



*Partnering in Academic Excellence*

## 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

(2025-26 )

### CONTROL SYSTEMS LABORATORY VI Semester E&E Engineering

Name: \_\_\_\_\_

U S N: \_\_\_\_\_

Batch: \_\_\_\_\_ Section: \_\_\_\_\_



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# Department of Electrical & Electronics Engineering

## BEEL606 - CONTROL SYSTEMS LABORATORY

Version 4.0

Feb- 2026

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Assistant Professor & HOD



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NH 206 (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka

## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### INSTITUTION VISION

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

### INSTITUTION MISSION

1. To provide high quality technical and professionally relevant education in a diverse learning environment.
2. To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a global society.
3. To prepare the next generation of skilled professionals to successfully compete in the diverse global market.
4. 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.
5. To offer a wide variety of off-campus education and training programmes to individuals and groups.
6. To stimulate collaborative efforts with industries, universities, government and professional societies.
7. To facilitate public understanding of technical issues and achieve excellence in the 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.



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## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### DEPARTMENT VISION

To establish a centre of excellence in Electrical and Electronics Engineering education and to foster the development of technically proficient professionals in Electrical Science and related fields while instilling a strong sense of ethics to serve the society efficiently.

### DEPARTMENT MISSION

|           |  |
|-----------|--|
| <b>M1</b> | To provide competent human resources, and to ensure that our students receive top-notch education and mentorship, enabling them to excel in electrical and electronics engineering and allied fields.  |
| <b>M2</b> | To provide quality infrastructure, and to create an environment conducive to innovative learning and research, empowering our students to explore the frontiers of Electrical Sciences and related disciplines.  |
| <b>M3</b> | To foster strong collaborations with industry and research institutions, and to facilitate the exchange of knowledge and ideas, allowing our students and faculty to remain at the cutting edge of technological advancements and practical applications in the field..                            |
| <b>M4</b> | To emphasize social responsibility and professional ethics in our curriculum and community engagement, and to prepare our graduates to be conscientious leaders who use their expertise to benefit society, making a positive impact through their work in Electrical Sciences and allied fields.. |



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### 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

# **Caution**

- 1. Do not play with electricity.*
- 2. Carelessness Not Only Destroys The Valuable  
Equipment in the lab but also costs your life.*
- 3. Mere conductivity of the experiment without a clear  
Knowledge of the theory is of no value.*
- 4. before you close a switch, think of the consequences.*
- 5. Do not close the switch until the faculty in charge  
Checks the circuit.*
- 6. What matters is not what you conduct but why you  
Conduct.*

## ***'Instructions to the Candidates'***

1. Students should come with thorough preparation for the experiment  
To be conducted.
2. Students will not be permitted to attend the laboratory unless they  
Bring the practical record fully completed in all respects pertaining to  
The experiment conducted in the previous class.
3. Name plate details including the serial number of the machine used  
For the experiment should be invariably recorded.
4. Experiment should be started only after the staff-in-charge has  
Checked the circuit diagram.
5. All the calculations should be made in the observation book.  
Specimen calculations for one set of readings have to be shown in  
the practical record.
6. Wherever graphs are to be drawn, A-4 size graphs only should be  
Used and the same should be firmly attached to the practical record.
7. Practical record should be neatly maintained.
8. They should obtain the signature of the staff-in-charge in the  
Observation book after completing each experiment.
- 9.** Theory regarding each experiment should be written in the practical  
Record before procedure in your own words.

# **CONTROL SYSTEM LAB**

## **OBJECTIVE:**

- 1.** To determine the time and frequency domain responses of a given second order system using software package or discrete components.
- 2.** To design and analyze Lead, Lag and Lag – Lead compensators for given specifications.
- 3.** To draw the performance characteristics of ac and dc servomotors and synchro-transmitter receiver pair.
- 4.** To 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.
- 5.** To write a script files to plot root locus, bode plot, Nyquist plots to study the stability of the system using a software package.

## **OUTCOME:**

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

- 1.** Use software package or discrete components in assessing the time and frequency domain responses of a given second order system.
- 2.** Design and analyze Lead, Lag and Lag – Lead compensators for given specifications.
- 3.** Determine the performance characteristics of ac and dc servomotors and synchro-transmitter receiver pair used in control systems.
- 4.** 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.
- 5.** Write a script files to plot root locus, bode plot, Nyquist plots to study the stability of the system using a software package.
- 6.** Work with a small team to carryout experiments and prepare reports that present lab work.

# Contents

| Sl.no | Experiment Name  | Page no |
|-------|--|---------|
| 1     | Experiment to draw the speed torque characteristics of (I) AC servo motor (ii) DC servo motor  | 2       |
| 2     | Experiment to draw synchro pair characteristics  | 9       |
| 3     | Experiment to determine frequency response of a second order system  | 14      |
| 4     | (a) To design a passive RC lead compensating network for the given specifications, via, the maximum phase lead and the frequency at which it occurs and to obtain the frequency response.<br>(b) To determine experimentally the transfer function of the lead compensating network.                             | 20      |
| 5     | (a) To design a passive RC lag compensating network for the given specifications, via, the maximum phase lag and the frequency at which it occurs and to obtain the frequency response.<br>(b) To determine experimentally the transfer function of the lag compensating network                                 | 26      |
| 6     | Experiment to draw the frequency response characteristics of the lag – lead compensator network and determination of its transfer function.  | 32      |
|       | Experiments 7 to 11 must be done using MATLAB/SCILAB only.   |         |
| 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.   | 37      |
| 8     | (a) To simulate a typical second order system and determine step response and evaluate time response specifications.<br>(b) To evaluate the effect of additional poles and zeros on time response of second order system.<br>(c) To evaluate the effect of pole location on stability                            | 41      |
| 9     | (a) To simulate a D.C. Position control system and obtain its step response.<br>(b) To verify the effect of input waveform, loop gain and system type on steady state errors.<br>(c) To perform trade-off study for lead compensator.<br>(d) To design PI controller and study its effect on steady state error. | 50      |
| 10    | (a) To examine the relationship between open-loop frequency response and stability, open-loop frequency and closed loop transient response<br>(b) To study the effect of open loop gain on transient response of closed loop system using root locus.  | 56      |
| 11    | (a) To study the effect of open loop poles and zeros on root locus contour<br>(c) Comparative study of Bode, Nyquist and root locus with respect to stability  | 60      |
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|       | Viva questions   | 71      |
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| Expt. No. | Title of the Experiments   | Page No. |
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| 1         | SPEED TORQUE CHARACTERISTICS OF AC & DC SERVOMOTOR                                   | 02       |
| 2         | SYNCHRO PAIR CHARACTERISTICS   | 10       |
| 3         | FREQUENCY RESPONSE CHARACTERISTICS OF SECOND ORDER SYSTEM                            | 14       |
| 4         | DESIGN, DETERMINATION OF TRANSFER FUNCTION & FREQUENCY RESPONSE FOR LEAD NETWORK     | 20       |
| 5         | DESIGN, DETERMINATION OF TRANSFER FUNCTION & FREQUENCY RESPONSE FOR LAG NETWORK      | 24       |
| 6         | DESIGN, DETERMINATION OF TRANSFER FUNCTION & FREQUENCY RESPONSE FOR LAG-LEAD NETWORK | 30       |

### Second Cycle Experiments

| Expt. No. | Title of the Experiments                                       | Page No. |
|-----------|--|----------|
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| 8         | STEP RESPONSE OF SECOND ORDER SYSTEM                           | 46       |
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| 10        | RELATIONSHIP BETWEEN FREQUENCY RESPONSE AND TRANSIENT RESPONSE | 56       |
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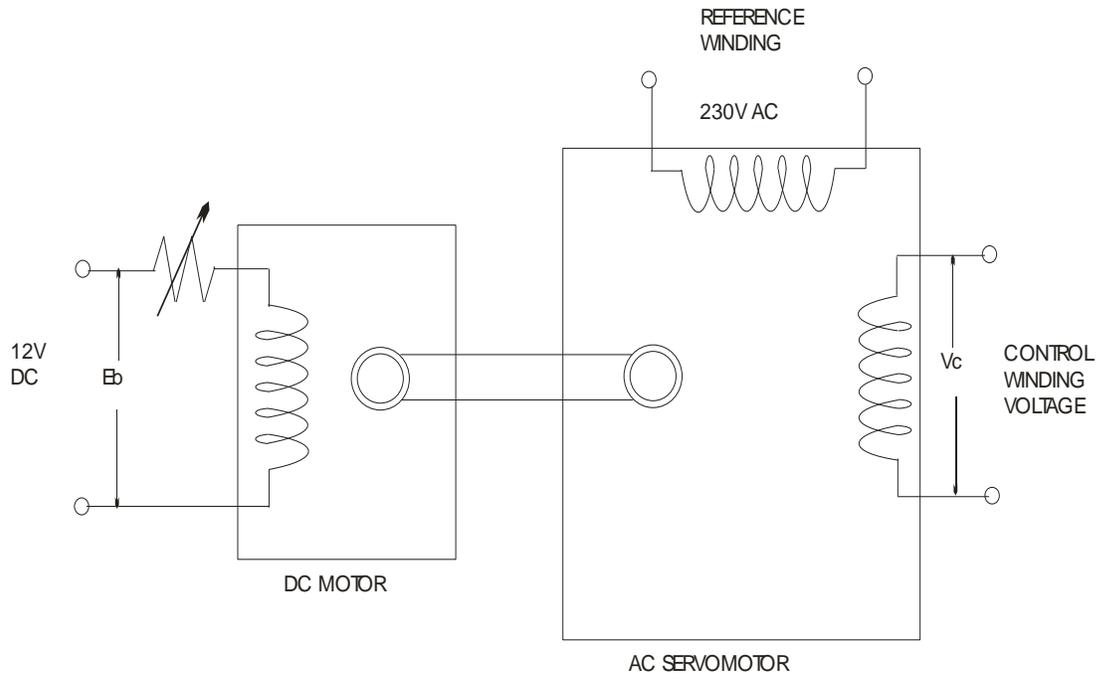
## DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### Course outcomes

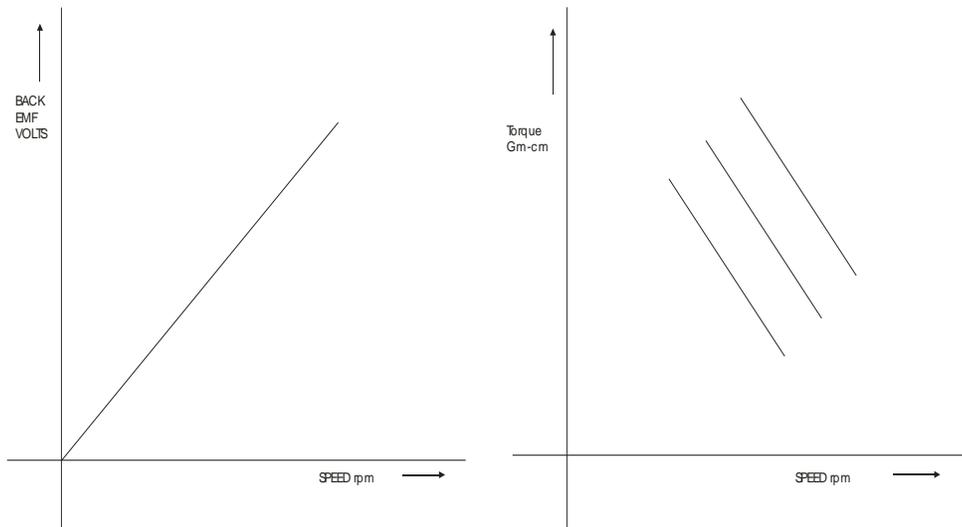
- CO1:To draw the speed torque characteristics of AC and DC servo motor.
- CO2 To determine the time and frequency responses of a given second order system using discrete components.
- CO3 To design and analyze Lead, Lag and Lead – Lag compensators for given specifications.
- CO4 To study the feedback control system and to study the effect of P, PI, PD and PID controller and Lead compensator on the step response of the system.
- CO5 To simulate and write a script files to plot root locus, bode plot, to study the stability of the system

| The cognitive process<br>Dimension the knowledge dimension | Remember | Apply | Understand | Analyze | Evaluate | Create |
|--|----------|-------|------------|---------|----------|--------|
| Factual  |          |       | CO1        |         |          |        |
| Conceptual   |          |       | CO2        | CO5     |          |        |
| Procedural   |          | CO3   |            | CO4     |          |        |
| meta –cognitive  |          |       |            |         |          |        |

**Circuit Diagram:**



**Graph:**



**Experiment: 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<br>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:**

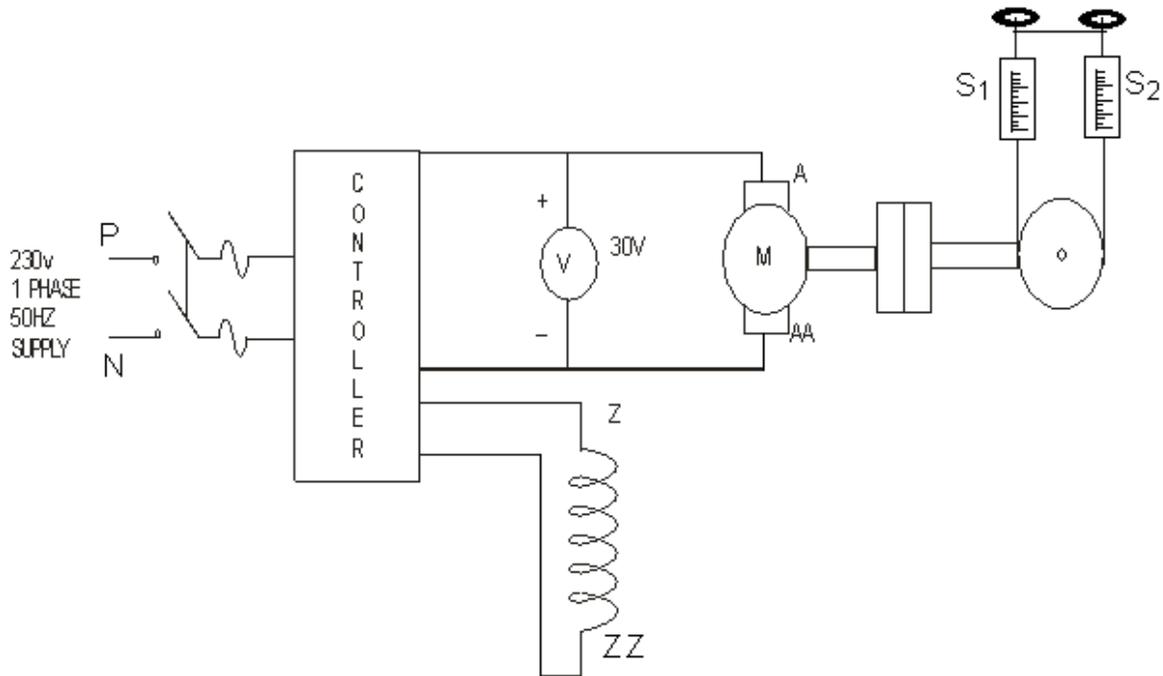
| <b>Sl.No</b> | <b>Speed rpm</b> | <b>Bacf emf Volts</b> |
|--------------|------------------|-----------------------|
|              |                  |                       |

**Torque V/S speed on Load:**

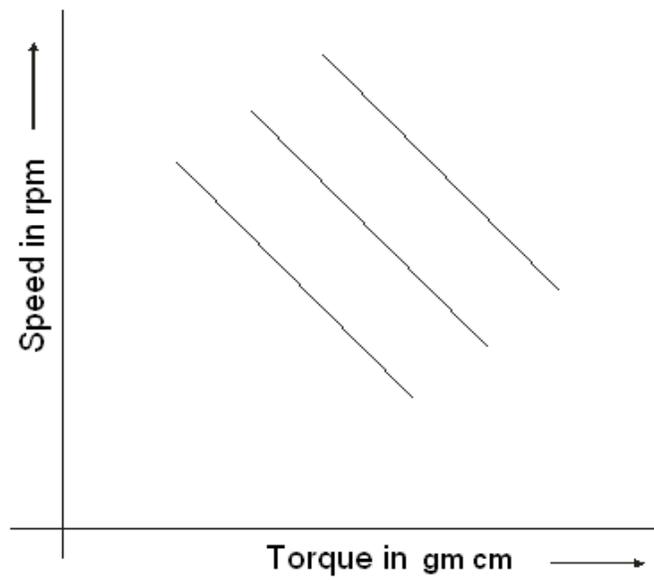
| % of Voltage   | Speed(N)<br>rpm | Back emf (E <sub>b</sub> )<br>Volts | Current (I <sub>a</sub> )<br>Amps | Torque=<br>$\frac{E_b \cdot I_a \cdot 60 \cdot (1.019 \cdot 10^4)}{2 \cdot \pi \cdot N}$<br>gm-cm |
|----------------|-----------------|-------------------------------------|-----------------------------------|---|
| 100%<br>(230V) |                 |                                     |                                   |   |
| 70%            |                 |                                     |                                   |   |
| 50%            |                 |                                     |                                   |   |

**Result:****Date:** \_\_\_\_\_**Signature of Faculty**

**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<br>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**

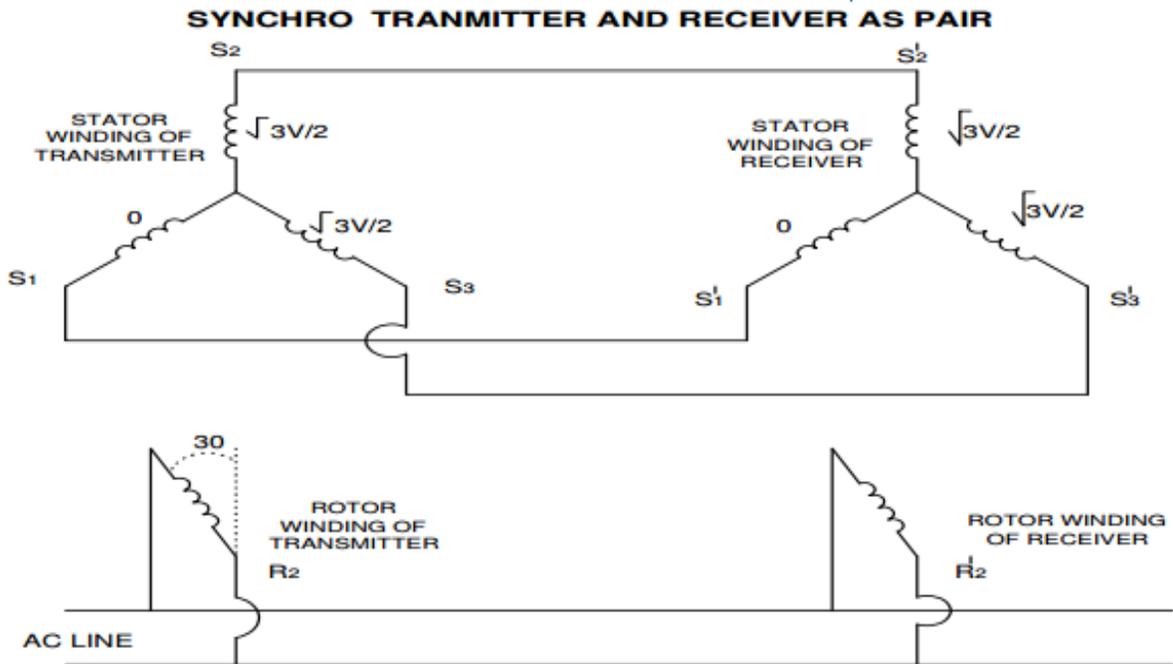
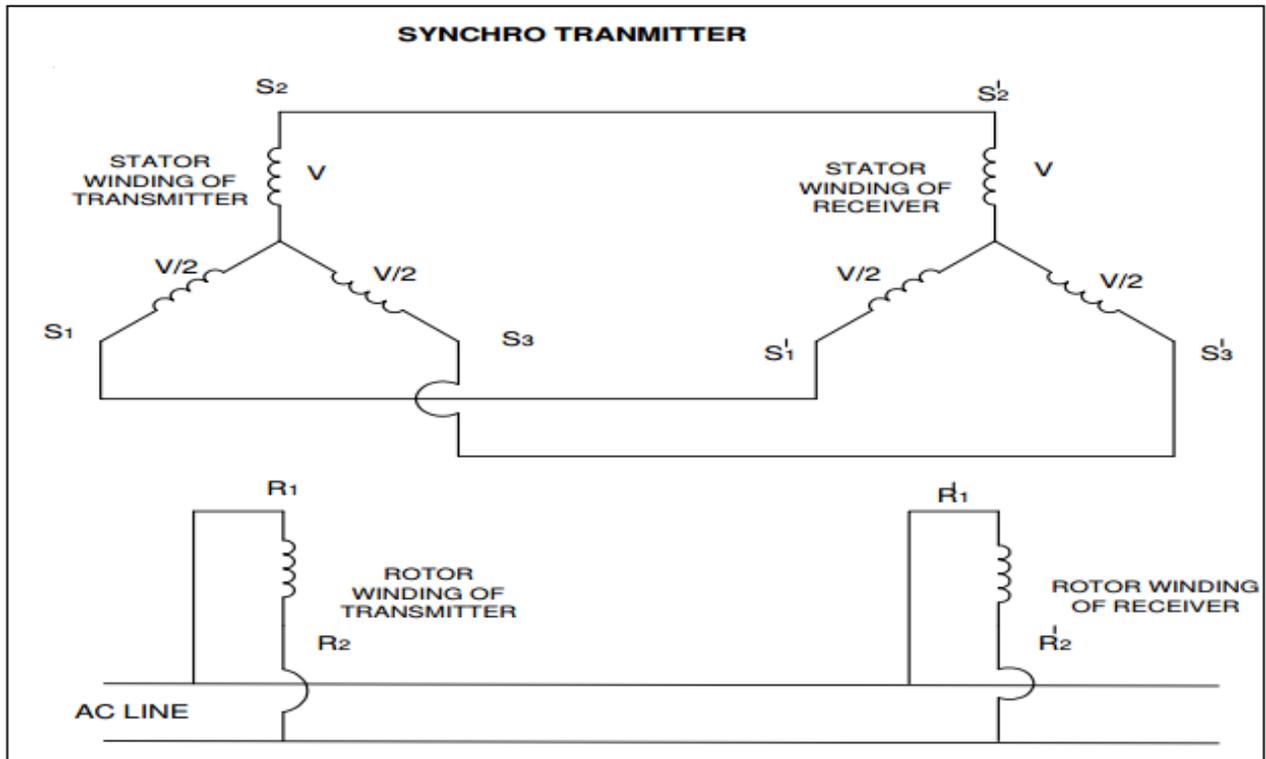
| <b>% of Voltage</b> | <b>Speed (N) rpm</b> | <b>S<sub>1</sub> gms</b> | <b>S<sub>2</sub> gms</b> | <b>(S<sub>1</sub>≈S<sub>2</sub>) gms</b> | <b>T=(S<sub>1</sub>≈S<sub>2</sub>)r gm-cm</b> |
|---------------------|----------------------|--------------------------|--------------------------|--|---|
| <b>100% (24V)</b>   |                      |                          |                          |  |   |
| <b>60% of 24V</b>   |                      |                          |                          |  |   |
| <b>40% of 24V</b>   |                      |                          |                          |  |   |

**Result:**

**Date:** \_\_\_\_\_

**Signature of Faculty**

**Circuit Diagram:**



Experiment: 2

Date: \_\_\_\_\_

### SYNCRO PAIR CHARACTERISTICS

**Aim:** To study synchro transmitter and receiver.

**Apparatus:**

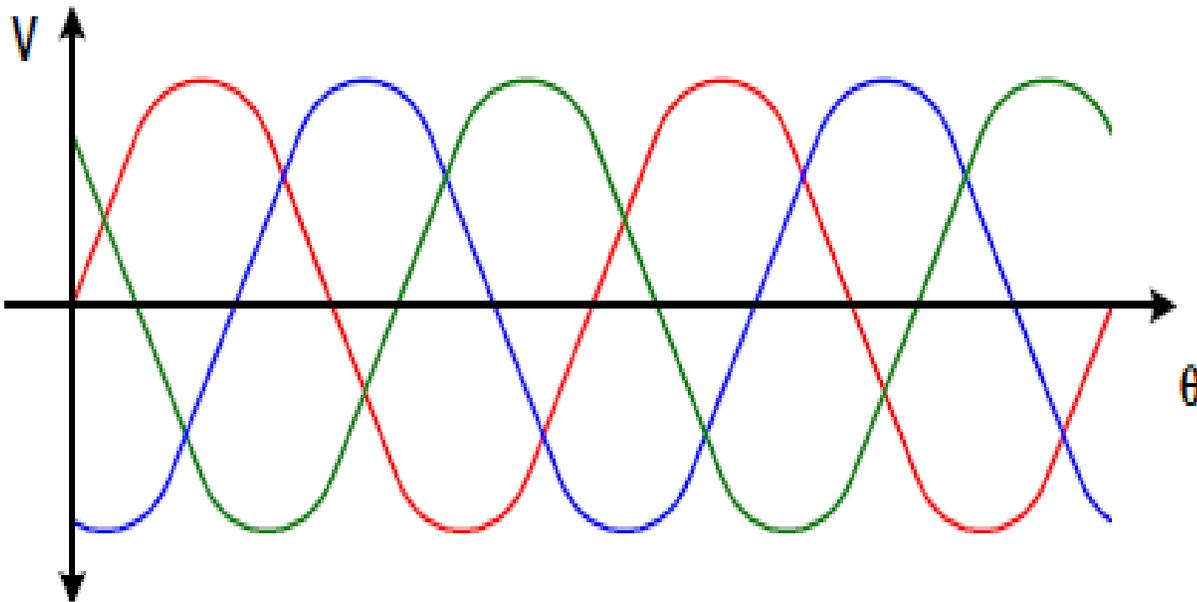
| Sl.No. | Apparatus                             | Nos. |
|--------|---------------------------------------|------|
| 1.     | Synchro transmitter and receiver unit | 1    |
| 2.     | Patch cards                           | few  |

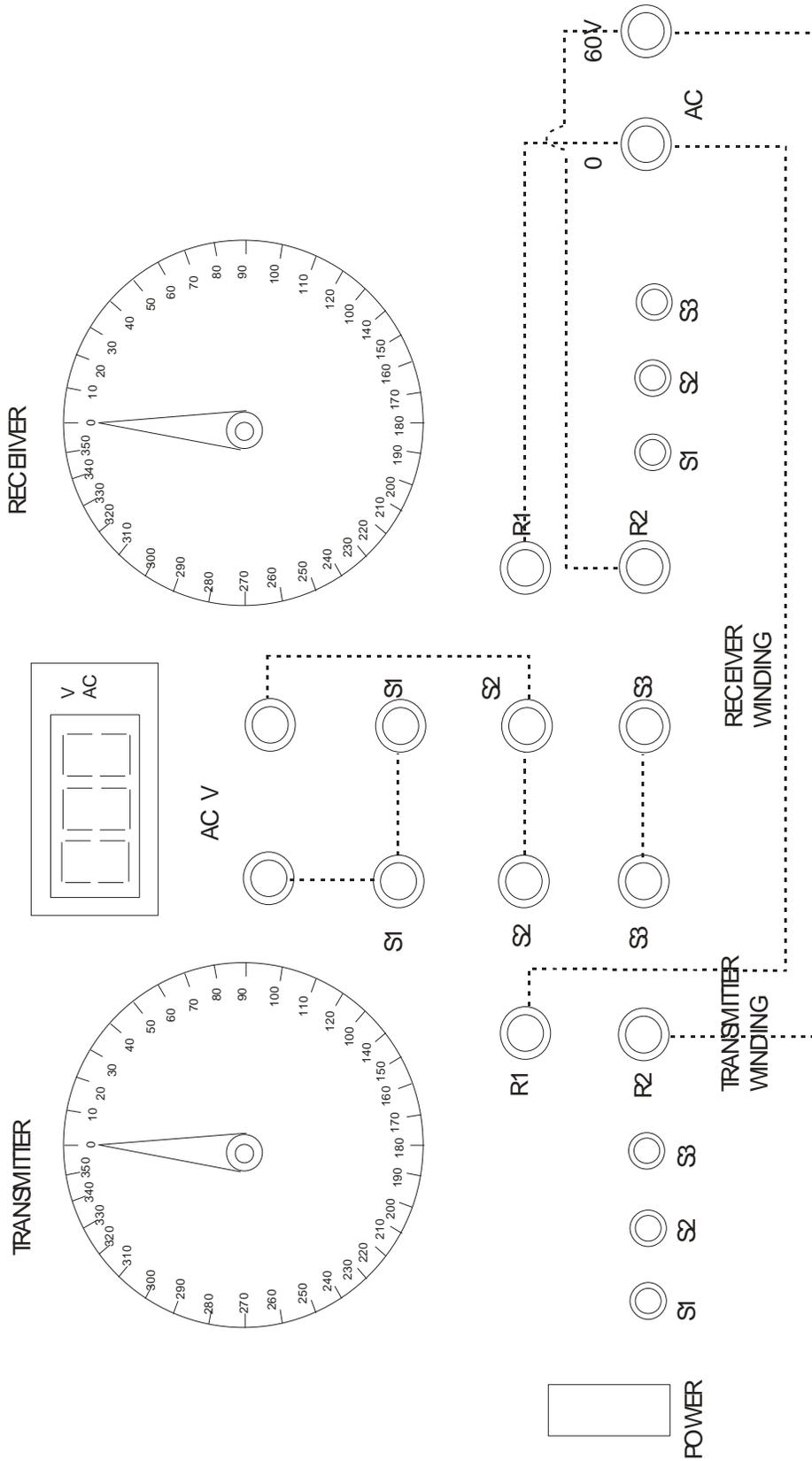
**Procedure:**

**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:**





**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°           |                          |            |            |

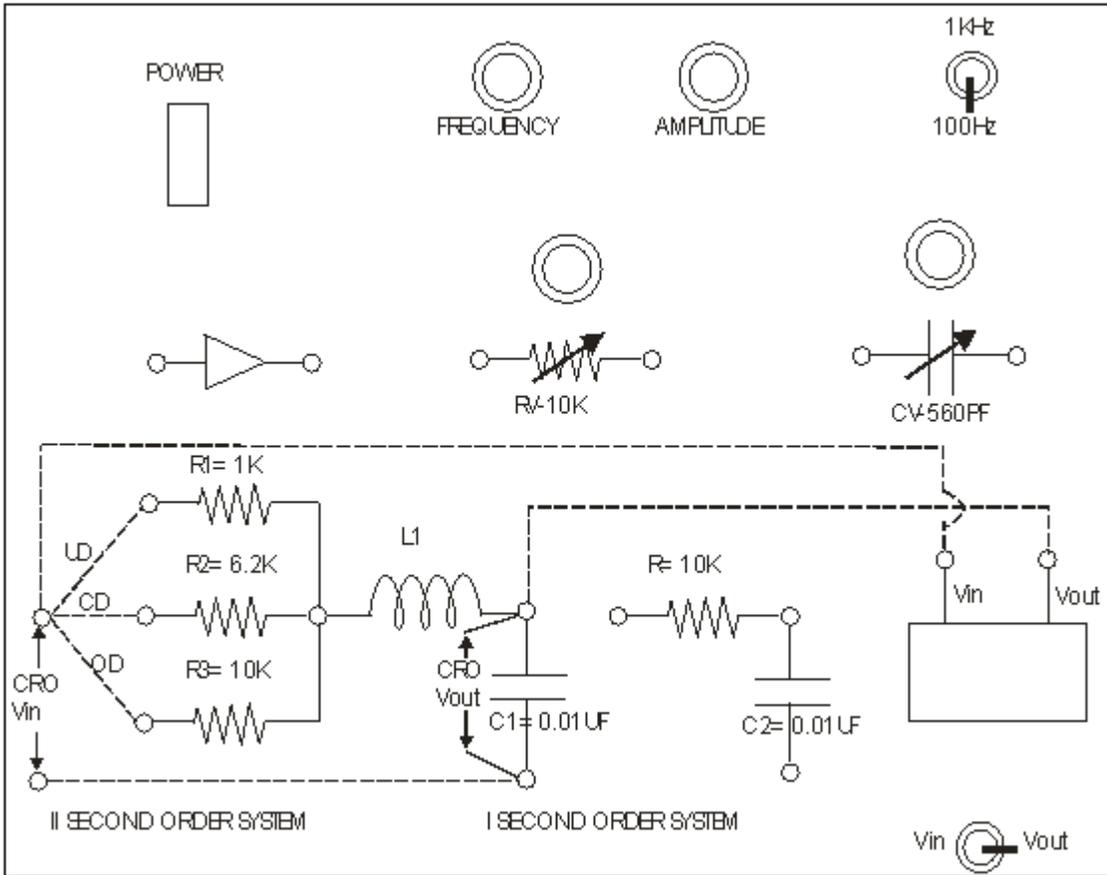
**Result:**

**Date:** \_\_\_\_\_

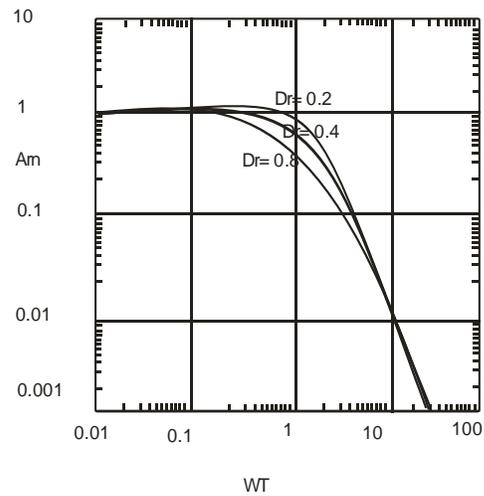
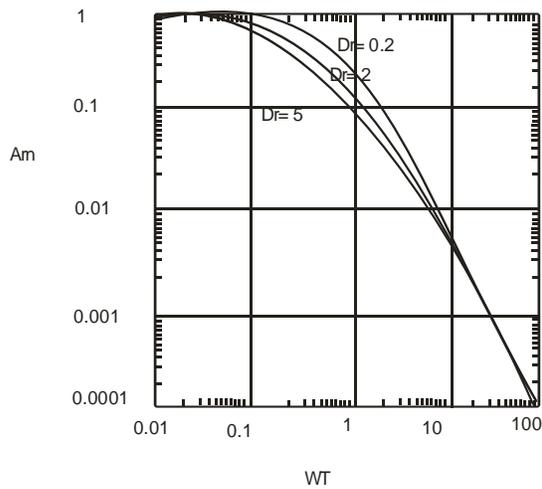
**Signature of Faculty**



**Circuit Diagram:**



**Graph:**



**Experiment: 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:**

$$R_1 = 1K\Omega$$

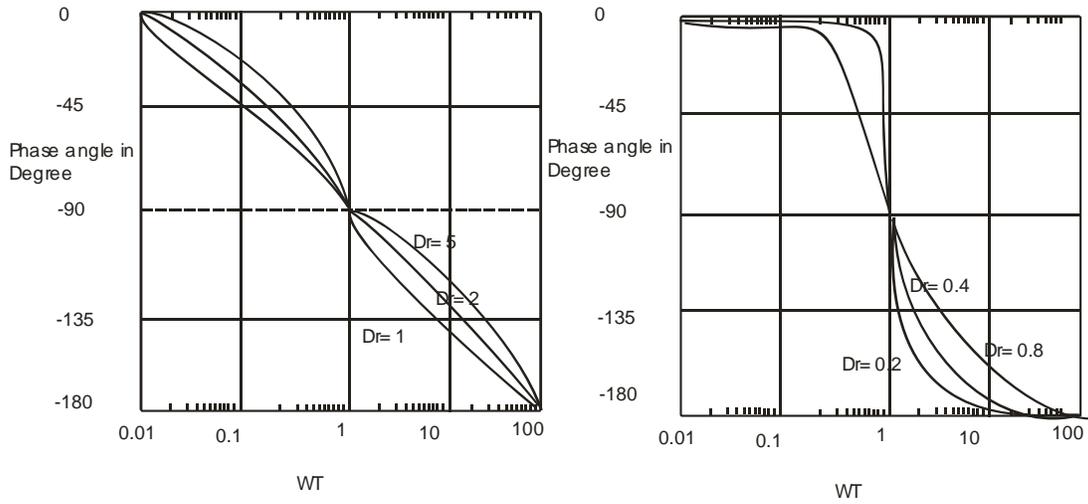
$$R_2 = 6.23K\Omega$$

$$R_3 = 10K\Omega$$

$$L = 100mH$$

$$C = 0.01\mu F$$

$$\tau = \sqrt{LC}$$



**Tabular Column:**

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

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

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

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

At  $\omega=0$ ,  $\Phi=0$

At  $\omega=\infty$ ,  $\Phi=-180^\circ$

**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.
- $R_1$  : 1K $\Omega$
- $R_2$  : 6.23K $\Omega$
- $R_3$  : 10K $\Omega$
- L : 100mH
- C : 0.01 $\mu$ F

| Frequency<br>Hz | $\omega = 2\pi f$ | $\omega\tau$<br>radians | $\delta=1$ (Critically damped) |       |                              |                       |
|-----------------|-------------------|-------------------------|--------------------------------|-------|------------------------------|-----------------------|
|                 |                   |                         | $V_i$                          | $V_o$ | Gain=<br>$20 \log(V_o/ V_i)$ | Phase angle<br>$\Phi$ |
| 100             |                   |                         |                                |       |                              |                       |
| 200             |                   |                         |                                |       |                              |                       |
| 400             |                   |                         |                                |       |                              |                       |
| 600             |                   |                         |                                |       |                              |                       |
| 800             |                   |                         |                                |       |                              |                       |
| 1K              |                   |                         |                                |       |                              |                       |
| 2K              |                   |                         |                                |       |                              |                       |
| 4K              |                   |                         |                                |       |                              |                       |
| 4.5K            |                   |                         |                                |       |                              |                       |
| 5K              |                   |                         |                                |       |                              |                       |
| 6K              |                   |                         |                                |       |                              |                       |
| 8K              |                   |                         |                                |       |                              |                       |

**Tabular  
Column:**

| Frequency<br>Hz | $\omega = 2\pi f$ | $\omega\tau$<br>radians | $\delta=1.58$ (over damped) |       |                              |                       |
|-----------------|-------------------|-------------------------|-----------------------------|-------|------------------------------|-----------------------|
|                 |                   |                         | $V_i$                       | $V_o$ | Gain=<br>$20 \log(V_o/ V_i)$ | Phase angle<br>$\Phi$ |
| 100             |                   |                         |                             |       |                              |                       |
| 200             |                   |                         |                             |       |                              |                       |
| 400             |                   |                         |                             |       |                              |                       |
| 600             |                   |                         |                             |       |                              |                       |
| 800             |                   |                         |                             |       |                              |                       |
| 1K              |                   |                         |                             |       |                              |                       |
| 2K              |                   |                         |                             |       |                              |                       |
| 4K              |                   |                         |                             |       |                              |                       |
| 4.5K            |                   |                         |                             |       |                              |                       |
| 5K              |                   |                         |                             |       |                              |                       |
| 6K              |                   |                         |                             |       |                              |                       |
| 8K              |                   |                         |                             |       |                              |                       |

$$\text{Resonant Peak } M_r = \frac{1}{2\xi\sqrt{1-\xi^2}}$$

$$\text{Resonant Frequency } \omega_r = \omega_n\sqrt{1-\xi^2}$$

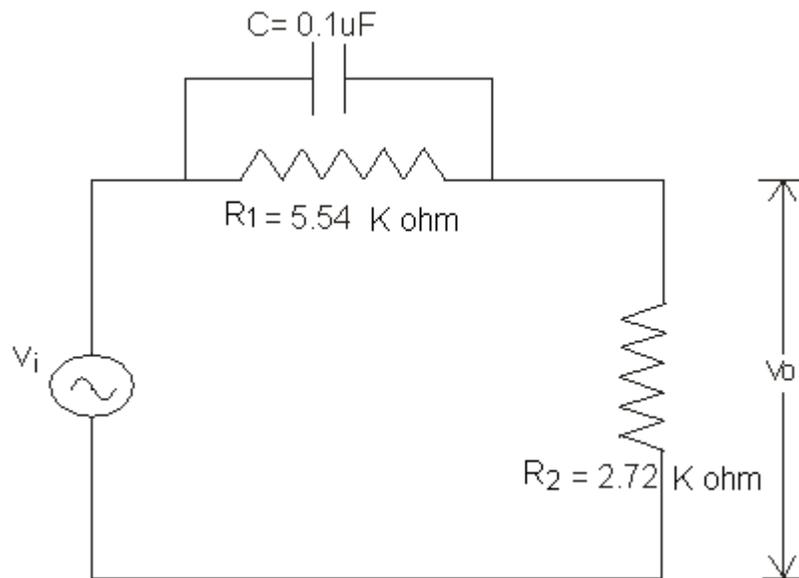
$$\text{Bandwidth } \omega_b = \omega_n\sqrt{(1-\xi^2) + \sqrt{4\xi^4 - 4\xi^2 + 1}}$$

**Result:**

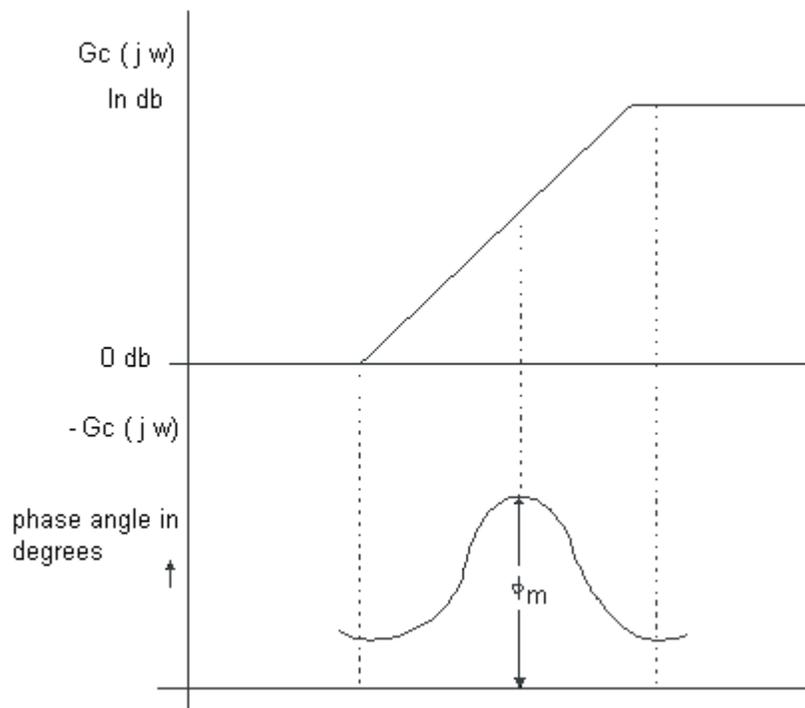
**Date:** \_\_\_\_\_

**Signature of Faculty**

**Circuit Diagram:**



**Graph:**



Experiment: 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.

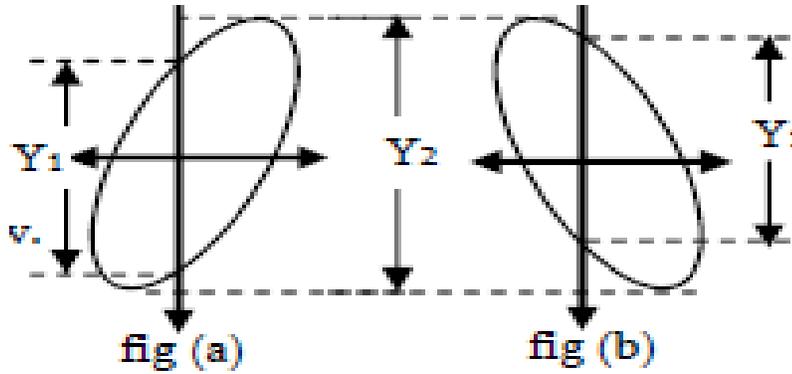
**Apparatus:**

| Sl. No | Apparatus        | Range                               | No s.  |
|--------|------------------|-------------------------------------|--------|
| 1      | Resistor         | 5.54K $\Omega$ , 2.7 or 2K $\Omega$ | 1 each |
| 2      | Capacitor        | 0.1 $\mu$ F                         | 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:-**



**Design:**

The general transfer function of the lead compensator is

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

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

Time constant  $T = R_1 C \text{-----} \rightarrow 1$

The corner frequencies are  $1/T$  and  $1/\alpha T \text{-----} \rightarrow 2$

The maximum phase lead  $\phi_m = \sin^{-1} \left( \frac{[1-\alpha]}{[1+\alpha]} \right) \text{-----} > 3$

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

and  $\omega_m$  is the frequency at which  $\phi_m$  occurs

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

- (1) For a given system phase lead  $\phi_m$  find the  $\alpha$  using equation (3)
- (2) Assuming  $R_1$ , find  $R_2$  from equation (1)
- (3) For a given  $\omega_m$  or time constant  $T$ , find  $C$  using equation (4) and or (2)
- (4) Find the corner frequencies  $\omega_1 = \frac{1}{T}, f_1 = \frac{\omega_1}{2\pi} \text{ Hz.}$   
 $\omega_2 = \frac{1}{\alpha T}, f_2 = \frac{\omega_2}{2\pi}$  and also  $\omega_m = \frac{1}{\sqrt{\alpha}} * \frac{1}{T}, f_m = \frac{\omega_m}{2\pi} \text{ Hz}$

**Example:**

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

$$\text{Given: } \Phi_m = 30^\circ \quad \omega_m = 2\pi f \quad f=500\text{Hz}$$

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

$$\omega_m = \frac{1}{\sqrt{\alpha T}} \quad \alpha = \frac{R_2}{R_1 + R_2} \quad T = R_1 C$$

$$\alpha = \frac{1 - \sin\phi_m}{1 + \sin\phi_m}$$

$$\alpha = 0.33$$

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

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

$$T = R_1 C$$

Assume C=0.1μf

$$R_1 = 5.54 \text{ K}\Omega$$

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

$$R_2 = 2.72 \text{ K}\Omega$$

Tabular Column:

| Sl. No. | Frequency (Hz) | $V_i$ (volts) | $V_o$ (volts) | Amplified o/p<br>$V_o' = (V_o / \alpha)$<br>(volts) | Magnitude in dB<br>$= 20 \log \left( \frac{V_o'}{V_i} \right)$ | Phase angle (degrees) |
|---------|----------------|---------------|---------------|---|--|-----------------------|
|         |                |               |               |   |  |                       |

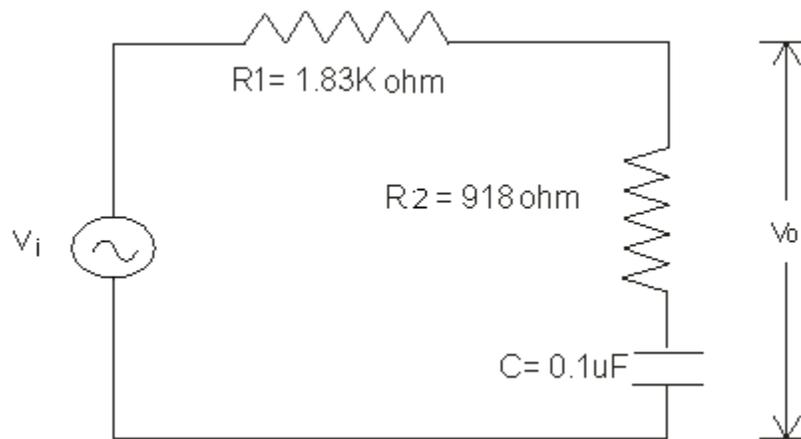
Result:

Date: \_\_\_\_\_

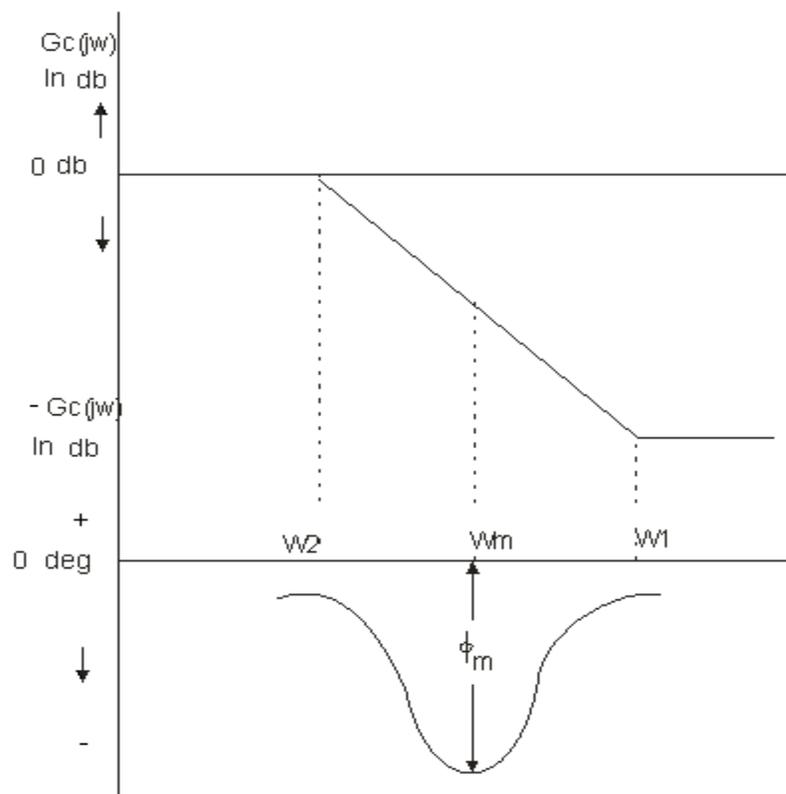
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**Circuit Diagram:**



**Graph:**



Experiment: 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         | 1.83K $\Omega$ , 918 $\Omega$ | 2    |
| 2.     | Capacitor        | 0.1 $\mu$ F                   | 1    |
| 3.     | Signal generator |                               | 1    |
| 4.     | CRO              |                               | 1    |
| 5.     | Probes           |                               | 3    |
| 6.     | Wires            |                               | few  |

**Procedure:**

- 1) Connections 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

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

Where  $\beta = \frac{R_1 + R_2}{R_2}$  -----→1

Time constant  $T = R_1 C$ -----→2

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

The maximum phase lag

$$C = \sin^{-1} \left( \frac{1 - \beta}{1 + \beta} \right) \text{-----} > 3$$

and  $\omega_m$  is the frequency at which  $\phi_m$  occurs.

$\omega_m$  is the geometric mean of two frequencies.

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

**Example:**

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

$$\text{Given: } \Phi_m = 30^\circ \quad \omega_m = 2\pi f \quad f=50\text{Hz}$$

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

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

$$\sin \phi_m = \frac{\beta - 1}{\beta + 1}$$

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

$$\beta = 3$$

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

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

$$T = R_1 C$$

$$\text{Assume } C = 0.1 \mu\text{f}$$

$$\mathbf{R_1 = 1.83 K\Omega}$$

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

$$\mathbf{R_2 = 918\Omega}$$

Tabular Column:

| Sl.No | Frequency (Hz) | $V_i$ (Volt) | $V_o$ (Volt) | Magnitude in dB=<br>$20\log \frac{V_o}{V_i}$ | Phase angle (degree) |
|-------|----------------|--------------|--------------|--|----------------------|
|       |                |              |              |  |                      |

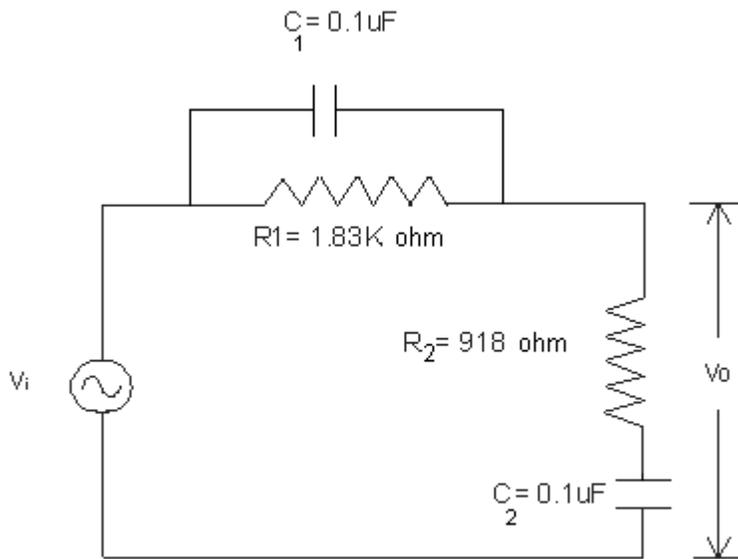
**Transfer Function:**

**Result:**

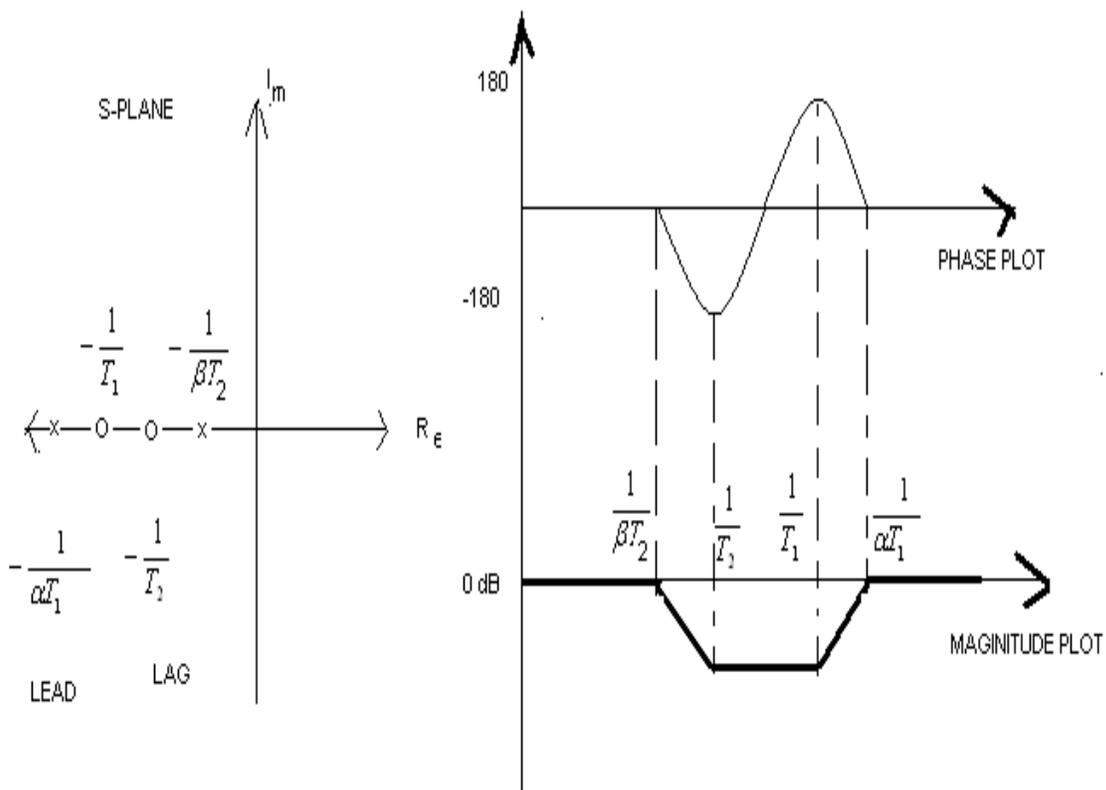
**Date:** \_\_\_\_\_

**Signature of Faculty**

**Circuit Diagram:**



**Graph:**



Experiment: 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

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

LAG      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  $\omega_1 = \frac{1}{\sqrt{T_1 T_2}}$

**Tabular Column:**

| Sl.No | Frequency (Hz) | V <sub>i</sub> (Volt) | V <sub>o</sub> (Volt) | Gain = 20log $\frac{V_o}{V_i}$ | 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.

Experiment: 7

Date: \_\_\_\_\_

**P, PI, PD AND PID CONTROLLER**

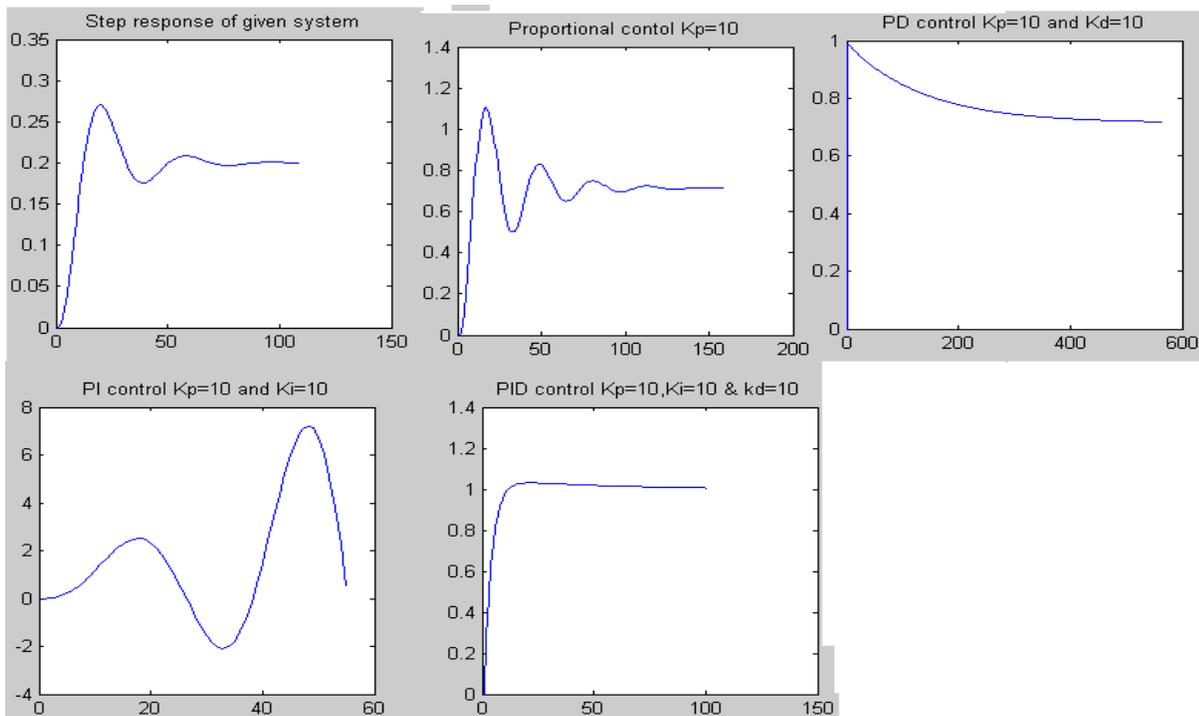
**Aim: To obtain step response of the given system and evaluate the effect P, PD, PI and PID controllers.**

**Procedure:**

- 1) Consider the open loop transfer function

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

- 2) Write the program using mat lab to simulate step response of the given System.
- 3) Evaluate the effect of P,PI,PD and PID controllers

**Graph:**

**Exercise:**

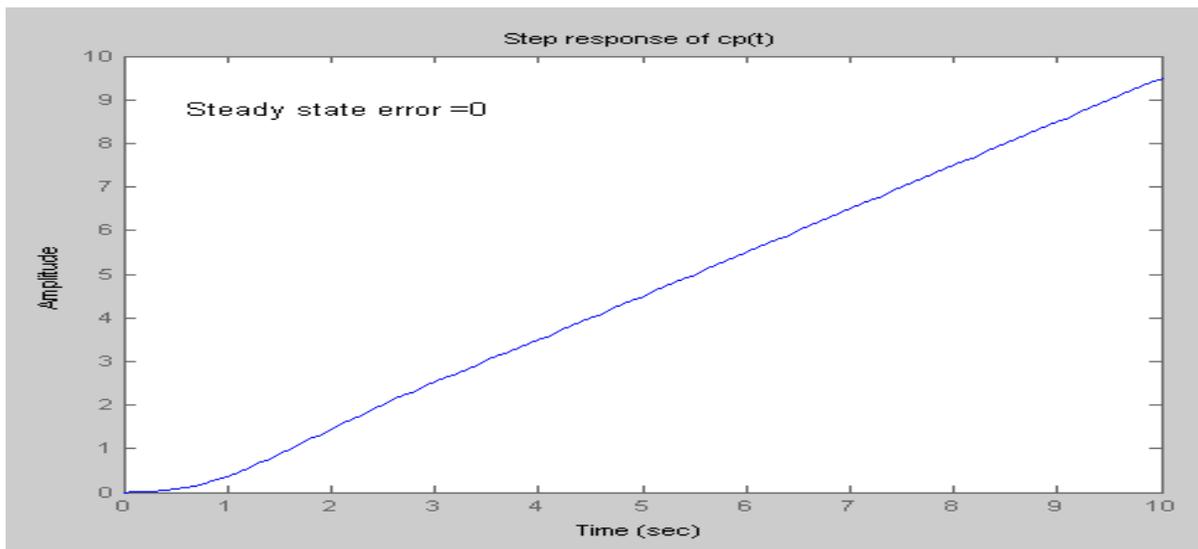
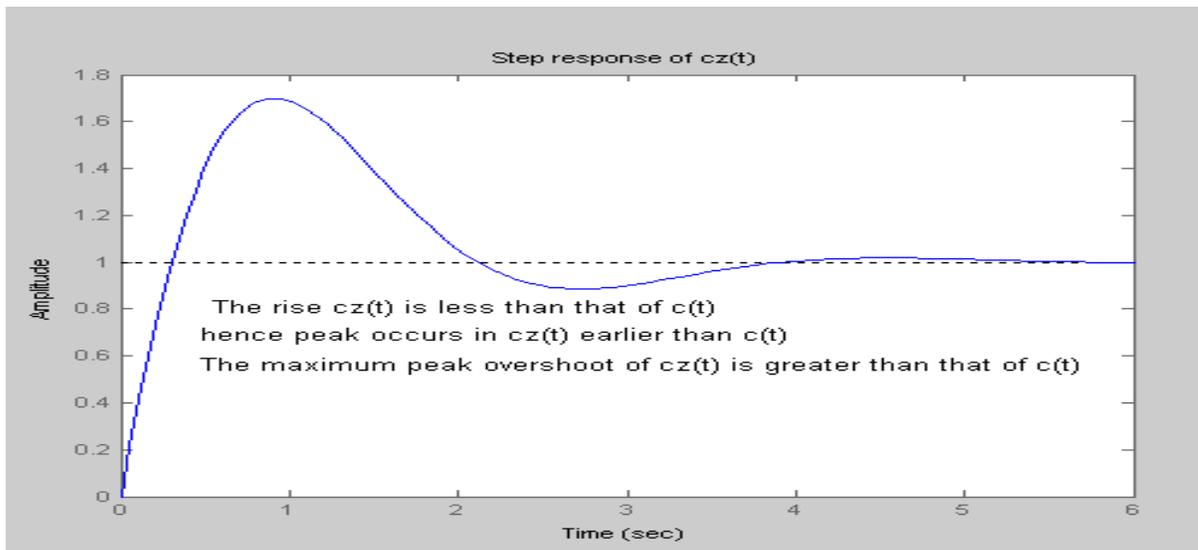
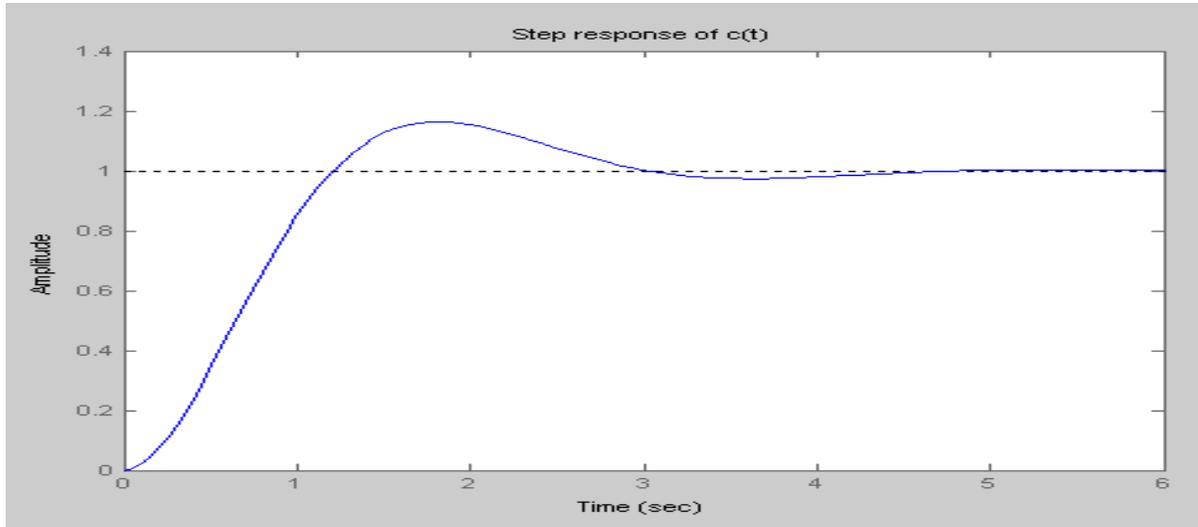
**1. TF** = 
$$\frac{144}{s^2 + 12s + 144}$$

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

**Result:**

**Date:** \_\_\_\_\_

**Signature of Faculty**



Experiment: 8

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))
Percent overshoot= exp(-zeta*pi/ sort(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,

$$\text{sys2}=\text{feedback}(\text{sys1},1);$$

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.

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

Where  $\xi$  = damping ratio

$\omega_n$  = undamped natural frequency.

**Time Domain specification:**

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

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

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

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

$\omega_n$ = undamped natural frequency.

$\xi$ =damping ratio.

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

Settling time  $t_s = \frac{4}{\xi\omega_n}$  for 2% tolerance

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

**Exercise:** Try the program for different Transfer functions.

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

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

**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 control Kp=10')
k=dcgain(G)
essP=1/(1+k)
```

**% PD controller**

```
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')
```

**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
```

**Experiment: 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 servo meter 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  $J_m = 3 \times 10^{-3} \text{Kg-m}^2$

Moment of inertia of load  $J_L = 5 \text{Kg-m}^2$

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

Motor torque constant,  $K_1 = 2 \text{ Newton-m/amp}$ ,

Tachogenerator constant  $K = 0.2 \text{ volt/rad/sec}$ ,

Sensitivity of error detector,  $K_p = 1 \text{ Volt/Rad}$

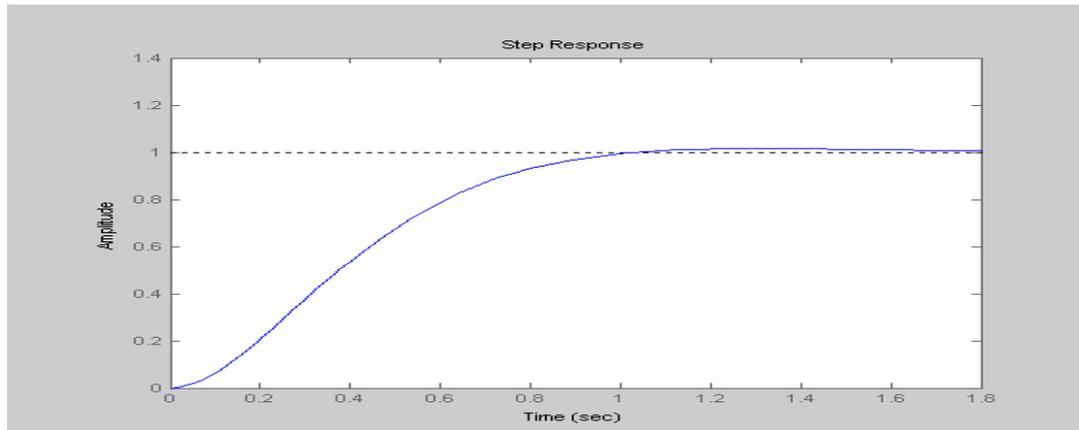
Amplifier gain  $= K_1 \text{ amps/volt}$

Undamped natural frequency  $= 4 \text{ rad/sec}$

Damped ratio  $= 0.8$

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

$$\text{Transfer function : } \frac{\theta_L}{\theta_m} = \frac{8K_1}{(S^2 + 80KK_1S + *K_1)}$$

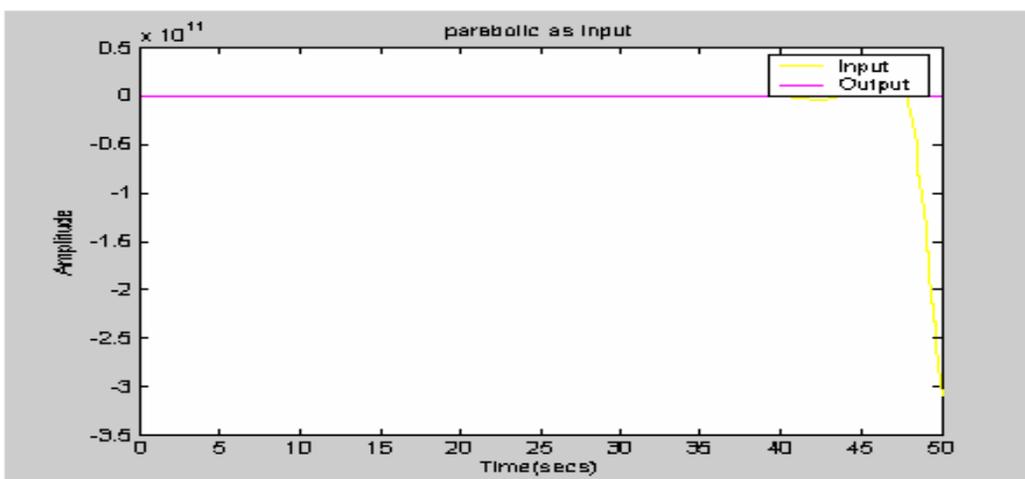
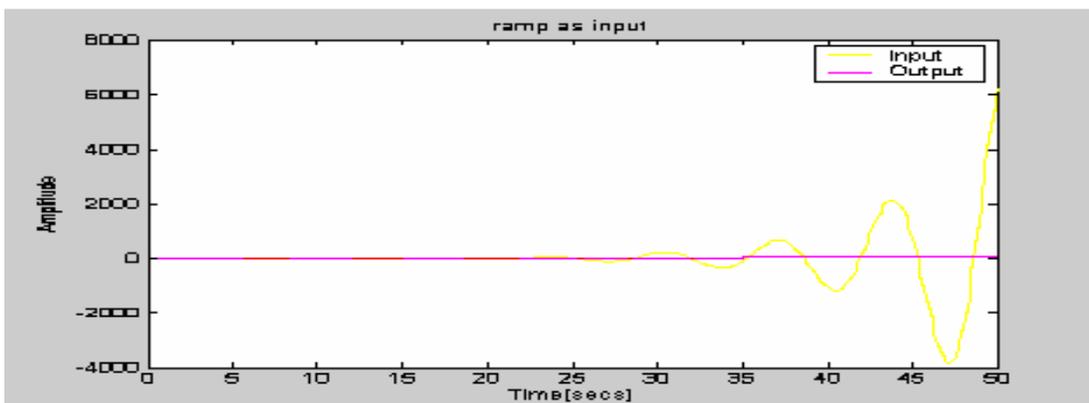
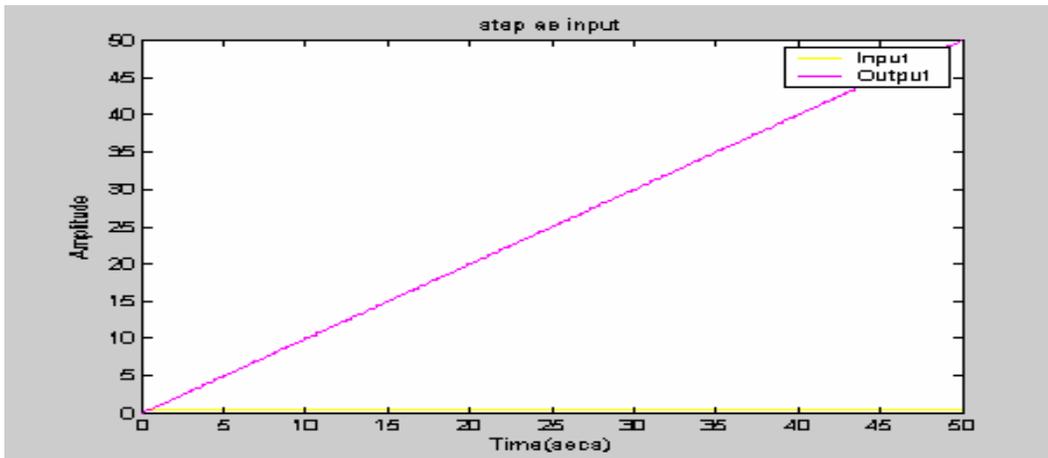
**Graph:****% ramp input**

```
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. TF** = 
$$\frac{144}{s^2 + 12s + 144}$$

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

**Result:**

**Date:** \_\_\_\_\_

**Signature of Faculty**

Program

% to obtain the relation between frequency response and transient response

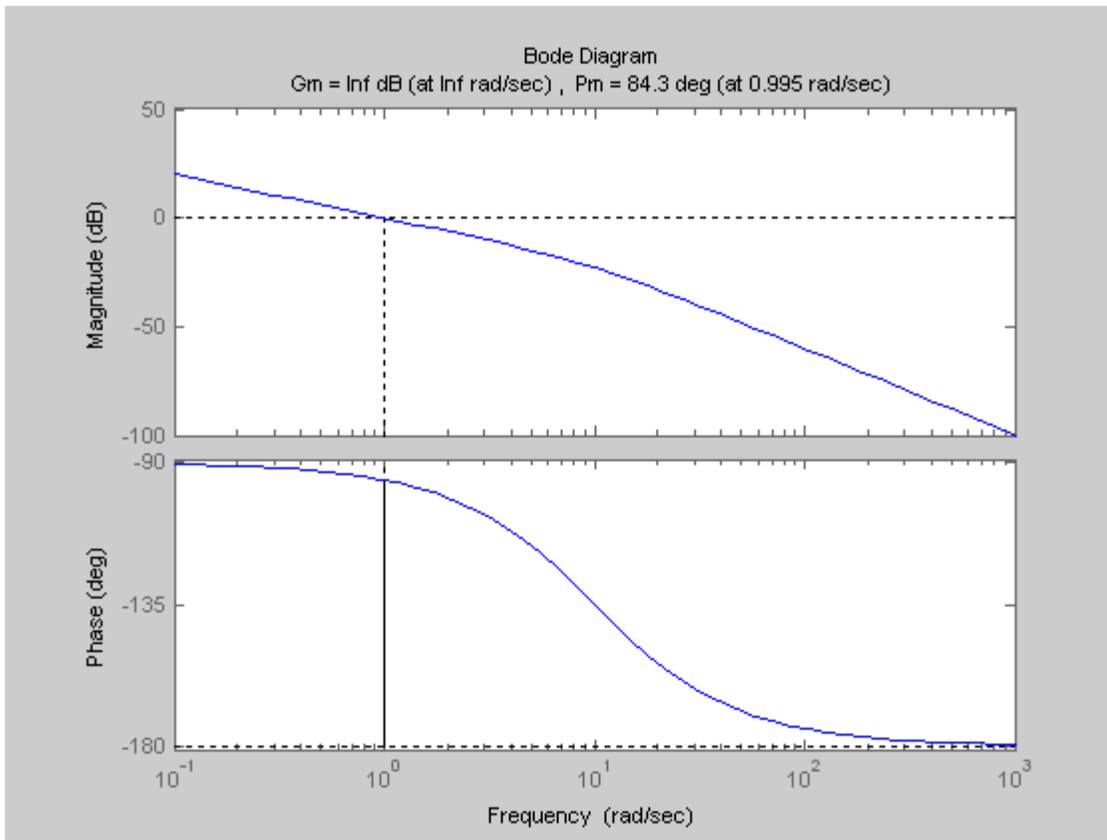
```
n=[1];
d=conv([1 0],[0.1 1])
g=tf(n,d);
bode(g)
margin(g)
[gm,pm,wcp,wcg]=margin(g)
GMdb=20*log10(gm)
figure
fplot('1/(2*z*sqrt(1-z^2))',[0.0 0.8,0.01 10])
hold on
fplot('exp(-pi*z/sqrt(1-z^2))',[0.0 0.8,0.01 10])
hold off
xlabel('zeta')
ylabel('resonant peak,max.overshoot')
figure
fplot('1*sqrt((1-2*z^2)+sqrt(4*z^4-4*z^2+2))',[0.0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

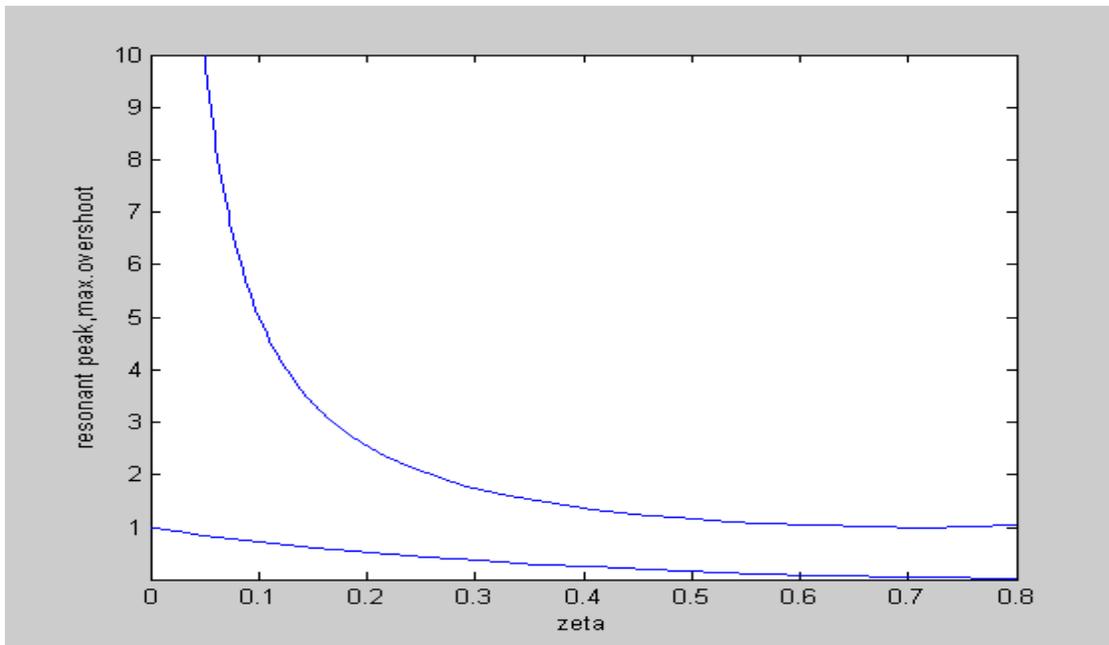
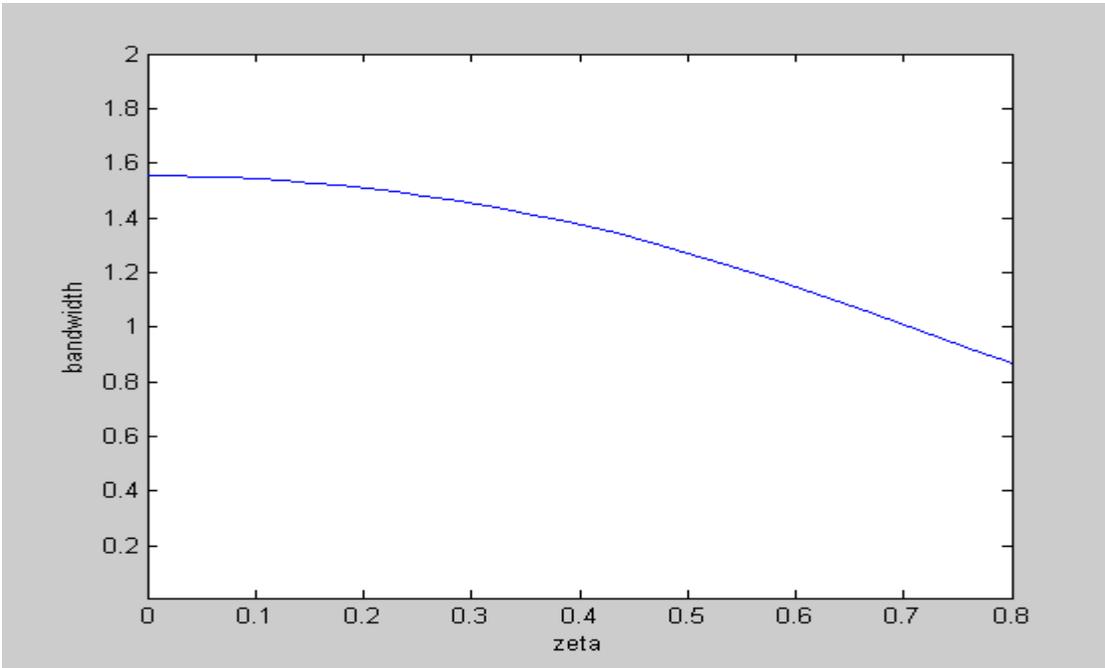
Experiment: 10

Date: \_\_\_\_\_

**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:**



**Calculation :**

**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');
```

**Experiment: 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  $\omega_{cg}$ , phase cross over Frequency  $\omega_{cp}$  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  $G(S) = \frac{1}{S^3 + 5S^2 + 6S}$

- 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.

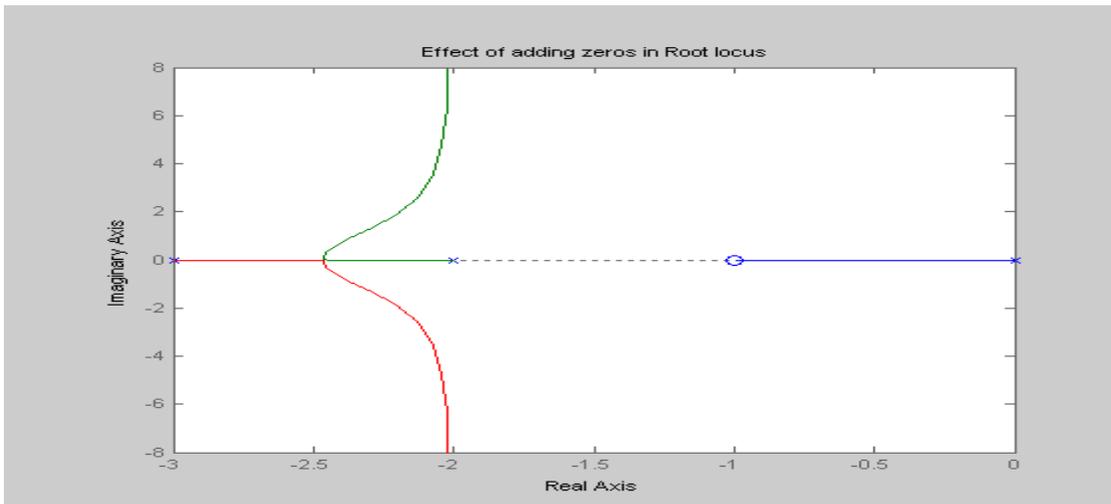
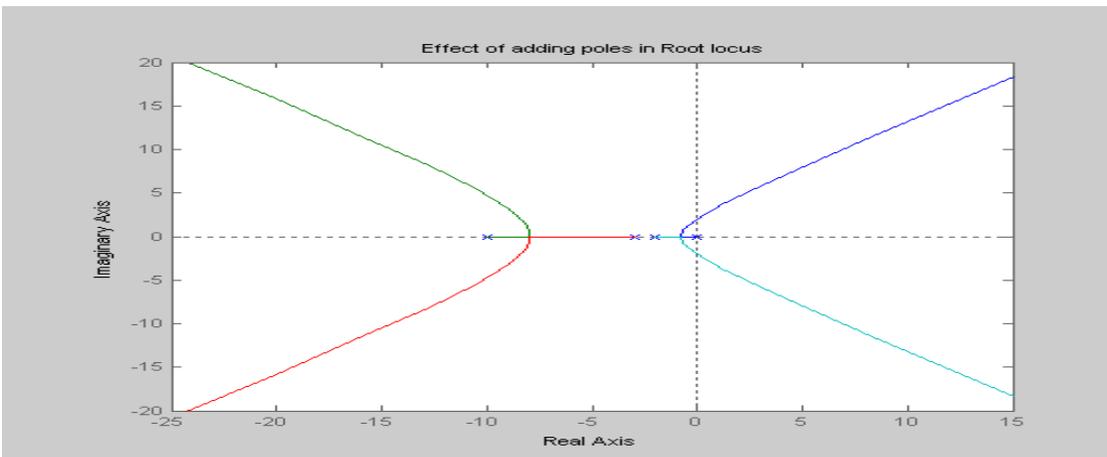
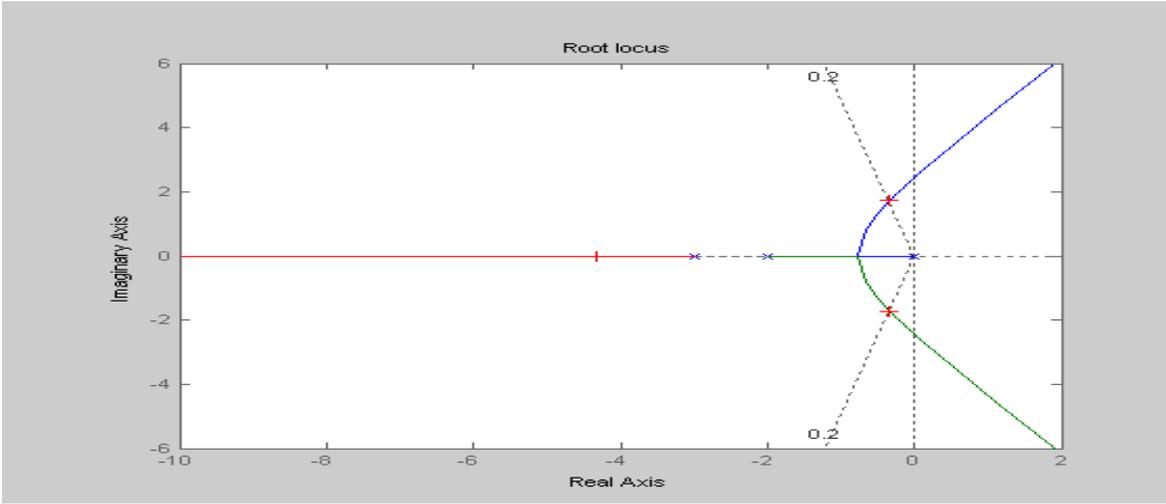
**Stability:**

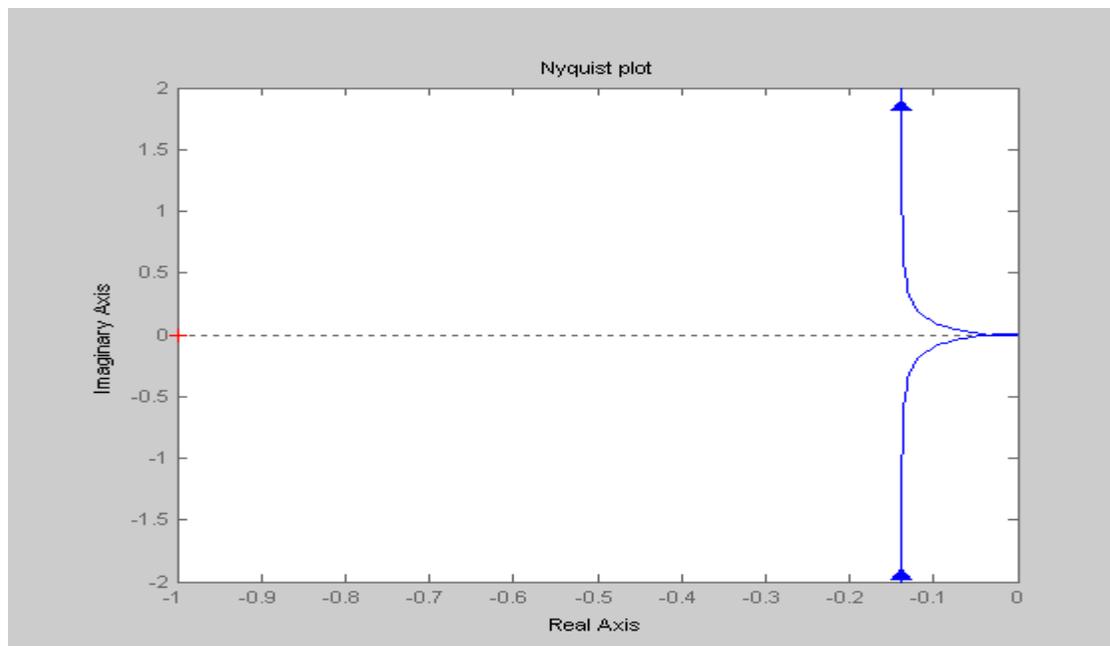
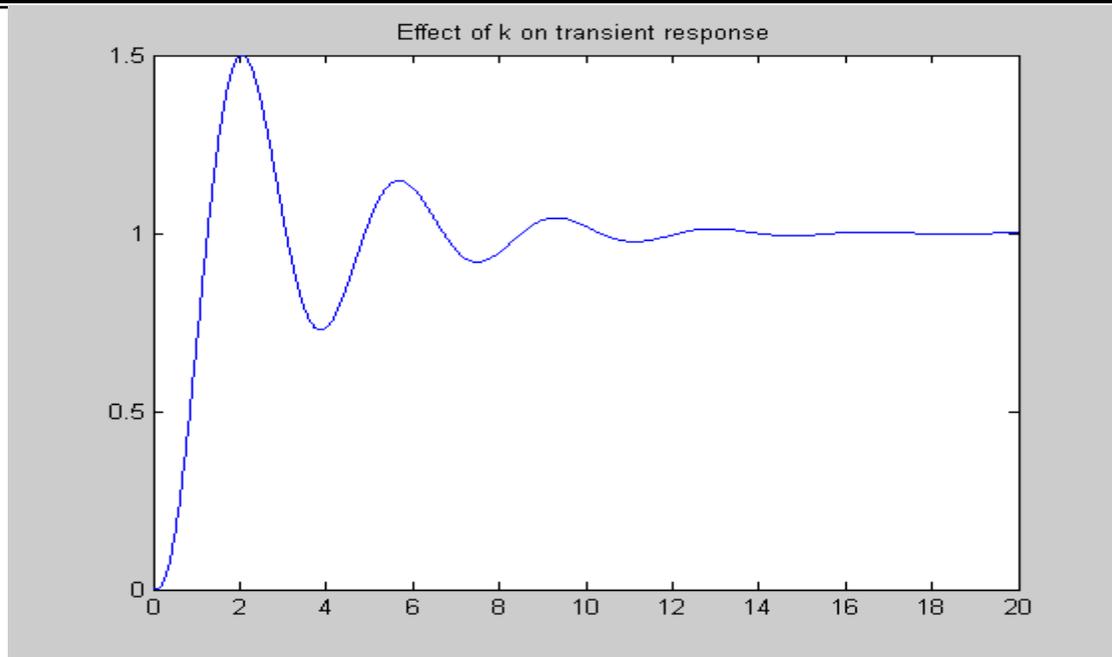
If the Gain margin and Phase margin are positive, the given minimum phase system is stable.

$\omega_{cg}$  is gain cross over frequency.

$\omega_{cp}$  is phase cross over frequency.

Graph:





**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<sup>2</sup>(s+2)(s+5)]

### Nquist plots:

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

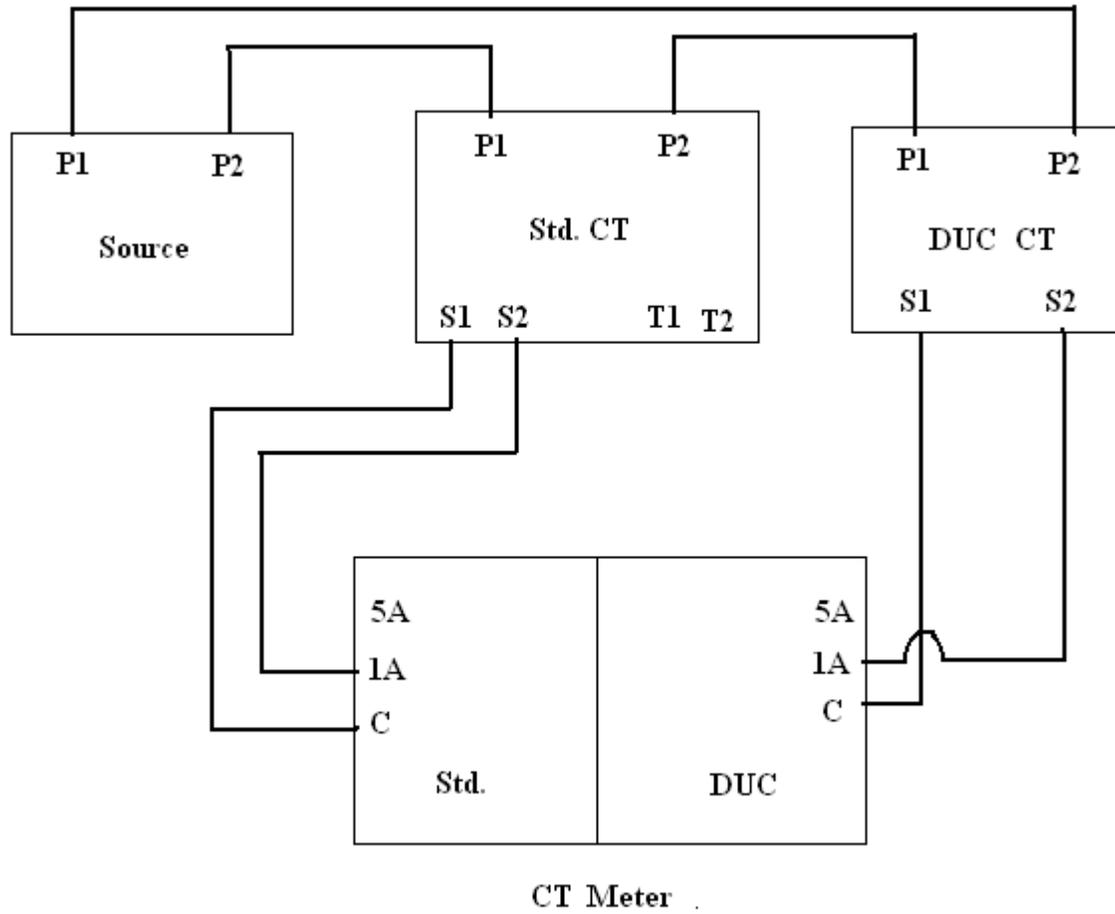
6. Num=s(s-3) & den=s(s+1)(s-1)

**Result:**

**Date:** \_\_\_\_\_

**Signature of Faculty**

# **Additional Experiment**



**Block Diagram**

Date: \_\_ / \_\_ / \_\_\_\_

## Current Transformer

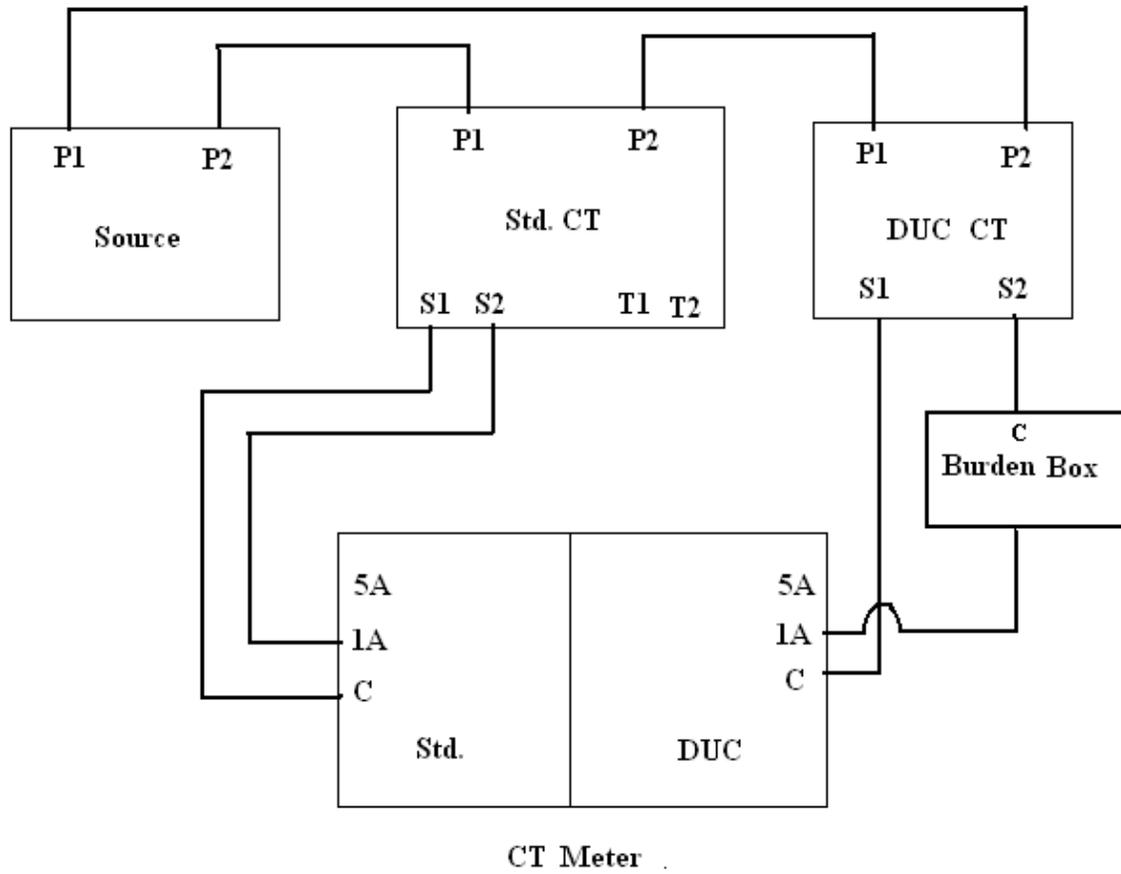
**Aim:** To find ratio and phase angle errors of given Current transformer

### 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  $I_d$ ,  $I_s$ , %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  $I_d$ ,  $I_s$ , %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

## **REFERENCES**

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, 4<sup>th</sup> 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, and 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 a PID controller?

## 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  $\xi = \underline{\hspace{2cm}}$  and between  $t = \underline{\hspace{1cm}}$  to  $\underline{\hspace{1cm}}$  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  $G(s) = \underline{\hspace{2cm}}$ . 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) 
$$G(s) = \frac{K}{S(S+2)(S+3)}$$

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

(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  $\xi = \underline{\hspace{2cm}}$  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) 
$$G(s) = \frac{K}{S(S+2)(S+3)}$$

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

a) Evaluate the effect adding open loop pole 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.