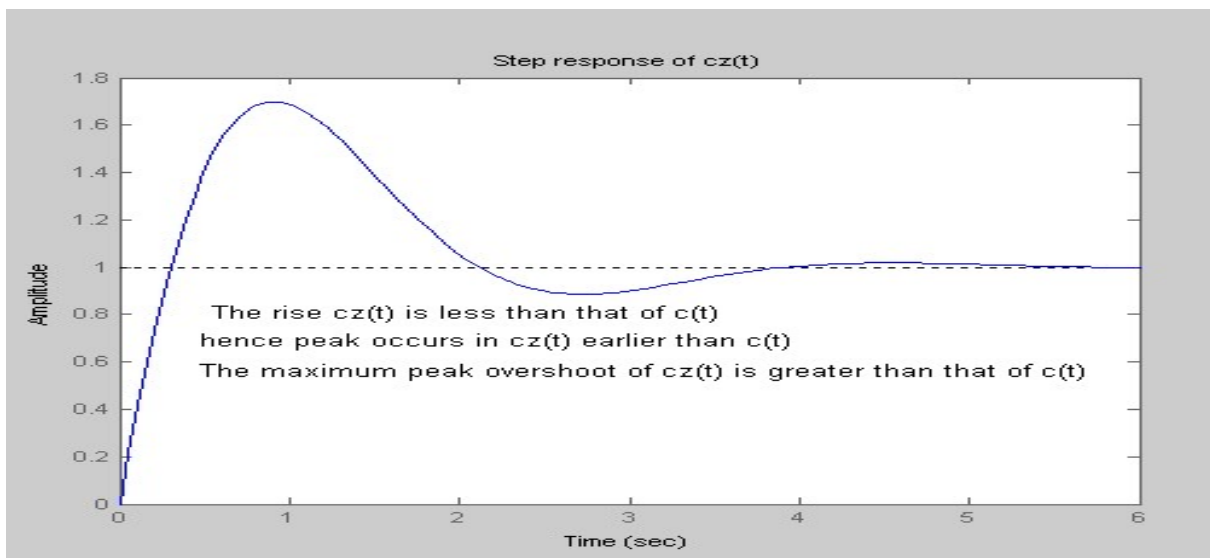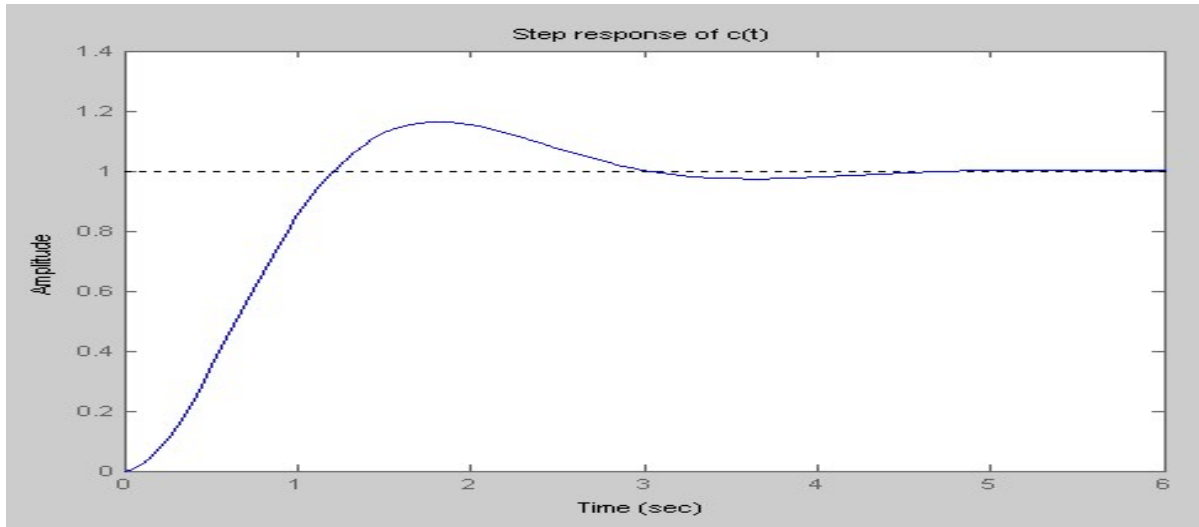
4. **Graphics:** MATLAB has extensive facilities for displaying vectors and matrices as graphs, as well as annotating and printing these graphs. It includes high-level functions for two-dimensional and three-dimensional data visualization, image processing, animation, and presentation graphics.

It also includes low-level functions that allow you to fully customize the appearance of graphics as well as to build complete graphical user interfaces on your MATLAB applications.

5. **The MATLAB Application Program Interface (API):** This is a library that allows you to write C and FORTRAN programs that interact with MATLAB. It includes facilities for calling routines from MATLAB (dynamic linking), calling MATLAB as a computational engine, and for reading and writing MAT-files.

STEPS FOR EXECUTION OF PROGRAM

1.   Double click on MATLAB logo.

2.   MATLAB Command window appears.

3.   Click on file.

4.   Go to new and then to M-File.

5.   MATLAB editor/debugger Window appears.

6.   Type the program for the given transfer function.

7.   Click on file.

8.   Go to save and save the program as *xyz*.m

9.   Come back to command window.

10.   Click on file.

11.   Go to run script and type the saved file name, here in this case it is *xyz*.m

12.   Figure appears for the program stored.

Step response of c(t)

Step response of cz(t)

The rise cz(t) is less than that of c(t)
hence peak occurs in cz(t) earlier than c(t)
The maximum peak overshoot of cz(t) is greater than that of c(t)

Step response of cp(t)

Steady state error =0
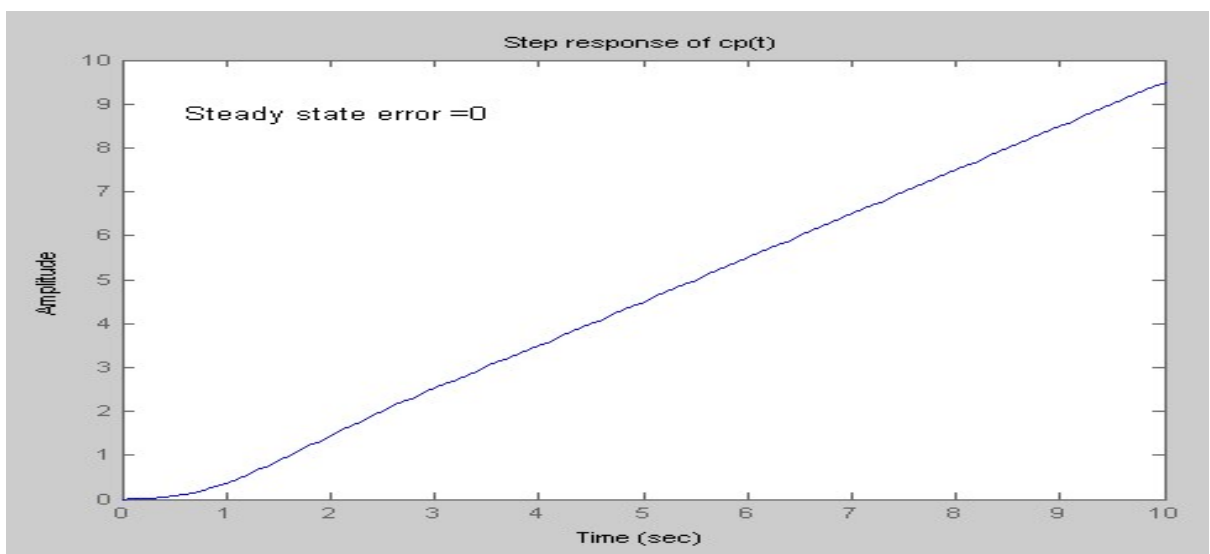
Exp: 7   **Date:** _____

STEP RESPONSE OF SECOND ORDER SYSTEM

Aim: **(a)** To simulate a typical second order system and determine step response and evaluate time response specifications.

(b) To evaluate the effect of additional poles and zeros on time response of second order system.

(c) To evaluate the effect of pole location on stability

(d) To evaluate the effect of loop gain of a negative feedback system on stability

Procedure for aim-(a):

1) Consider a transfer function

$$\frac{C(s)}{R(s)} = \frac{1}{S^2 + 2S + 4}$$

2) Write the program using mat lab to simulate step response of the given system.

3) Evaluate time domain specifications:
   i.   Run the program. Step response appears on the screen.
   ii.   Right click anywhere in the plot region, this opens the following menu
         list in the plot region.
                   Plot type   >
                   System   >
                   Characteristics   >
                   Zoom   >
                   Grid   >
   iii. Click on **Characteristics**, the following submenu will appear in the plot region.
                   Peak response
                   Setting time
                   Rise time
                   Steady state
   iv.   Select the submenu item, the LTI viewer displays the respective marker on the plot, click on the marker and hold the mouse button down to read the values of the plot.
   v.   Left click anywhere on a particular point to see the response values of that plot at that point

Program (a)
```
clc
% prg c(t)
num = 1;
den = [1 2 4];
G = tf(num, den)
kp=dcgain(G)
ess=1/(1+kp)
w = sqrt (den(3))
zeta = den(2) / (2*w)
TD=(1+0.7*zeta)/w
TS = 4/ (zeta*w)
TP = pi/ (w*sqrt(1-zeta^2))
TR=(pi-atan((sqrt(1-zeta^2))/zeta))/(w*sqrt(1-zeta^2))
Percentovershoot= exp(-zeta*pi/ sqrt(1-zeta^2))*100
step(G)
title('Step response of c(t)')
figure
Pzmap(G)
title('pole zero map of c(t)')
figure
```

Program (b-1)
```
%prg cz(t) " adding Zero to the given system"
num1 = conv(num,[1 1]);
G1 = tf(num1, den)
step(G1)
gtext('The rise cz(t) is less than that of c(t)')
gtext('hence peak occurs in cz(t) earlier than c(t)')
gtext('The maximum peak overshoot of cz(t) is greater than that of c(t)')
title('Step response of cz(t)')
figure
Pzmap(G1)
title('pole zero map of cz(t)')
```

Program (b-2)
```
%prg cp(t) " adding Pole to the given system"
den2=conv(den,[1 0]);
G2=tf(num, den2);
kp1=dcgain(G2)
ess1=1/(1+kp1)
step(G2)
title('Step response of cp(t)')
figure
gtext('Steady state error =0')
Pzmap(G2)
title('pole zero map of cp(t)')
```

Procedure for aim-(b):

1. Consider the same transfer function as in the previous procedure.
2. Add zero to the transfer function by changing the numerator using the following command:

    num1 = conv(num,[1 1]);

3. Observe the step response of the new zero added system.
4. Similarly add pole to the transfer function by changing the denominator using the following command:

    den2=conv(den,[1 0]);

5. Now observe the step response of the new pole added system.

Procedure for aim-(c):

1. To evaluate the effect of pole location on stability, consider any system and plot root locus for that system using the below command

    rlocus=(sys);

2. Observe the pole location to determine the stability of the system.
3. Follow the steps done in program (c).

Procedure for aim-(d):

1. To obtain the step response of a second order system having unity feedback (negative) first give a feedback to a certain system using the following command,

    sys2=feedback(sys1,1);

2. Then follow the steps done in program (d).

Program (c):

%Effect of poles location on stability

num=[0 0 1];

den=[3 2 0];

sys=tf(num,den);

rlocus=(sys);

legend(' (i) If all the poles lies to the left of the imaginary line, then the system is stable. (ii) If any of the poles lie on imaginary axis, then it is marginally stable.(iii) If any of the poles lie to the right side of the imaginary axis, then it is unstable system.')

Program (d)

%Step response of the given system

num1=[1];

den1=[1 0.5 0];

sys1=tf(num1,den1);

sys2=feedback(sys1,1);

step(sys2)

title('step response of given system');

xlabel('time in sec');

ylabel('Amplitude');

ltiview('step',sys2)

Note:
Second order system is represented by the transfer function.

$$\frac{C(s)}{R(s)} = \frac{\omega_n^2}{\left(s^2 + 2\xi\omega_n s + \omega_n^2\right)}$$

Where ξ = damping ratio

                ω_n = undamped natural frequency.

Time Domain specification:

Percentage maximum overshoot $\%M_p = 100 \times e^{\frac{\pi\xi}{\sqrt{1-\xi^2}}}$

Peak time $t_p = \dfrac{\pi}{\omega_n \sqrt{1-\xi^2}}$

Rise time $t_r = \dfrac{\pi - \tan^{-1}(\omega_d / \xi\omega_n)}{\omega_d}$

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

ω_n= undamped natural frequency.

ξ=damping ratio.

Delay time $t_d = \dfrac{1+0.7\xi}{\omega_n}$

Settling time $t_s = \dfrac{4}{\xi\omega_n} \; for\,2\%tolerance$

$t_s = \dfrac{3}{\xi\omega_n} \; for\,5\%tolerance$

Exercise: Try the program for different Transfer functions.

1. $$TF = \frac{25}{s^2 + 10\,s + 25}$$

2. TF $= \dfrac{20}{s^2 + 5s + 25}$

Result:

Date:_____   **Signature of Faculty**

%Program to observe the effect P,PD,PI and PID controllers
```
num=[1];
den=[0.5 1 4];
sys1=tf(num,den);
f=feedback(sys1,1);
f1=step(f);
subplot(2,3,1);plot(f1);
title('Step response of given system')
```

% Proportional controller
```
kp=10;
numP=kp*num;
sys=tf(numP,den);
G=feedback(sys,1)
m=step(G);
subplot(2,3,2);plot(m);
title('Proportional contol Kp=10')
k=dcgain(G)
essP=1/(1+k)
```

% PD controler
```
Kd=10;
numc=[Kd*kp kp];
nr=conv(numc,num);
sys1=tf(nr,den);
G1=feedback(sys1,1)
m=step(G1);
subplot(2,3,3);plot(m);
title('PD control Kp=10 and Kd=10')
```

%PI controller
```
ki=10;
numI=[kp ki*kp];
denI=[1 0];
dr=conv(denI,den);
sys2=tf(numI,dr)
G2=feedback(sys2,1);
m=step(G2);
subplot(2,3,4);plot(m);
k=dcgain(G2)
essPI=1/(1+k)
title('PI control Kp=10 and Ki=10')
```

%PID controller
```
nr1=conv(numc,[1 ki]);
sys3=tf(nr1,dr);
G3=feedback(sys3,1);
m=step(G3);
subplot(2,3,5);plot(m);
k=dcgain(G3)
essPID=1/(1+k)
title('PID control Kp=10,Ki=10 & kd=10')
```

Exp: 8   **Date:**_____

P,PI,PD AND PID CONTROLLER

Aim: To obtain step response of the given system and evaluate the effect
       P,PD,PI and PID controllers.

Procedure:

     1) Consider th`e open loop transfer function

$$G(s) = \frac{1}{0.5S^2 + S + 4}$$

     2) Write the program using matlab to simulate step response of the given
        System.

     3) Evaluate the effect of P,PI,PD and PID controllers

Graph:
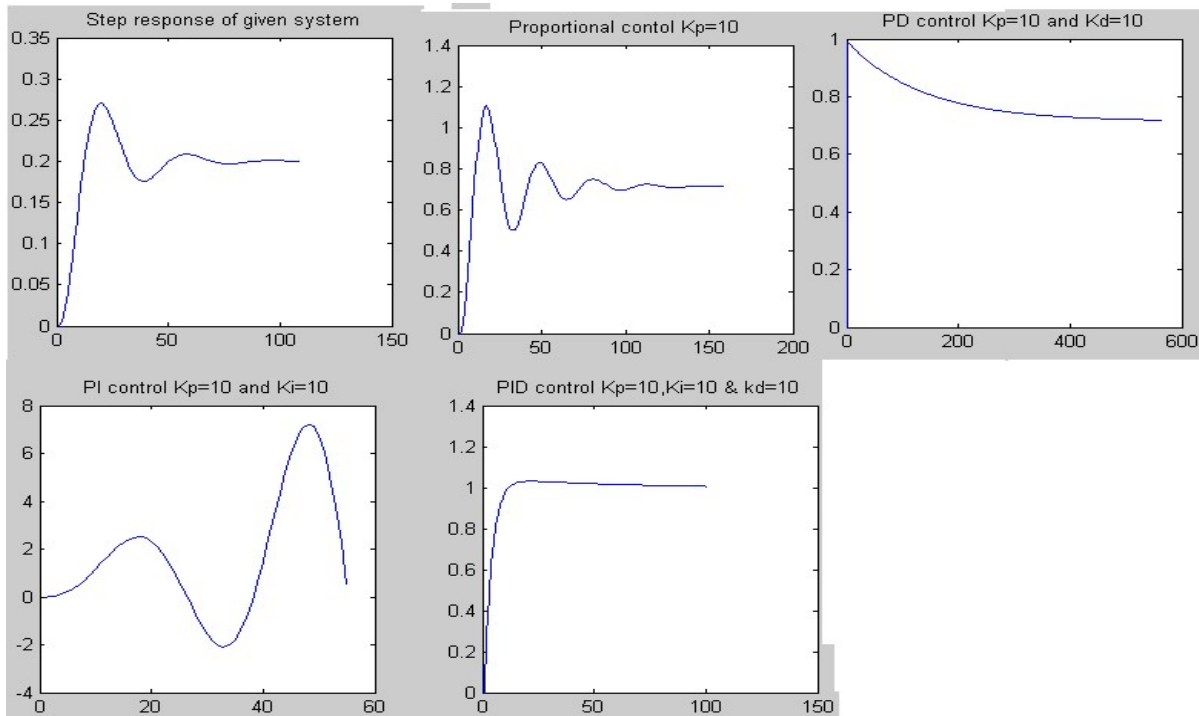
Exercise:

1. TF = $\dfrac{144}{s^2 + 12\,s + 144}$

2. TF $= \dfrac{20}{s^2 + 7s + 25}$

Result:

Date: _____   **Signature of Faculty**

Program:

% DC position step response

w=4; g=0.8;
k1=w^2/8;
K=(2*g*w)/(80*k1);
num1=[0 0 8*k1];
den1=[1 80*K*k1 8*k1];
sys=tf(num1,den1);
step(sys)
title('Dc position step response')
figure

% step response With Feed back

G = tf(num1,den1)
sys = feedback(G,1)
kv=dcgain(G)
ess=1/kv
t = 0:0.1:50;
u = t;
[y,t,x] = step(sys,u,t);
plot(t,y,'-',t,u,'o')
xlabel('Time(secs)')
ylabel('Amplitude')
title('step as input')
legend('Input', 'Output')
figure

Exp: 9   **Date:_____**

DC POSITION CONTROL SYSTEM

a) To obtain the step response of a DC Position control system using MAT LAB.

b) To verify the effect of input wave form, loop gain system type on steady state Errors.

c) To perform trade-off study for lead compensator.

d) To design PI controller and study its effect on steady state error.

Procedure:

1) A DC position control servomechanism comprises of a DC servometer with constant armature current, potentiometer error detector DC amplifier and a tachogenerator coupled to motor shaft. A fraction K of tachogenerator output is feedback to procedure stabilization effect. The following particulars refer to the system.

   Moment of inertia of motor $J_m = 3 \times 10^{-3}$ Kg-m^2

   Moment of inertia of load $J_L = 5$ Kg-m^2

   Motor to load gear ratio, $\theta_L/\theta_m = 1/50 = n$

   Motor torque constant, $K_1 = 2$ Newton–m/amp,

   Tachogenerator constant K= 0.2 volt/rad/sec,

   Sensitivity of error detector, $K_p = 1$ Volt/Rad

   Amplifier gain $= K_1$ amps/volt

   Undamped natural frequency= 4 rad/sec

   Damped ratio =0.8

   Motor and load friction and motor field time constant are assumed to negligible.

Transfer function : $\dfrac{\theta_L}{\theta_m} = \dfrac{8K_1}{(S^2 + 80KK_1 S + {}^*K_1)}$

Graph:
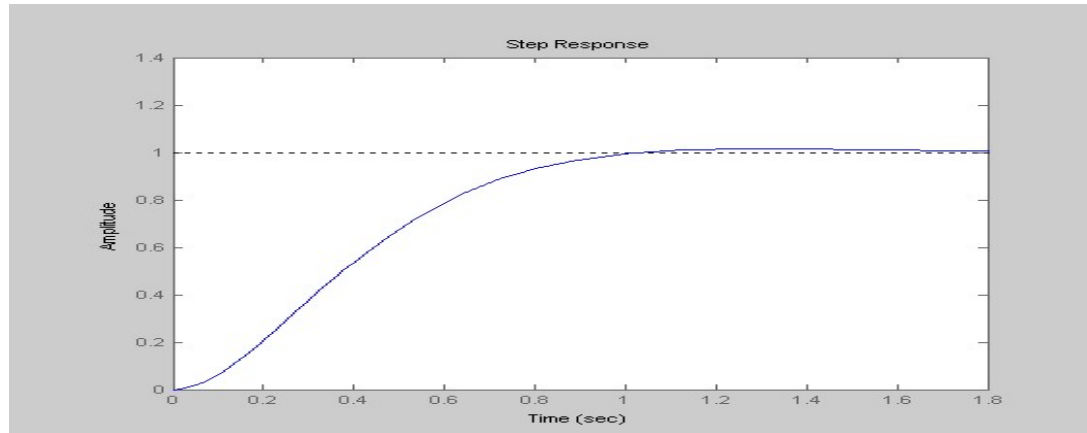
% ramp input

```
d=conv(den1,[1 0 0]);
G = tf(num1,d)
sys = feedback(G,1)
kv=dcgain(G)
ess=1/kv
t = 0:0.1:50;
u = t;
[y,t,x] =step(sys,u,t);
plot(t,y,'y',t,u,'m')
xlabel('Time(secs)')
ylabel('Amplitude')
title('ramp as input')
legend('Input', 'Output')
figure
```

% parabolic input

```
dr=conv(den1,[1 0 0 0 ]);
G = tf(num1,dr)
sys = feedback(G,1)
kv=dcgain(G)
ess=1/kv
t = 0:0.1:50;
u = t;
[y,t,x] = step(sys,u,t);
```

```
plot(t,y,'y',t,u,'m')
xlabel('Time(secs)')
ylabel('Amplitude')
title('parabolic as input')
legend('Input', 'Output')
```
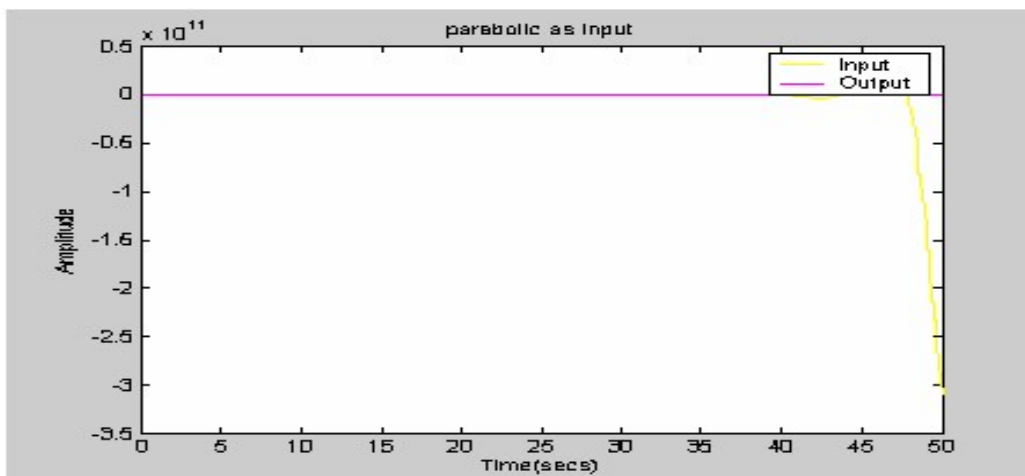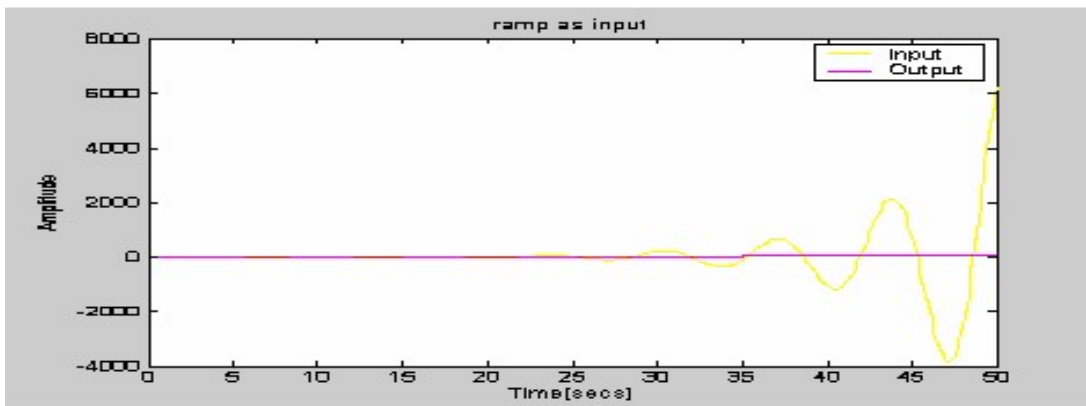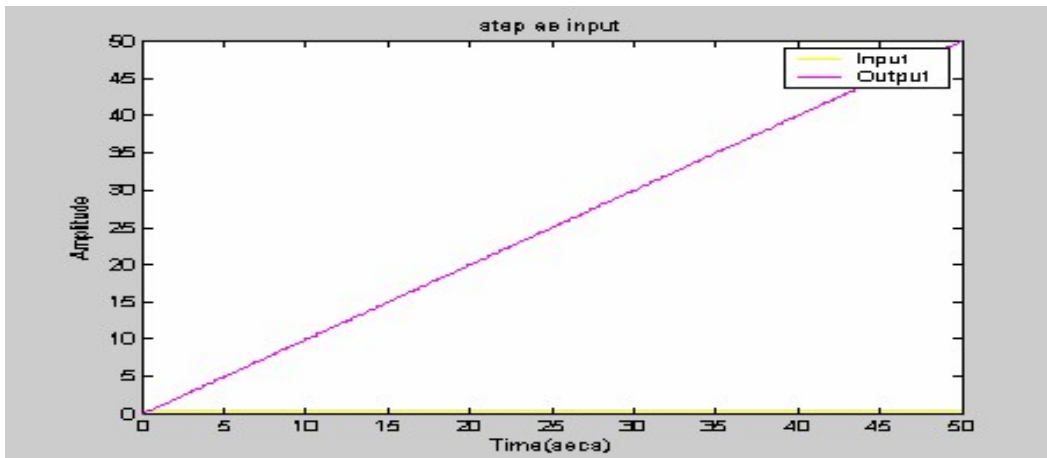
Exercise:

$$1.\ \mathbf{TF} = \frac{144}{s^2 + 12\ s + 144}$$

$$2. \text{TF} = \frac{20}{s^2 + 7s + 25}$$

Result:

Date: _____   **Signature of Faculty**

<u>Program</u>

% to obtain the relation between frequency response and transient response
n=[1];
d=conv([1 0],[0.1 1])
g=tf(n,d);
bode(g)
margin(g)
[gm,pm,wcp,wcg]=margin(g)
GMdb=20*log10(gm)
figure
fplot('1/(2*z*sqrt(1-z^2)),[0.0 0.8,0.01 10])
hold on
fplot('exp(-pi*z/sqrt(1-z^2))',[0.0 0.8,0.01 10])
hold off
xlabel('zeta')
ylabel('resonant peak,max.overshoot')
figure
fplot('1*sqrt((1-2*z^2)+sqrt(4*z^4-4*z^2+2))',[0.0 0.8,0.01 2])
xlabel('zeta')
ylabel('bandwidth')

RELATIONSHIP BETWEEN FREQUENCY RESPONSE AND TRANSIENT RESPONSE

Aim: To obtain the relation between frequency response and transient response

Procedure:

1. Write a Mat Lab program to:
    a) obtain the bode plot for the given transfer function and find the stability
    b) draw graph of peak overshoot and resonant peak Vs damping ratio
    c) draw a graph of bandwidth Vs damping ratio

Graph:
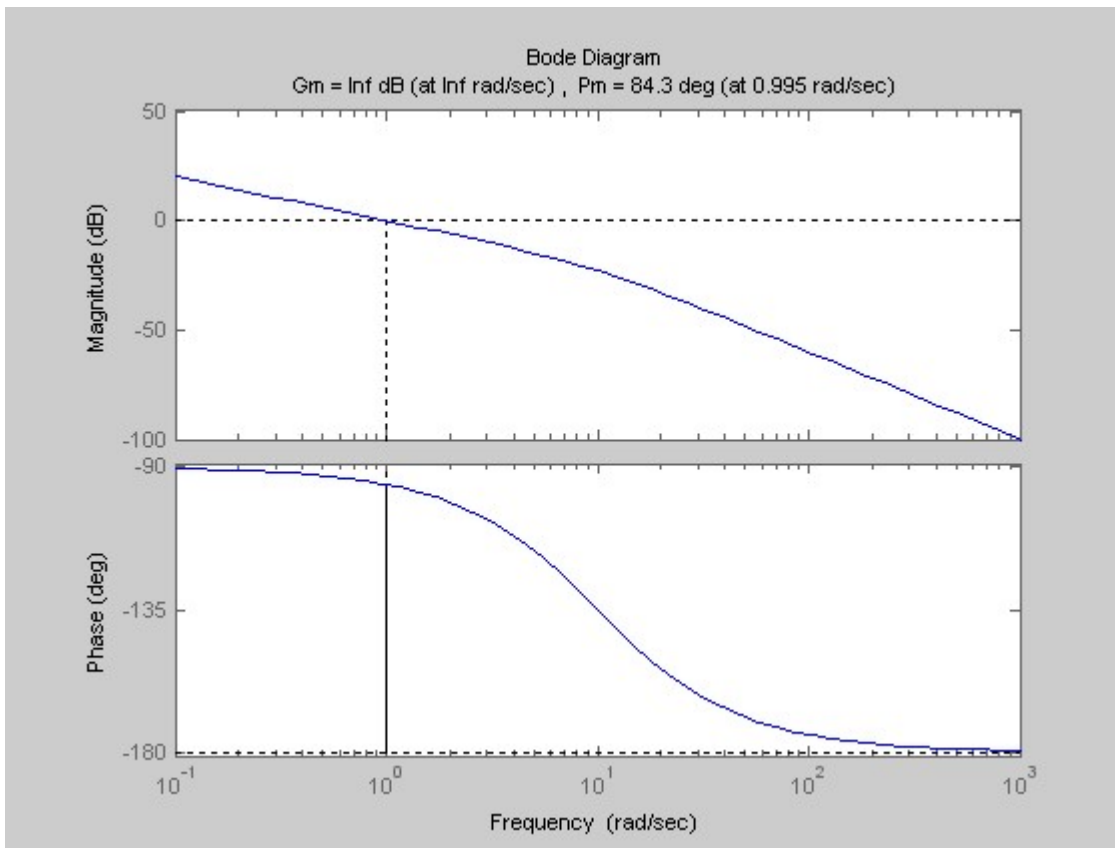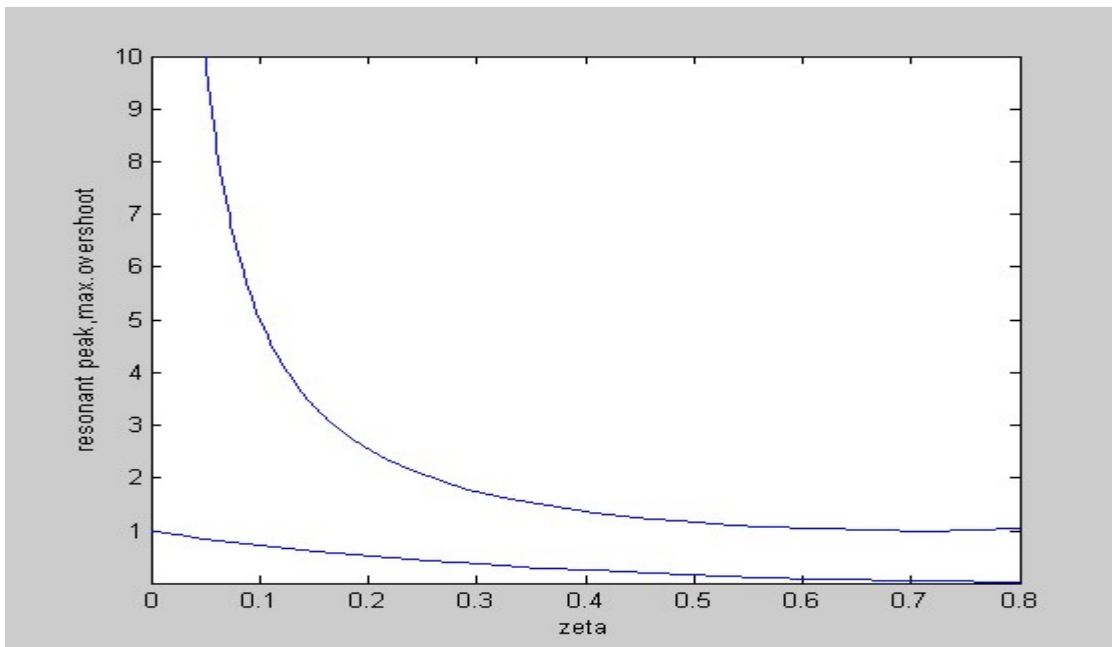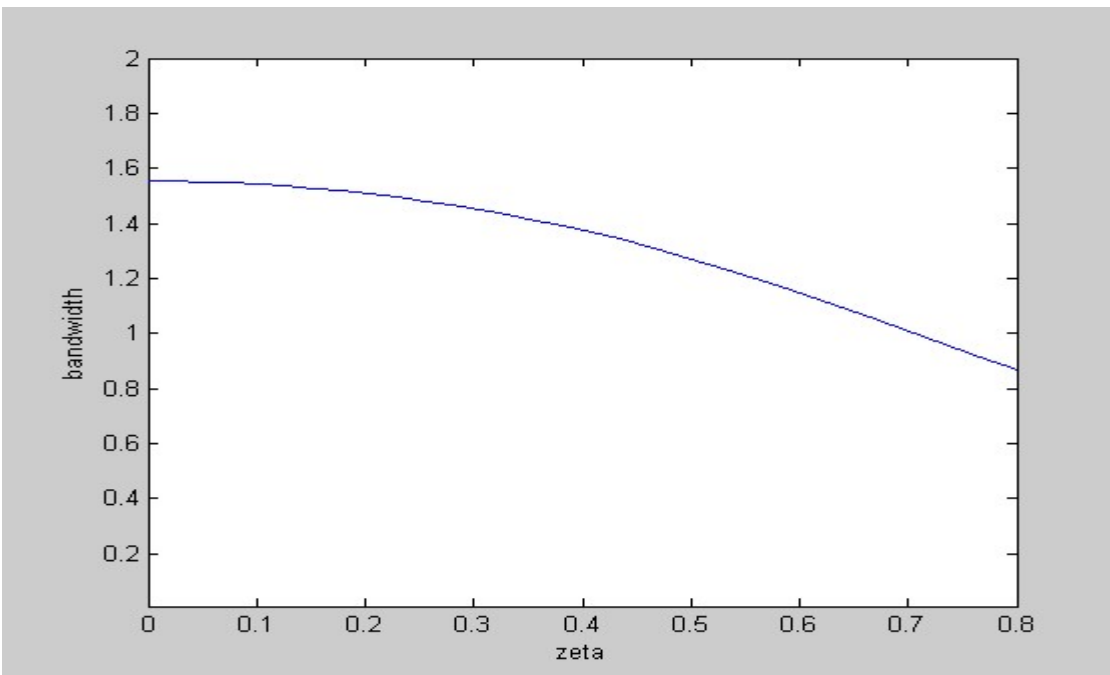
Result:

Date: _____   **Signature of Faculty**

%Program

```
n=[0 0 0 1];
d=[1 5 6 0];
sys=tf(n,d);
rlocus(sys);
sgrid(0.2,0.0);
k=rlocfind(sys)
title('Root locus');
figure


%Effect of adding poles
dr=conv([1 10],d);
sys1=tf(n,dr);
rlocus(sys1);
title(' Effect of adding poles in Root locus');
figure


%Effect of adding zeros
nr=conv([1 1],n);
sys2=tf(nr,d);
rlocus(sys2);
title(' Effect of adding zeros in Root locus');
figure

% effect of k on the transient response
t=0:0.01:20;
n=[0 0 0 k]
d=[1 5 6 0+k];
c=step(n,d,t);
plot(t,c)
title('Effect of k on transient response');
figure
% bode plot for the given system
bode(sys)
margin(sys)
[gm,pm,wcp,wcg]=margin(sys);
gmdb=20*log10(gm)
title(' Bode plot');


% nyquist plot
nyquist(sys)
title(' Nyquist plot');
```

Exp: 11   **Date:**_____

ROOT LOCUS, BODE & NYQUIST PLOT USING MAT LAB

Aim: 1) To sketch the root locus for the given transfer function and hence to
verify, using MAT LAB, Break away point, Intersection with Imaginary
axis, range of K for Stability and to find Closed loop transfer function at
any value of K.

  2) To sketch the nyquist plots for the given transfer function

  3) To sketch the bode plots for the given transfer function and hence to verify,
using MAT LAB,GM, PM, gain cross over frequency ωcg, phase cross over
frequency ωcp and the value of K for a specified GM/PM.

Procedure:

1) Draw root loci for the given transfer function & find the breakaway point and
Imaginary axis Intersection point, range of K for stability.

2) Verify the values using MAT LAB.

Let the open loop transfer function is $G(S) = \dfrac{1}{S^3 + 5S^2 + 6S}$

3) Draw bode plots for the given transfer function & find Gain margin, Phase
margin and their corresponding frequencies. Also find the value of K for
specified Gain margin/Phase margin.

4) Verify the above values using Mat Lab.

5) Draw Nyquist plot for the given transfer function.

Note:

The coefficients of numerator & denominator of G(S) to be typed depends on the
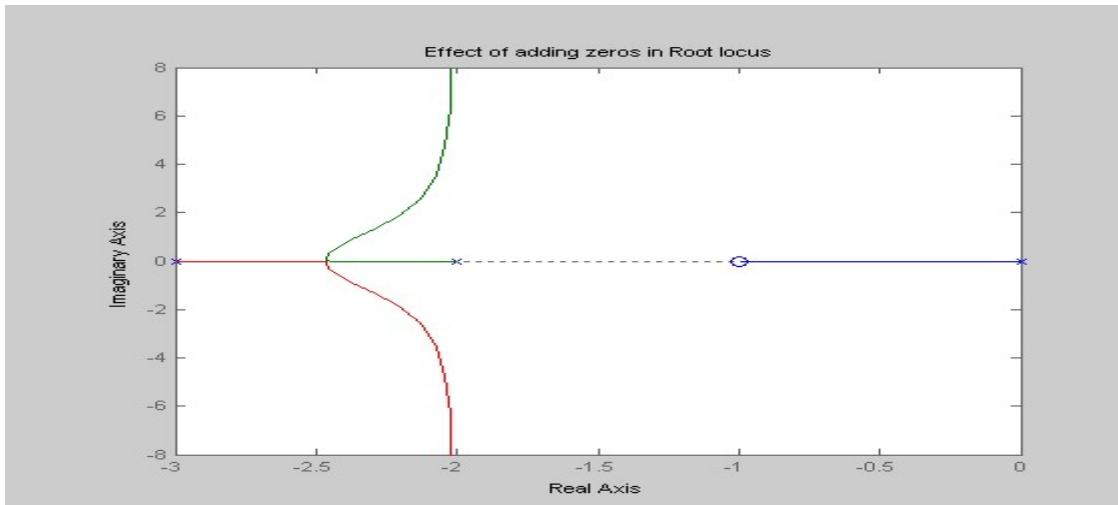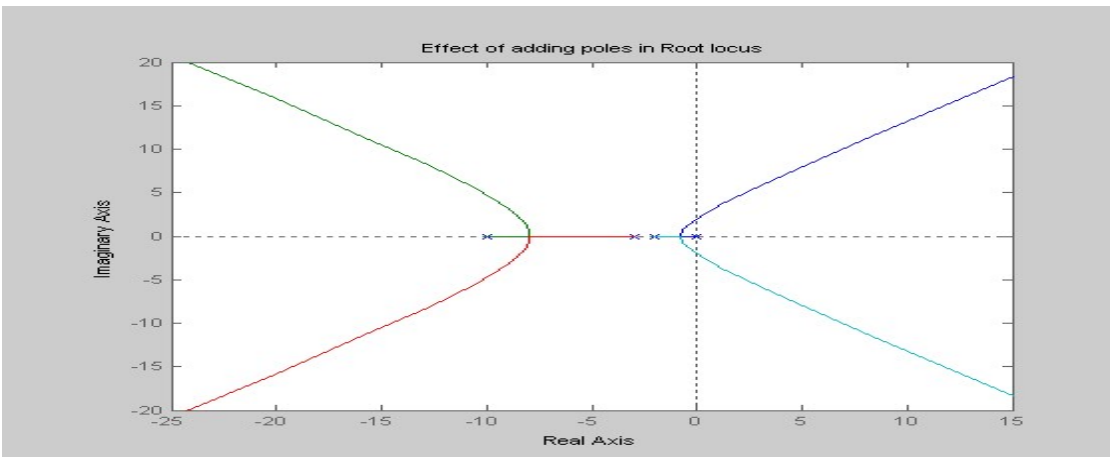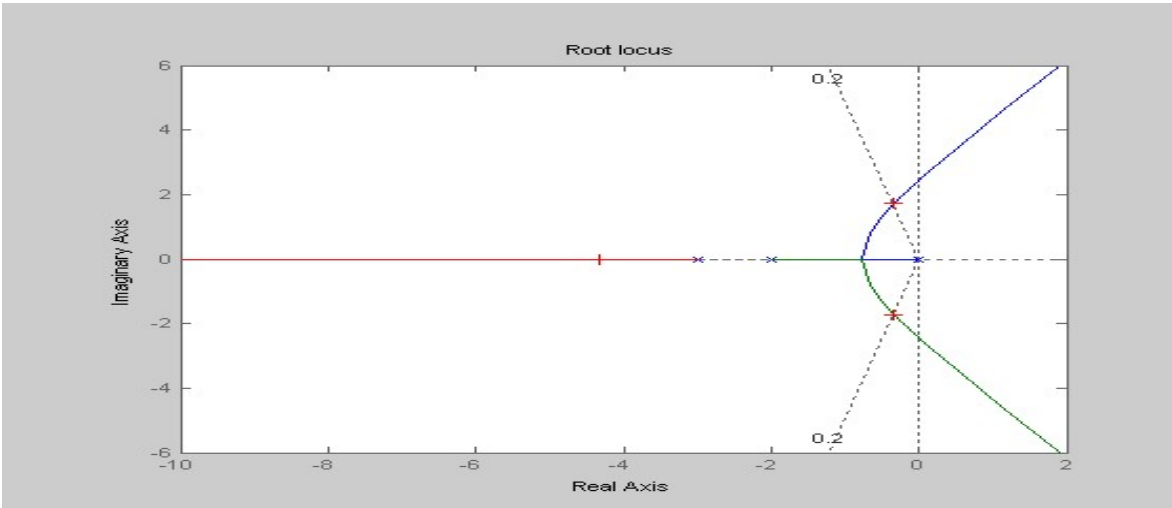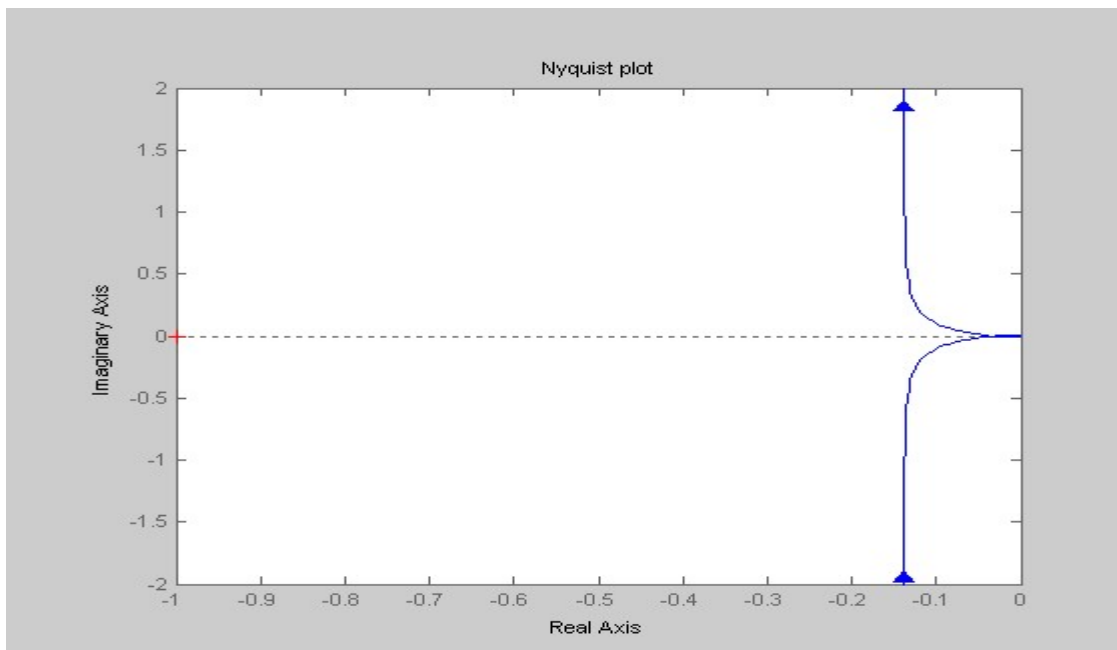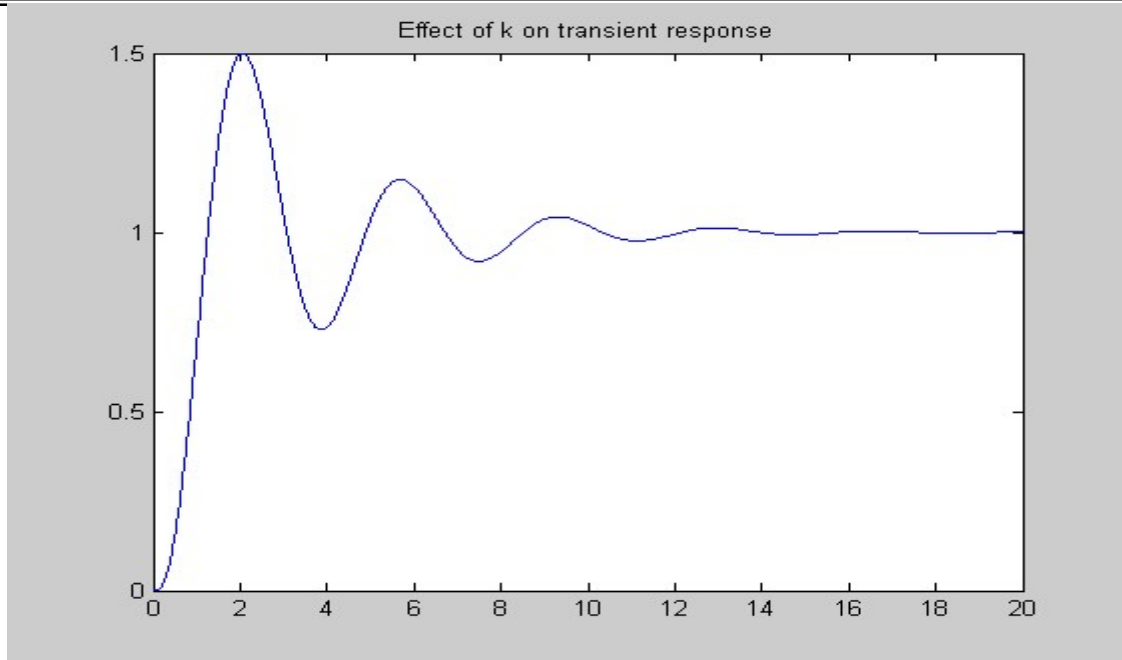given transfer function.

Stability:

If the Gain margin and Phase margin are positive, the given minimum phase
system is stable.

ω_{cg} is gain cross over frequency.

ω_{cp} is phase cross over frequency.

Graph:

Effect of k on transient response

Nyquist plot

Exercise :

Root locus:

1. Num= [1]   & den=[s(s+2)(s+4)]

2. num=[10] & den=[1 9 10 0]

Bode Plots
3. Num: [25]   & den=[1 4 25]

4. Num: [40]   & den=[s^2(s+2)(s+5)]
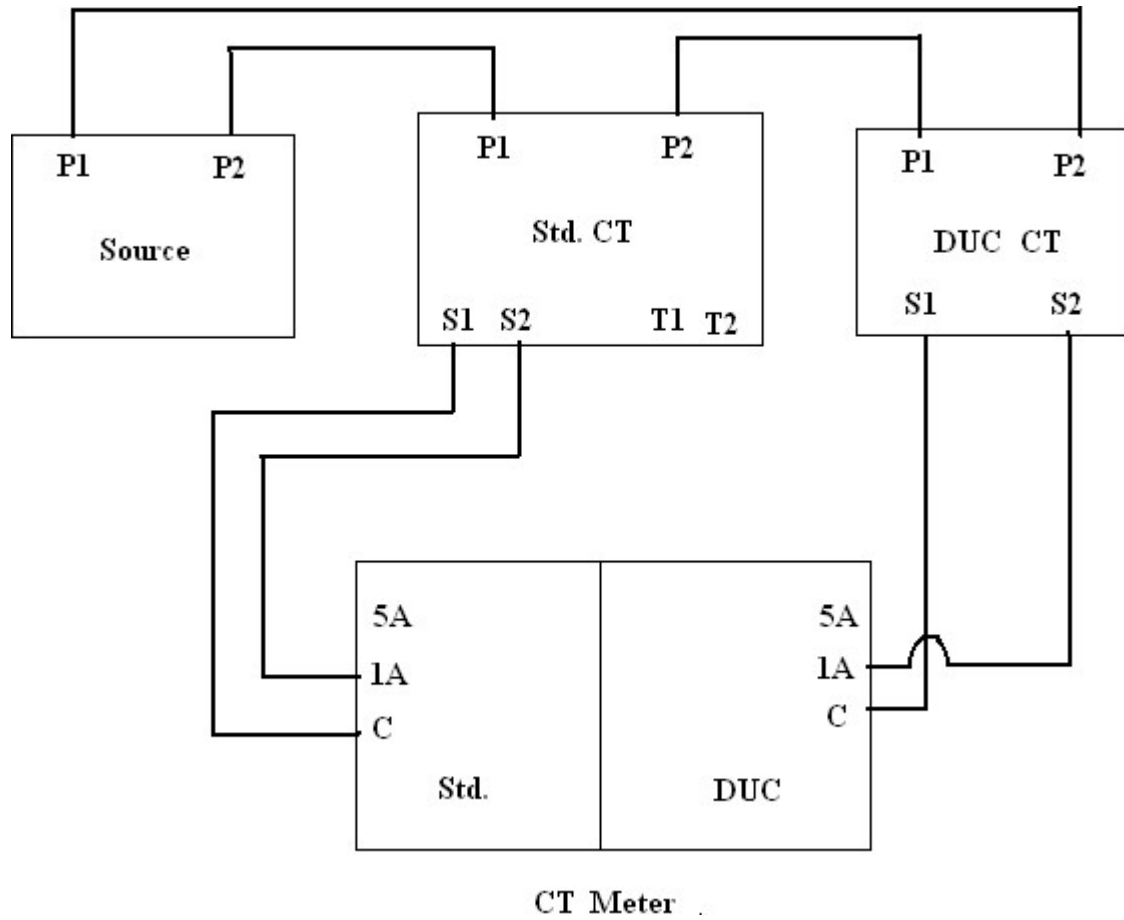
Nquist plots:
5. num=[1 2] & den=[(s-1)(s+1)

6. num=s(s-3) & den=s(s+1)(s-1)

Result:

Date: _____   **Signature of Faculty**

Additional Experiment

Block Diagram

Date:____/____/ _____

Current Transformer

**Aim:** To find ratio and phase angle errors of given Current transformer

Apparatus Required:

Sl. No.	Particulars	Range	Quantity
1.	Current transformers	------	---
2.	Connecting wires	------	---

Procedure:

1. Connections are made as shown in the diagram.

2. Bring variac of CT test kit to zero position.

3. Connect ac power supply 230v.

4. Switch 'ON' MCB in CT test kit.

5. Select the CT secondary circuit (5A or 1A) in CT test meter, according to the DUC (5A or 1A).

6. Apply current 25%, 50%, 75% and 100 %. *(5A=100%)*

7. Tabulate Id, Is, %ratio error and %phase angle error.

8. Repeat above all steps by connecting burden box in series with the secondary of DUC CT and CT test kit.

9. Tabulate Id, Is, %ratio error, %phase angle error.
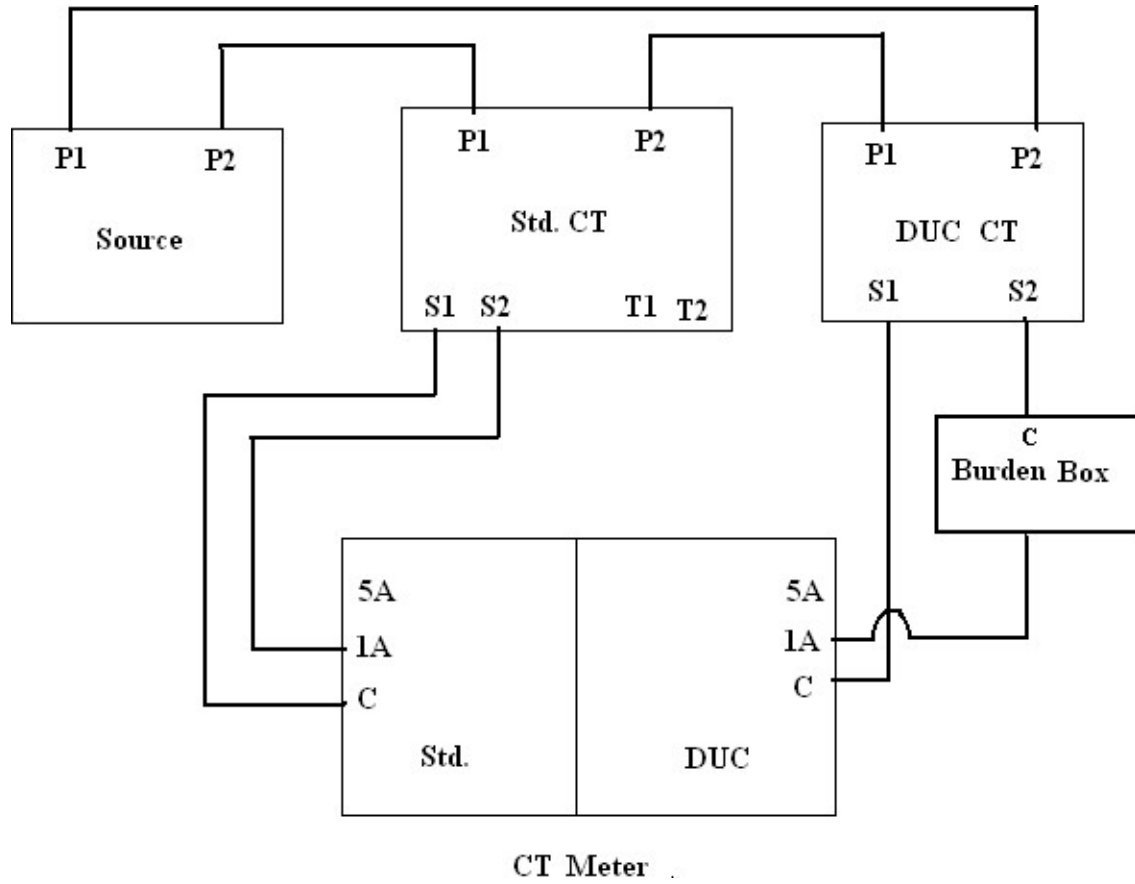
Block Diagram with Burden Box

Tabular Column:

- **Without Burden Box:**

DUC CT	I_d	I_s	% Ratio Error	Phase Angle Error
100%				
75%				
50%				
25%				

- **With Burden Box:**

DUC CT	I_d	I_s	% Ratio Error	Phase Angle Error
100%				
75%				
50%				
25%				

Result:

Date…………….   **Signature of the Faculty**

<u>REFERENCES</u>

1. **J. Nagarath and M.Gopal**, "Control Systems Engineering", New Age International

   (P) Limited, Publishers, Fourth edition – 2005

2. **"Modern Control Engineering ",** K. Ogata, Pearson Education Asia/ PHI, 4th Edition, 2002.

3. **"Control Systems – Principles and Design",** M. Gopal, TMH, 1999

Viva Questions

1. Define control system.
2. Explain the classification of control system.
3. What is the necessity of introducing feedback in to control system.
4. Explain the effects of PI,PD & PID controllers.
5. Define stability & relative stability.
6. Explain different methods of finding stability of control system.
7. Define Gain Margin, Phase Margin, Gain cross over frequency & phase cross over frequency with respect to bode plots.
8. Define Nyquist stability criteria.
9. Define steady state & transient response.
10. What is meant by Damping, overshoot & settling time.
11. Discuss the effect of damping ratio on the stability of control system.
12. What is lag, lead & lag lead compensation.
13. Why compensation is required.
14. What are time domain & frequency domain specification. Define them.
15. Why these specification are required.
16. Define steady state error.
17. Define steady state response.
18. What are static error constants.
19. What is servomotor.
20. What is frequency response.
21. What is the difference between induction motor & servomotor.
22. What is root locus technique.
23. Question on MATLAB
24. Difference between AC servomotor & DC servomotor.
25. Application of AC servomotor.
26. Difference between Stepper motor & DC servomotor.
27. How damping ratio affects the time response of second order system.
28. What is PID controllers.

Model Questions

1. Simulate the second order system given by the transfer function ------------, using MAT Lab and obtain the step response and evaluate the time domain specification. Also evaluate the effect of additional pole and zero on the time response of the system.

2. Simulate the second order system given by the transfer function------------, using MAT Lab 'FOR' loop and obtain the step responses for damping ratio
   ξ = _____and between t=_____to_____Seconds. Evaluate the effect of pole location on stability.

3. Write a MAT Lab program to plot the step response of unity feedback system whose open loop transfer function $G(s) =$. Also study effect of P,PI,PD and PID controller on the step response of the system.

4. Design a passive RC LAG Compensating network for the given specifications. Obtain the frequency response experimentally and draw bode magnitude and phase angle plots.

5. Design a passive RC LEAD Compensating network for the given specifications. Obtain the frequency response experimentally and draw bode magnitude and phase angle plots.

6. Obtain the frequency response for Lag-Lead compensating network by conducting suitable experiment.

7. Obtain the Torque/speed characteristics of AC servomotor with following control voltage.
   i)   Rated value
   ii)   70% of the rated value
   iii)   50% of the rated value

8. Obtain the Torque/speed characteristics of DC servomotor with following control voltage.
   i)   Rated value
   ii)   60% of the rated value
   iii)   40% of the rated value

9. Conduct an experiment to demonstrate the frequency response of a second order system using simulator Kit and also evaluate Resonant Peak M_r, resonant frequency w_r and band width w_b.

10. Write a MAT Lab program to plot the root locus of the feed back system whose open loop transfer function is (i) $G(s) = \dfrac{K}{S(S+2)(S+3)}$

$$(ii)\ G(s) = \dfrac{K}{S^3 + 2S^2 + 5S + 1}$$

(a) Evaluate the effect of adding open loop pole and zero on the root locus contour.

(b) Find the value of open loop gain K of the closed loop system for a damping ratio $\xi = \underline{\quad\quad}$ and plot the step response of the closed loop system with this value of K.

(c) Determine the maximum value of k from the root locus plot show that this value K_{max} exhibits sustained oscillations for a unit step input.

11. Write a MAT Lab program to plot the root locus of unity feed back system whose open loop transfer function is $(i)G(s) = \dfrac{K}{S(S+2)(S+3)}$

$$(ii)G(s) = \dfrac{K}{S^3 + 2S^2 + 5S + 1}$$

a) Evaluate the effect adding open loop ploe and zero on the root locus contour.

b) Estimate the effect of open loop gain on the transient response of the closed loop system by using root locus.

c) Estimate the stability of given unity feed back system using root locus and bode plot.

12. Conduct an experiment to demonstrate synchro transmitter and receiver.

13. Simulate the step response of DC position control system using MATLAB.

14. Using MAT LAB
(a) Obtain the bode plot for the given transfer function and find its stability.
(b) Draw a graph of Resonant peak and peak overshoot Vs damping ratio.
(c) Draw the graph bandwidth Vs damping ratio.