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Hirasugar Institute of Technology, Nidasoshi

Inculcating Values, Promoting Prosperity

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

LABORATORY MANUAL

CONTROL SYSTEM LABORATORY

Semester: VI

Subject Code: 18EEL66

Lab Incharge:

Prof. O. B. Heddurshetti

Lab Instructor:

Shri. R. S. Bardol

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

VISION

“To be the centre of excellence in teaching and learning to produce the competent & socially responsible professionals in the domain of Electrical & Electronics Engineering.”

MISSION

- I. To educate students with core knowledge of Electrical and Electronics Engineering to excel in their professional career.
- II. To develop problem solving skills, professional skills and ethical values among the students for the betterment of mankind.
- III. To prepare technically competent and socially responsible Electrical Engineer to serve the future needs of the society.

Program Educational Objectives (PEOs):

Engineering Graduates will be able to:

- PEO1:** Achieve successful professional career in Electrical Engineering and allied disciplines.
- PEO2:** Pursue higher studies and continuously engage in upgrading the professional skills.
- PEO3:** Demonstrate professional & ethical values, effective communication skills and teamwork to solve issues related to profession, society and environment.

Program Specific Outcomes (PSOs):

Engineering Graduates will be able to:

- PSO1:** Apply knowledge & competencies to analyze & design Electrical & Electronics circuits, control and power systems, machines & industrial drives.
- PSO2:** Use software/hardware tools for the design, simulation and analysis of Electrical and Electronics Systems.



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Lab Manual

**2021-22
(Even Sem)**

Sl. No.	LIST OF 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	(a) 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 the frequency response. (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.



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1.0 a

SPEED – TORQUE CHARACTERISTIC OF A TWO - PHASE A.C. SERVOMOTOR

Experiment No	Date Conducted	Marks
1.0a		

1. TITLE: SPEED –TORQUE CHARACTERISTICS OF 2-PHASE AC SERVO MOTOR

2. LEARNING OBJECTIVES:

- Understanding of servo motor.
- Understanding of speed-torque variation for different rated voltages.

3. AIM:

a) Experiment to draw the speed – torque characteristic of a two - phase A.C. servomotor.

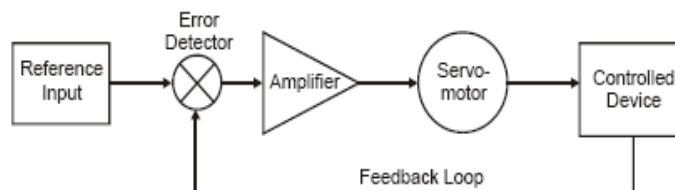
4. MATERIAL / EQUIPMENT REQUIRED:

S. No	Apparatus	Qty
1	AC Servo motor unit	01No
2	Digital Multimeter	01No
5	Connecting wires	Few


5. THEORY / HYPOTHESIS:

The motors that are used in automatic control systems are called servo-motors. The servomotors are used to convert an electrical signal applied them into an angular displacement of shaft. Depending on the supply required to run the motor, they are broadly classified as DC servo motor and AC servomotors. But, the DC servomotors are expensive than AC servomotors. But, the DC servo motors have linear characteristics and so it is easier to control DC motors are capable of delivering over 3 times their rated torque for a short time but AC motors will short at 2 to 2.5 times their rated torque. In DC servomotors mainly 2 types of motors are classified 1. Permanent magnetic motors and electromagnetic field motors. The DC servo motors are generally used for large power applications such as in machine tools and robotics.

The servomotors used in industry today are used in a closed-loop servo system. To understand how the servomotor is used in the system, it is first necessary to review the entire system. The following figure indicates a block diagram of a typical servo system.



A reference input (typically called a velocity input) is sent to the servo amplifier, which controls the speed of the servomotor. Directly mounted to the machine (or to the servomotor) is a feedback device (either an encoder or resolver). This device changes mechanical motion into electrical signals and is used as a *feedback loop*. This feedback loop is then sent to the *error detector*, which compares the actual operation with that of the reference input. If there is an error, that error is fed directly to the amplifier, which makes the necessary corrections.

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In many servo systems, both velocity and position are monitored. (Note: In servo systems, the word "velocity" is often used to describe speed control. Velocity indicates a rate of change of position, with respect to time. It also indicates a rate of motion in a particular direction, with respect to time.) The velocity loop control may take its command from the velocity loop feedback device—a resolver or tachometer mounted directly to the motor.

These AC servo motors are basically two-phase, reversible, induction motors modified for servo operation. AC servo motors are used in applications requiring rapid and accurate response characteristics. To achieve these characteristics, these AC servo motors have small diameter, high resistance rotors. The AC servo motor's small diameter provides low inertia for fast starts, stops, and reversals. High resistance provides nearly linear speed-torque characteristics for accurate servo motor control.

An induction motor designed for servo use is wound with two phases physically at right angles or in space quadrature. A fixed or reference winding is excited by a fixed voltage source, while the control winding is excited by an adjustable or variable control voltage, usually from a servo-amplifier. The servo motor windings are often designed with the same voltage/turns ratio, so that power inputs at maximum fixed phase excitation, and at maximum control phase signal, are in balance.

The inherent damping of servo motors decreases as ratings increase and the servo motors are designed to have a reasonable efficiency at the sacrifice of speed-torque linearity.

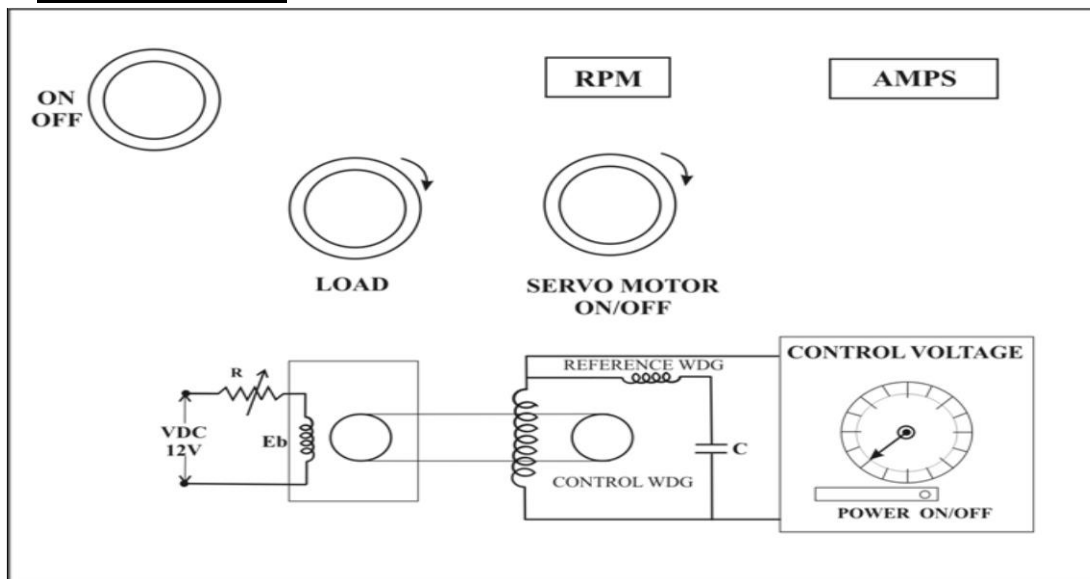
Induction type servo motors are available in fractional and integral horsepower sizes.

6. PROCEDURE / PROGRAMME / ACTIVITY:

1. Study all the controls in front panel.
2. Initially keep load current in zero position, indicating that armature circuit of machine is not connected, auxiliary DC supply of $\pm 12V$.
3. Servo Motor supply switch is kept in OFF position.
4. Ensure load potentiometer and control voltage of autotransformer is at minimum position.
5. Switch ON the mains supply to unit and also AC servo motor supply switch, vary the control voltage from auto-transformer.
6. With load switch in OFF position vary the speed of the AC servomotor by varying the control voltage and note down the back emf generated by DC machine.
7. Now with the load switch in OFF position, switch ON the AC Servo Motor and keep the speed in minimum position.
8. Vary the control winding voltage by varying the auto transformer and set the speed for maximum. Now switch ON the load and start loading AC servomotor by varying the load potentiometer.
9. Note down the corresponding values of I_a & speed.
10. Set the control winding voltage to 75% of rated voltage & start applying the load slowly.
11. Repeat the above procedure for different control winding voltage.
12. Draw the graph of speed Vs Torque for various control winding voltage.



**7. BLOCK / CIRCUIT / MODEL / REACTION DIAGRAM:
PANEL DIAGRAM: 2-PHASE AC SERVO MOTOR**



8. OBSERVATION TABLE / LOOKUP TABLE / TRUTH TABLE:

Back emf E_b	Speed In RPM

- For 100% of rated Voltage i.e. 220V

I _a in Amps	Speed in RPM	E _b in volts	P = E _b × I _a	Torque T = $\frac{P \times 60}{2 \pi N}$ gm cm

- For 75% of rated Voltage i.e. 165 V

I _a in Amps	Speed in RPM	E _b in volts	P = E _b × I _a	Torque T = $\frac{P \times 60}{2 \pi N}$ gm cm



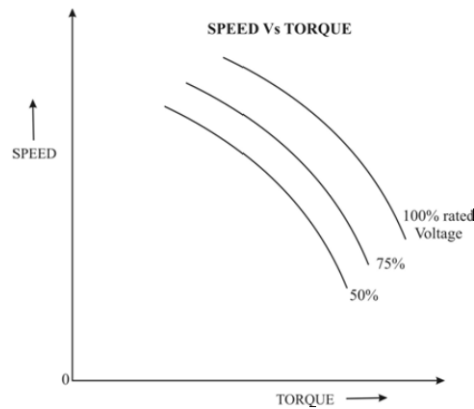
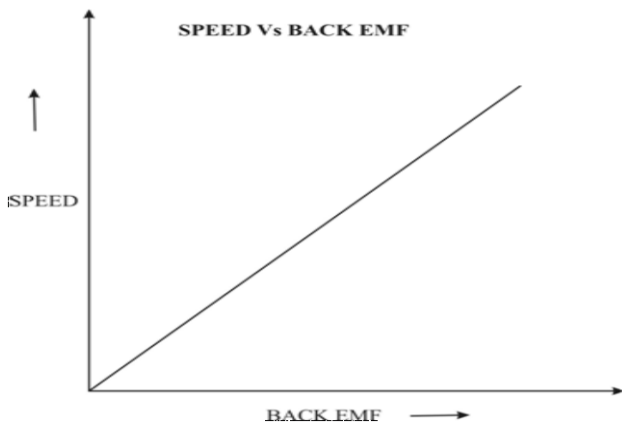
- For For 50% of rated Voltage i.e. 110 V

I_a in Amps	Speed in RPM	E_b in volts	$P = E_b \times I_a$	Torque $T = \frac{P \times 60}{2 \pi N}$ gm cm

9. FORMULA / CALCULATIONS:

$$T = \frac{P \times 60}{2 \pi N} = \text{_____ gm cm}$$

10. GRAPHS / OUTPUTS:



11. RESULTS & ANALYSIS:

12. OUTCOME & CONCLUSIONS:

13. REMARKS:



1.0 b SPEED –TORQUE CHARACTERISTICS OF A DC SERVO MOTOR

EXPERIMENT NO:	Date Conducted	Marks
1.0 b		

1. TITLE: SPEED –TORQUE CHARACTERISTICS OF A DC SERVO MOTOR

2. LEARNING OBJECTIVES:

- Understanding of speed-torque variation for different rated voltages.
- Understanding of DC servo motor.

3. AIM:

Experiment to draw speed torque characteristic of a D.C. servomotor

4. MATERIAL / EQUIPMENT REQUIRED:

S. No	Apparatus	Qty
1	DC Servo motor unit	01No
2	Digital Multimeter	01No
3	Connecting wires	Few

5. THEORY / HYPOTHESIS:


The motors that are used in automatic control systems are called servo-motors. The servomotors are used to convert an electrical signal applied them into an angular displacement of shaft. Depending on the supply required to run the motor, they are broadly classified as DC servo motor and AC servomotors. But, the DC servo-motors are expensive than AC servomotors. But, the DC servo motors have linear characteristics and so it is easier to control DC motors are capable of delivering over 3 times their rated torque for a short time but AC motors will short at 2 to 2.5 times their rated torque. In DC servomotors mainly 2 types of motors are classified 1. Permanent magnetic motors and electromagnetic field motors.

The DC servo motors are generally used for large power applications such as in machine tools and robotics.

A servomotor is a motor which forms part of a servomechanism. The servomotor is paired with some type of encoder to provide position/speed feedback. A stepper motor is one type of servomotor. A stepper motor is actually built to move angular positions based upon each possible step around the entire rotation, and may include micro steps with a resolution such as 256 micro steps per step of the stepper motor. A servomechanism may or may not use a servomotor. For example, a household furnace controlled by a thermostat is a servomechanism, because of the feedback and resulting error signal, yet there is no motor being controlled directly by the servomechanism

A **servomechanism**, sometimes shortened to **servo**, is an automatic device that uses error-sensing negative feedback to correct the performance of a mechanism.

DC servo motors are normally used as prime movers in computers, numerically controlled machinery, or other applications where starts and stops are made quickly and accurately. Servo motors have lightweight, low-inertia armatures that respond quickly to excitation-voltage changes. In addition, very low armature inductance in these servo motors results in a low electrical time constant (typically 0.05 to 1.5 msec) that further sharpens servo motor response to command signals. Servo motors include permanent-magnetic, printed-circuit, and moving-coil (or shell) dc servo motors. The rotor of a shell dc servo motor consists of a cylindrical shell of copper or aluminum wire coils which rotate in a magnetic

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field in the annular space between magnetic pole pieces and a stationary iron core. The servo motor features a field, which is provided by cast AlNiCo magnets whose magnetic axis is radial. Servo motors usually have two, four, or six poles.

Dc servo motor characteristics include inertia, physical shape, costs, shaft resonance, shaft configuration, speed, and weight. Although these dc servo motors have similar torque ratings, their physical and electrical constants vary.

DC Servo Motor Selection: The first selection approach is to choose a servo motor large enough for a machine that has already been designed; the second is to select the best available servo motor with a specific feature and then build the system around it; and the third is to study servo motor performance and system requirements and mate the two.

The final servo motor system design is usually the least sophisticated that meets the performance specifications reliably. Servo motor requirements may include control of acceleration, velocity, and position to very close tolerances. This says that the servo designer must define the system carefully, establish the servo motor's performance specifications, determine critical areas, and set up tolerances. Only then will the designer be able to propose an adequate servo-system and choose a servo motor type.

6. PROCEDURE / PROGRAMME / ACTIVITY:

1. Study all the controls in front panel.
2. Adjust zero reading in both the balances.
3. Servo Motor supply switch is kept in OFF position. Spring balance at zero reading and speed potentiometer at minimum position.
4. Switch ON the mains supply to the unit, both the motors starts rotating and its speed is indicated by the RPM meter, Now vary the speed potentiometer to the maximum position and check the dc voltage it should be 24V. If it is slightly more, adjust it for 24V. At this voltage note down the speed and current.
5. Slowly, start loading the motor by adjusting the wheel and note down current, speed, W1, W2 spring balanced reading for every 25gm to 50 gm of load.
6. Load the motor up to 200gm, since its torque is 400gm cm and radius of break drum is 2cm. Now increase the load fully and set the DC voltage up to 75% of its rated voltage i.e. 18V and repeat the above steps.
7. Set the DC voltage to 50% of rated voltage and repeat the above step.
8. Draw the graph of speed Vs torque for different voltage settings.



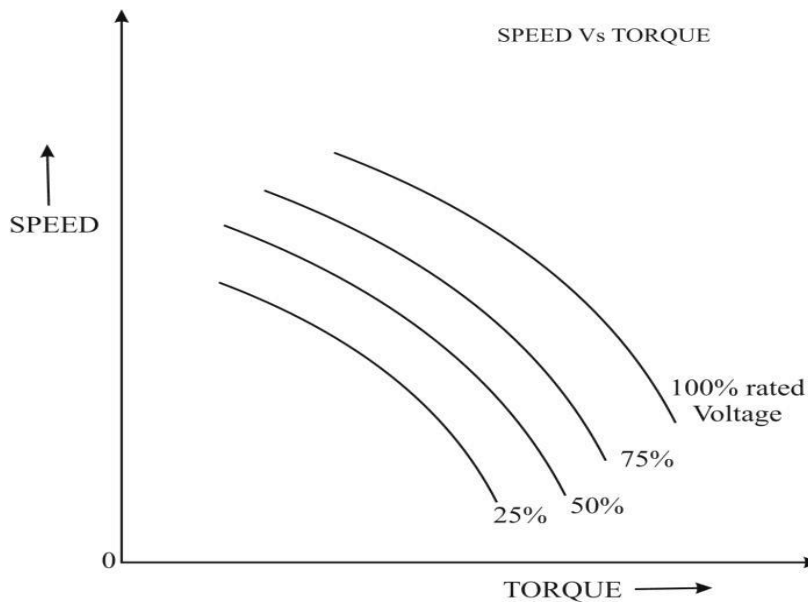
- For 50% of rated voltage = 12V

S. No	Voltage in Volts	Current in Amp.	Speed in rpm	W1 in gms	W2 in gms	W=W1-W2	Torque T=W*r in gmcm.

9. FORMULA / CALCULATIONS:

$$r = \frac{\text{Circumference}}{2 \Pi}$$


10. GRAPHS / OUTPUTS:



11. RESULTS & ANALYSIS:

12. OUTCOME & CONCLUSIONS:

13. REMARKS:

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EXPERIMENT NO	Date Conducted	Marks
02		

1. TITLE: SYNCRO PAIR CHARACTERISTICS.

2. LEARNING OBJECTIVES:

- Understanding of synchro
- Understanding of synchro-transmitter
- Understanding of synchro-transmitter-receiver
- Understanding of importance of synchros

3. AIM:

- To study the characteristics of synchros as transmitter and synchro transmitter- receiver pair.

4. MATERIAL / EQUIPMENT REQUIRED:

S. No.	Apparatus	Range	Qty
1	Synchros pair unit	--	1 No.
2	Voltmeter	(0-50v) MI	3 Nos.
3	1-Ph variac	--	1 No.
4	Patch cords	--	Few

5. THEORY / HYPOTHESIS:

Definition: A synchros or electromagnetic transducer commonly used convert an angular position of a shaft into an electric signal.

Study of Synchro Transmitter and receiver:-

In this part or experiment we can see that because of the transformer action the angular position of rotor is transformed into a unique set of stator voltages.

Synchro Transmitter:

A synchro that provides voltages related to the angular position of its rotor; when its two input leads are excited by an alternating-current voltage, the magnitudes and polarities of the voltages at the three output leads define the rotor position. Also known as selsyn generator; selsyn transmitter; synchro generator; transmitter; transmitter synchro.

Synchro Receiver:

A synchro that provides an angular position related to the applied angle-defining voltages; when two of its input leads are excited by an alternating-current voltage and the other three input leads are excited by the angle-defining voltages, the rotor rotates to the corresponding angular position; the torque of rotation is proportional to the sine of the difference between the mechanical and electrical angles. Also known as receiver synchro; selsyn motor; selsyn receiver; synchro motor.

6. PROCEDURE / PROGRAMME / ACTIVITY:

- 1) Make the connections as per CKT diagram.
- 2) Apply 50v AC supply to the transmitter.
- 3) Adjust the pointer on the rotor of the transmitters to zero position



- 4) Observe the position across to rotate of the receiver. If it is not zero the rotor, so as to obtain zero voltage and this value is referred to as electrical zero position of the receiver.
- 5) Holding firm by position of rotor shaft at transmitters slightly. Note down the voltage across the rotor of the receiver.
- 6) Now continue the readings up to 360 , in steps of 30 by increasing the angular positions of the transmitter in steps.
- 7) Take rotor shaft position of transmitters on X- axis and voltage on Y axis and draw a graph.
- 8) Draw graph by taking transmitter angular position on X- axis and receiver angular position on Y axis.

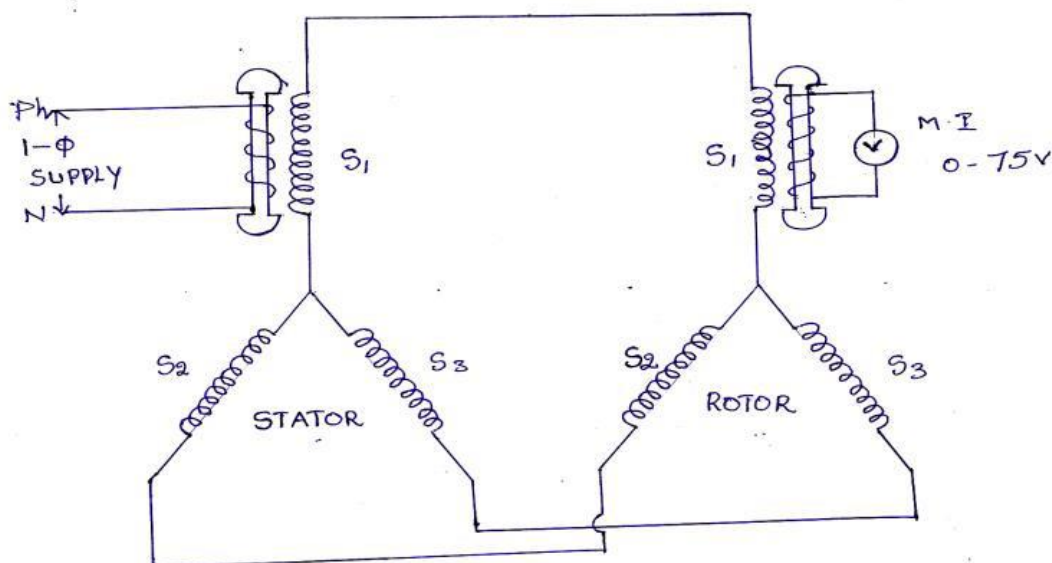
STUDY OF SYNCHRO TRANSMITTER:

PROCEDURE:-

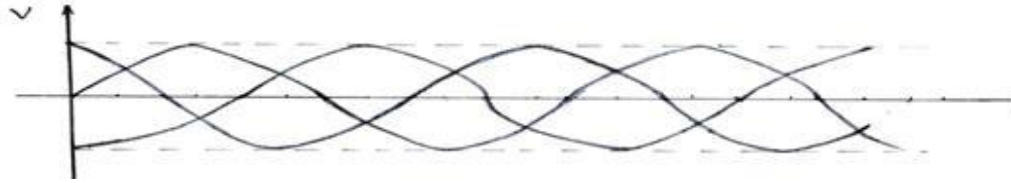
- 1) Apply 50V, AC to the rotor of synchro transmitter.
- 2) Measure the voltage between s1, s2, s3 for various shaft positions from 0-3600. There voltage which have to be -ve sign has to be desired form the knowledge of voltage between wave forms.
- 3) Similarly measure the voltage between S2 and S3, S3 and S1 various shaft positions.
- 4) Plot the graph of rotor position in degrees Vs (S1, S2),(S2,S3) and (S3,S1) respectively.

7. BLOCK / CIRCUIT / MODEL / REACTION DIAGRAM:

• CIRCUIT DIAGRAM




• Study of synchro transmitter: Circuit Diagram :



10. RESULTS & ANALYSIS:

11. OUTCOME & CONCLUSIONS:

12. REMARKS:

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EXPERIMENT NO:	Date Conducted	Marks
3a		

1. TITLE: FREQUENCY RESPONSE OF SECOND ORDER SYSTEM

2. LEARNING OBJECTIVES:

- Understanding of frequency domain specifications.

3. AIM:

- To determine experimentally the frequency response of a second -order system and evaluation of frequency domain specifications.

4. MATERIAL / EQUIPMENT REQUIRED:

S. No.	Apparatus	Range	Qty
1	Resistor	135Ω	01No
2	Inductor	0.01H	01No
3	Capacitor	10 μF	01No
4	Signal Generator	--	01No
5	CRO with probes	--	01Set
6	Bread board	--	01No
7	Connecting wires	--	Few

5. THEORY / HYPOTHESIS:

All the examples presented in this tutorial are modeled by linear constant coefficient differential equations and are thus linear time-invariant (LTI). LTI systems have the extremely important property that if the input to the system is sinusoidal, then the steady-state output will also be sinusoidal at the same frequency but in general with different magnitude and phase. These magnitude and phase differences as a function of frequency comprise the **frequency response** of the system.

The frequency response of a system can be found from the transfer function in the following way: create a vector of frequencies (varying between zero or "DC" to infinity) and compute the value of the plant transfer function at those frequencies. If is the open-loop transfer function of a system and is the frequency vector, we then plot . Since is a complex number, we can plot both its magnitude and phase (the **Bode Plot**) or its position in the complex plane (the **Nyquist Diagram**). Both methods display the same information in different ways.

Second order systems are commonly encountered in practice, and are the simplest type of dynamic system to exhibit oscillations. In fact many real higher order systems are modeled as second order to facilitate analysis. Examples include mass-spring-damper systems and RLC circuits.



9. FORMULA / CALCULATIONS:

We get

$$\omega_n = \sqrt{1/LC} \quad \text{rad/sec}$$

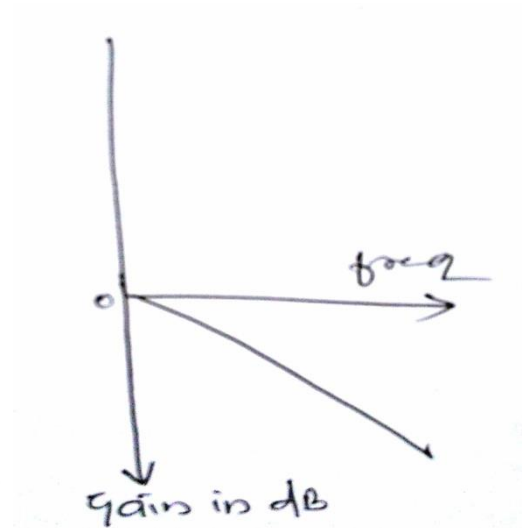
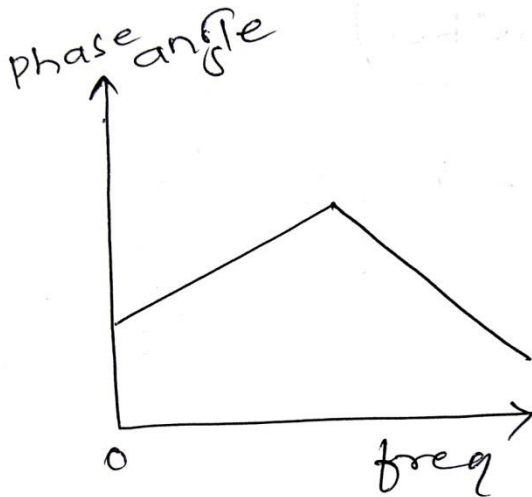
Given $L = \underline{\hspace{2cm}}$ H & $C = \underline{\hspace{2cm}}$ μF

$$\omega_n =$$

$$\xi = (R/2) * \sqrt{C/L}$$

$$\xi =$$

10. GRAPHS / OUTPUTS:



11. RESULTS & ANALYSIS:

12. OUTCOME & CONCLUSIONS:

13. REMARKS:



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EXPERIMENT NO:	Date Conducted	Marks
4a		

1. TITLE: RC LEAD COMPENSATING NETWORK

2. LEARNING OBJECTIVES:

- To identify maximum phase lead.
- To understand compensating network.
- To understand frequency response.

3. AIM:

- 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.
- To determine experimentally the transfer function of the lead compensating network.

4. MATERIAL / EQUIPMENT REQUIRED:

S. No	Apparatus	Range	Qty
1	Decade Resistance Box	-	02No
2	Decade capacitance Box	-	01No
3	Signal Generator	-	01No
4	CRO with probes	-	01Set
5	Connecting wires	-	Few

5. THEORY / HYPOTHESIS:

Consider a lead compensator having the following transfer function

$$K_c \alpha [(Ts+1)/(\alpha Ts+1)] = K_c [s+(1/T)] / [s+(1/\alpha T)] \text{ where } (0 < \alpha < 1)$$

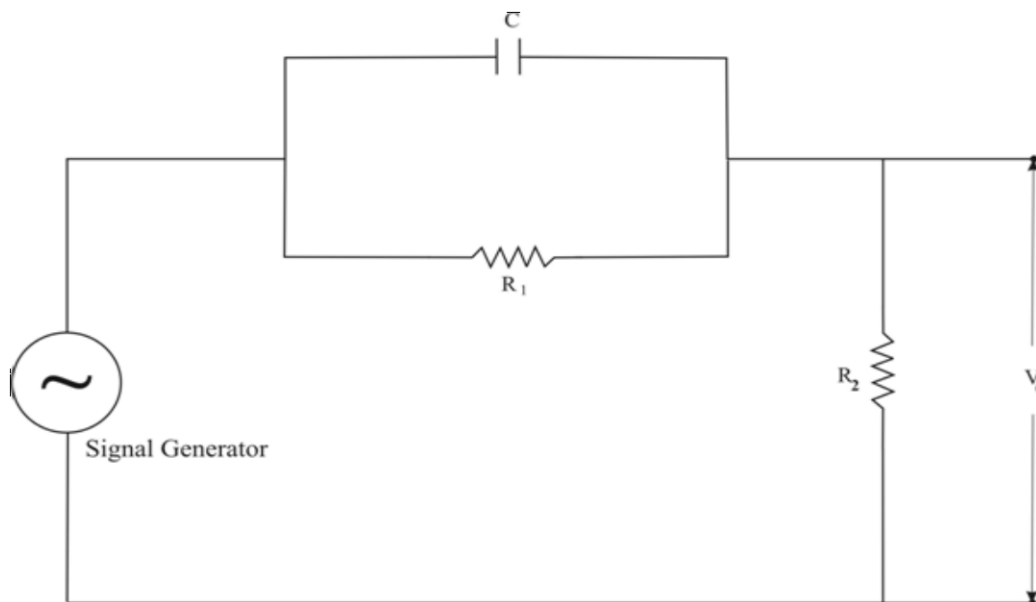
It has zero at $s = -(1/T)$ and a pole at $s = -(1/\alpha T)$. Since $0 < \alpha < 1$, we see that the zero is always located to the right of the pole in the complex plane. Note that for a small value of α the pole is located far to the left. The maximum value of α is limited by the physical construction of the lead compensator. The minimum value of α is usually taken to be about 0.05 (this means that the maximum phase lead that may be produced by a lead compensator is about 65 degrees). The primary function of the lead compensator is to reshape the frequency response curve to provide sufficient phase lead angle to offset the excessive phase lag associated with the components of the fixed system.



6. PROCEDURE / PROGRAMME / ACTIVITY:

- Design the lead compensating network for given max, phase angle and given frequency using formula.
- Rig up the circuit as shown in fig.
- Using signal generator, apply sinusoidal input signal of 2 V (peak to peak) at low frequency say 100Hz.
- Increase the frequency of input signal gradually and at each step note down the peak to peak amplitude of the signal. Also note down the phase difference between input and output signal at each step using Lissajous pattern on CRO.
- The input signal amplitude remains same for all the frequencies.
- Calculate gain in dB and phase angle by using given formula.
- Plot the graph of gain in dB Vs frequency and phase angle Vs frequency.

7. BLOCK / CIRCUIT / MODEL / REACTION DIAGRAM:





8. OBSERVATION TABLE / LOOKUP TABLE / TRUTH TABLE:

Frequency in Hz	Output Voltage $V_{0(p-p)}$ in Volts	Gain in dB = $20 \log(V_0/V_i)$	$\Phi_m = \sin^{-1}(b/a)$ in degree

9. FORMULA / CALCULATIONS:

- **Design of lead compensating network**

Given $\Phi_m =$ _____ degree and $f =$ _____ KHZ

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

therefore $\alpha =$ _____

$$\omega_n = 1 / (T \sqrt{\alpha}) \text{ but } \omega_n = 2 \Pi f_n \text{ Hz}$$

$$T = 1 / (2 \Pi f_n \sqrt{\alpha}) \text{ Sec.}$$

$$T = \text{_____ } \mu\text{S}$$

$$\text{Also } T = R_1 C \text{ and } \alpha = R_2 / (R_1 + R_2)$$

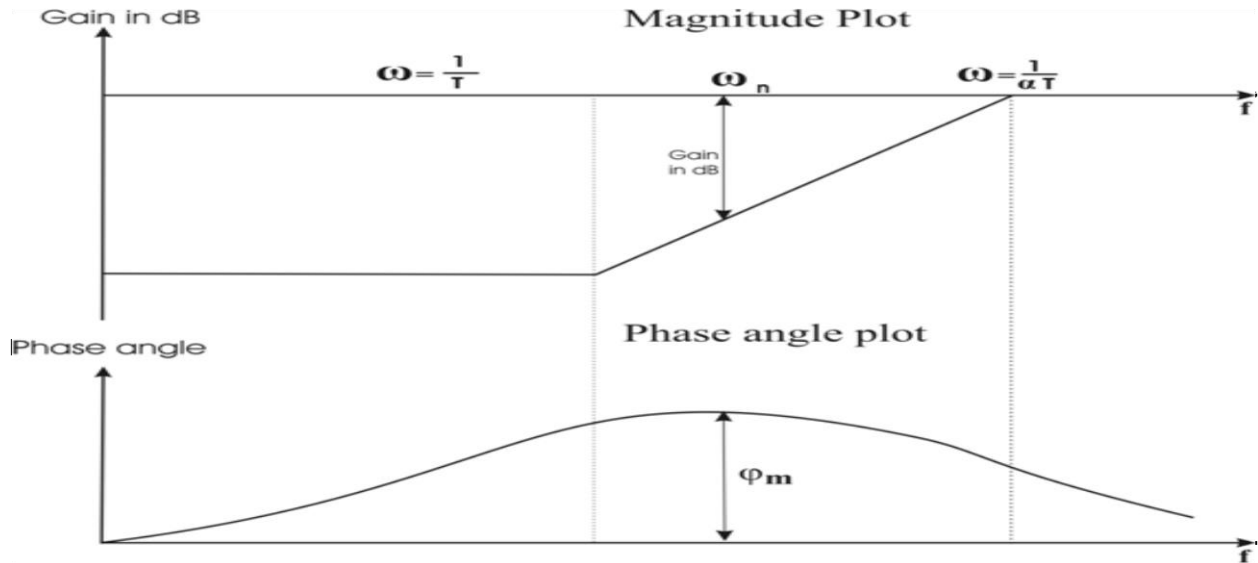
$$\text{Let } C = \text{_____ } \mu\text{F}$$

$$R_1 = T / C = \text{_____ } \Omega$$

$$R_2 = \alpha R_1 / (1 - \alpha) = \text{_____} = \text{_____ } \Omega$$



10. GRAPHS / OUTPUTS:



11. Results & Analysis:

Frequency in HZ	$V_{0(p-p)}$ in Volts	Gain in dB	Phase angle Φ_m	Φ_m

12. OUTCOME & CONCLUSIONS:

13. REMARKS:



EXPERIMENT NO:	Date Conducted	Marks
4b		

1. TITLE: RC LEAD COMPENSATING NETWORK

2. LEARNING OBJECTIVES:

- Determination of Transfer function from bode plot
- Ability to use MATLAB commands.

3. AIM: Determination of frequency response of lead compensating network using MAT LAB.

4. MATERIAL / EQUIPMENT REQUIRED:

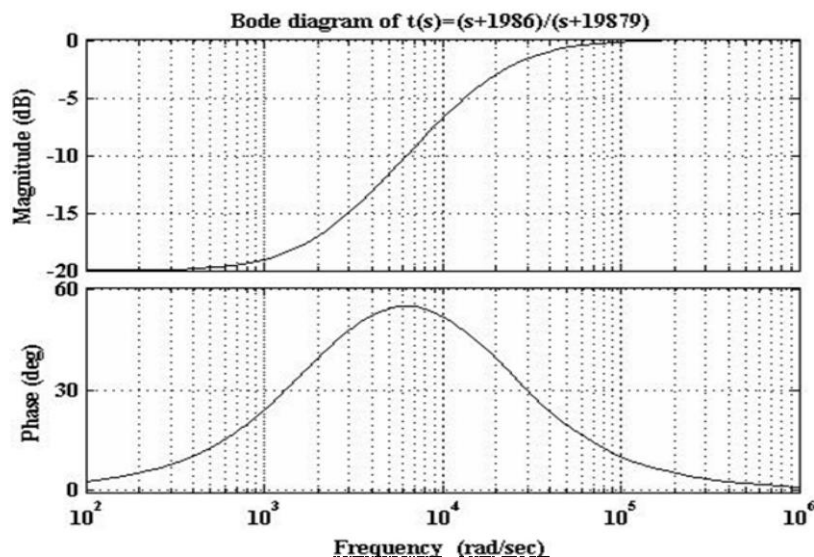
- Computer system
- MATLAB

5. PROCEDURE / PROGRAMME / ACTIVITY:

LEAD NETWORK

```
%bode plot for lead network  
  
num=[0 1 1986];  
  
den=[1 1 19879];  
  
bode(num,den);  
  
grid;  
  
title('Bode diagram of t(s)=(s+1986)/(s+19879)')
```

6. GRAPHS / OUTPUTS:





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7. RESULTS & ANALYSIS:

- **Simulation Results:**

At given design frequency-

F= _____ KHz, i.e. ω = _____ rad/sec.

Gain magnitude = _____ dB.

Phase angle= _____


- **Theoretical Result:**

Gain magnitude = _____ dB.

Phase angle = _____ °

8. Outcome & Conclusions:

9. REMARKS:

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EXPERIMENT NO:	Date Conducted	Marks
5a		

1. TITLE: DESIGN OF LAG COMPENSATING NETWORK

2. LEARNING OBJECTIVES:

- Able to identify maximum phase lag.
- Able to understand compensating network.
- Able to understand frequency response.

3. AIM:

- (a) To design 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.
- (b) To determine experimentally the transfer function of the lag compensating network

4. MATERIAL / EQUIPMENT REQUIRED:

S. No	Apparatus	Range	Qty
1	Decade Resistance Box	-	02No
2	Decade Capacitance Box	-	01No
3	Signal Generator	-	01No
4	CRO with probes	-	01Set
5	Connecting wires	-	Few

5. THEORY / HYPOTHESIS:

The characteristics of lag compensator's:

Consider lag compensator having the following transfer function:

$$G_c(s) = K_c \beta \frac{(Ts+1)}{(\beta Ts+1)} = K_c \frac{s+(1/T)}{[s+(1/\beta T)]} \text{ where } (\beta > 1)$$

In the complex plane, lag compensator has a zero at $s = -(1/T)$ and a pole at $s = -(1/\beta T)$. The pole is located to the right of the zero.

The magnitude of a lag compensator becomes 10 (or 20dB) at low frequencies and unity (or 0dB) at high frequencies. Thus lag compensator is essentially a low pass filter.

The primary function of lag compensator is to provide attenuation in the high frequency range to give a system sufficient phase margin. The phase lag characteristic is of no consequence in lag compensation.



9. FORMULA / CALCULATIONS:

- **Design of lag compensating network**

Given $\Phi_m =$ _____ degree and $f =$ _____ kHz

$$\alpha = \beta = \frac{1 - \sin \Phi_m}{1 + \sin \Phi_m}$$

therefore $\alpha =$ _____

$$\omega_n = 1 / (T \sqrt{\alpha}) \text{ but } \omega_n = 2 \pi f_n \text{ Hz}$$

$$T = 1 / (2 \pi f_n \sqrt{\alpha}) \text{ Sec.}$$

$$T = \text{_____ } \mu\text{S}$$

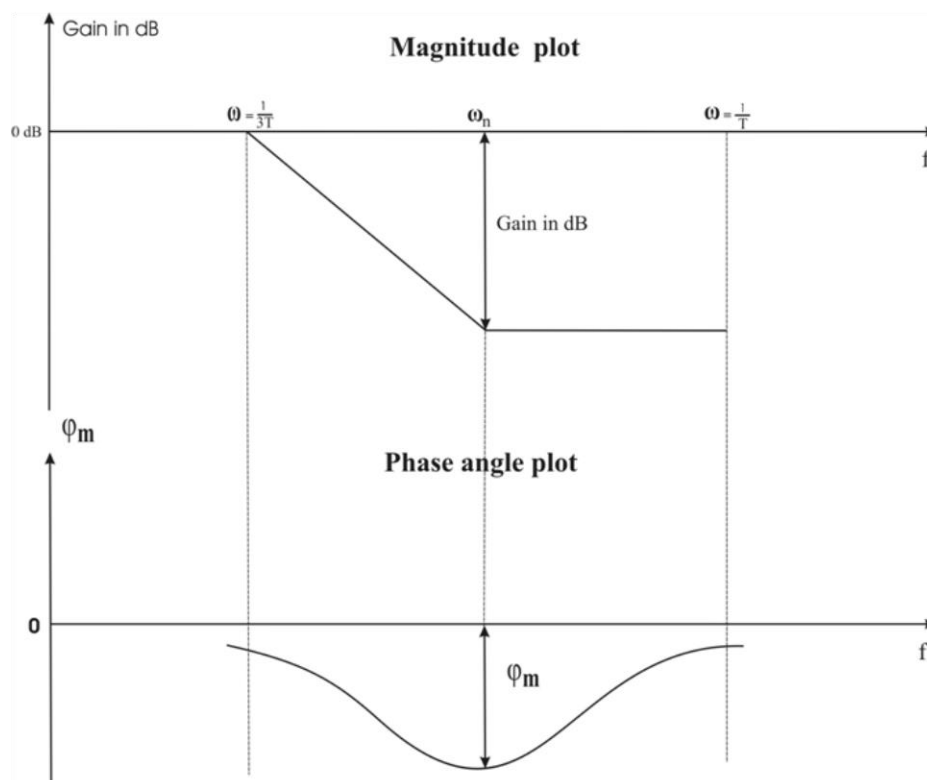
$$\text{Also } T = R_2 C \text{ and } \beta = (R_1 + R_2) / R_2$$


$$\text{Let } C = \text{_____ } \mu\text{F}$$

$$R_2 = T / C = \text{_____ } \Omega$$

$$R_1 = \beta R_2 - R_2 = \text{_____} = \text{_____ } \Omega$$

10. GRAPHS / OUTPUTS:



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11. RESULTS & ANALYSIS:

Frequency in Hz	$V_{0(p-p)}$ in Volts	Gain in dB	Phase angle Φ_m	Φ_m

12. OUTCOME & CONCLUSIONS:

13. REMARKS:



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EXPERIMENT NO:	Date Conducted	Marks
5b		

1. TITLE: FREQUENCY RESPONSE OF LAG COMPENSATING NETWORK USING MATLAB

2. LEARNING OBJECTIVES:

- Determination of Transfer function from bode plot
- Ability to use MATLAB commands.

3. AIM: Determination of frequency response of lag compensating network using MATLAB.

4. MATERIAL / EQUIPMENT REQUIRED:

- Computer system
- MATLAB

5. THEORY / HYPOTHESIS:

- Refer above expt theory.

6. PROCEDURE / PROGRAMME / ACTIVITY:

LAG NETWORK

```
%bode plot for lag network
```

```
num=[0 6.59*10(-5) 1];
```

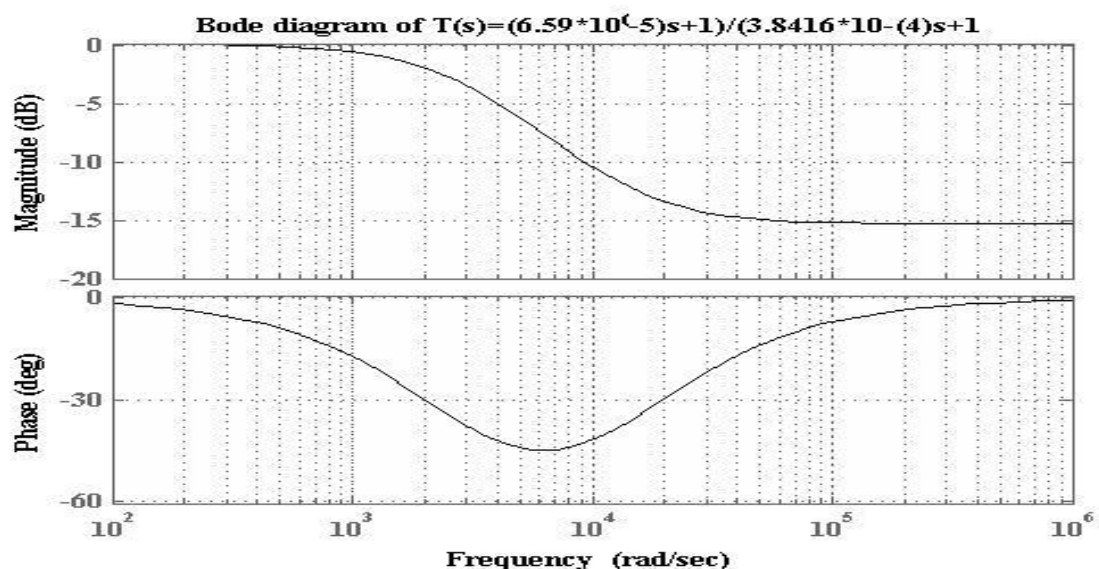
```
den=[0 3.8416*10(-4) 1];
```


```
bode(num,den);
```

```
grid;
```

```
title('Bode diagram of T(s)=(6.59*10(-5)s+1)/(3.8416*10(-4)s+1')
```

7. GRAPHS / OUTPUTS:



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8. RESULTS & ANALYSIS:

- **SIMULATION RESULTS:**

At given design frequency of ____Hz.


Gain in dB = _____dB. Phase angle= ____°.

- **Theoretical Results:**

Gain in dB= _____dB Phase angle= ____°.

9. OUTCOME & CONCLUSIONS:

9. REMARKS:

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EXPERIMENT NO:	Date Conducted	Marks
6a		

1. TITLE: DESIGN OF LEAD - LAG COMPENSATING NETWORK

2. LEARNING OBJECTIVES:

- Able to identify phase lead-lag.
- Able to understand compensating network.
- Able to understand frequency response.
- Importance of compensating network.

3. AIM:

- Experiment to draw the frequency response characteristic of a given lag- lead compensating network.

4. MATERIAL / EQUIPMENT REQUIRED:

S. No	Apparatus	Range	Qty
1	Decade Resistance Box	-	02 Nos.
2	Decade Capacitance Box	-	02 Nos.
3	Signal Generator	0.01 μF	01 No.
4	CRO with probes	-	02 Nos.
5	Connecting wires	-	Few

5. THEORY / Hypothesis:

Characteristic of lead lag compensator: Consider the lead-lag compensator given by

$$G_c(s) = K_c \frac{[S+(1/T_1)] [S+(1/T_2)]}{[s+ \alpha /T_1] [S+(1/\beta T_2)]} \times \frac{[S+(1/T_2)] [T_2 s+1]}{[S+(1/T_2)] [T_2 s+1]} = \beta \frac{[S+(1/T_2)] [T_2 s+1]}{[S+(1/T_2)] [T_2 s+1]} \quad (\beta > 1)$$

$[S+(1/\beta T_2)] [\beta T_2 s+1]$
produces the effect of the lag network.

And the term,

$$\frac{[S+(1/T_1)] [T_1 s+1]}{[S+(\alpha/T_1)] [(T_1/\alpha)s+1]} = (1/\alpha) \frac{[S+(1/T_1)] [T_1 s+1]}{[S+(\alpha/T_1)] [(T_1/\alpha)s+1]} \quad (\alpha > 1)$$

produces the effect of the lead network.

In designing the lead lag compensator, we frequently choose $\alpha = \beta$. (This is not necessary. We can, of course, choose $\alpha \neq \beta$. The polar plot of the the lead lag compensator will be drawn.

The design of lead lag compensator by the frequency response approach is based on the combination of the design techniques which have been done under lag compensation and lead compensation.



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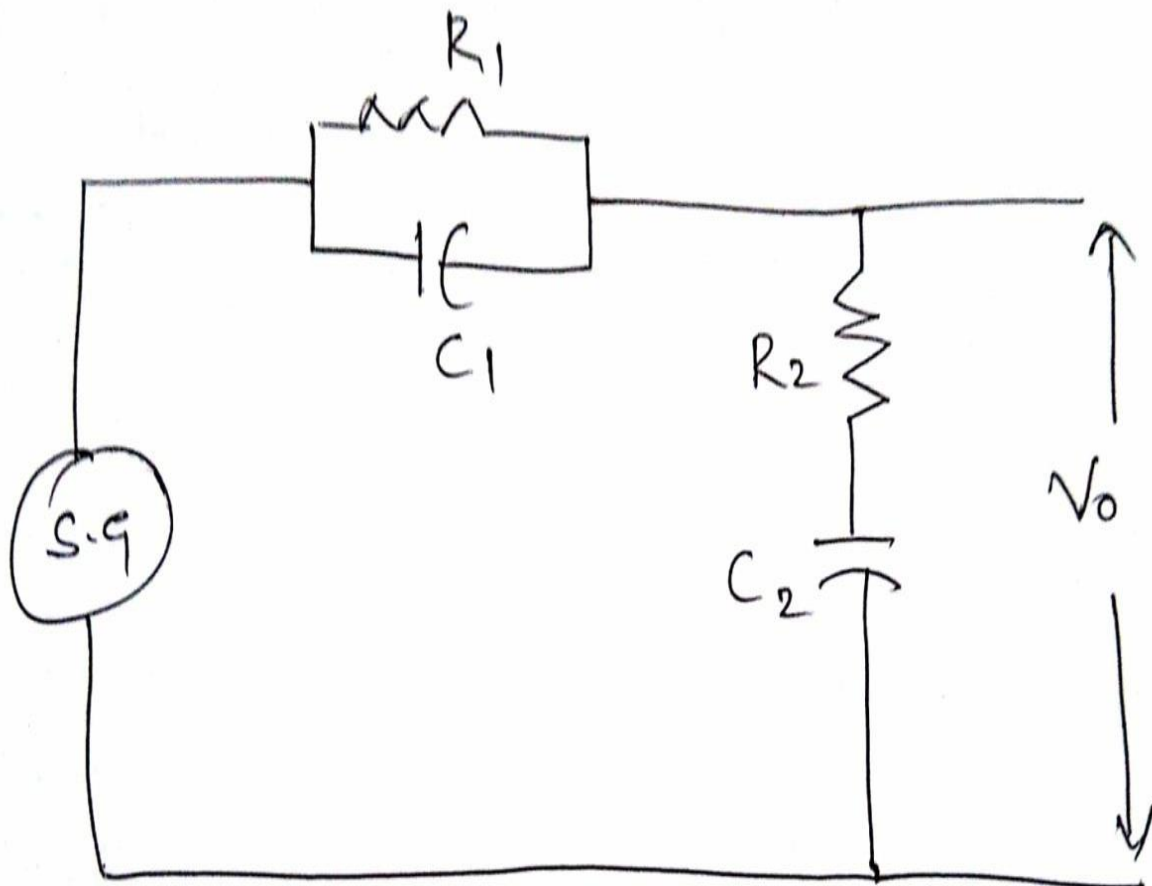
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6. PROCEDURE / PROGRAMME / ACTIVITY:

- Design the lead-lag compensating network for given phase angle and frequency using formula.
- Rig up the circuit as shown in fig.
- Apply sinusoidal input signal of 2 V (peak to peak) at low frequency say 100Hz.
- Increase the frequency of input signal gradually and at each step note down the peak to peak amplitude of the signal. Also note down the phase difference between input and output signal at each step using lissages pattern on CRO.
- The input signal amplitude remains same for all the frequency range.
- Plot the graph of gain in dB Vs frequency and phase angle Vs frequency

7. Block / Circuit / model / reaction Diagram:





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$$\omega_n = 1 / (T\sqrt{\beta}) \text{ but } \omega_n = 2 \Pi f_n \text{ Hz}$$

$$T = 1 / (\omega_n \sqrt{\beta}) = 1 / (2 \Pi f \sqrt{\beta}) = \text{_____ sec.}$$

$$\text{Also } T = R_2 C \text{ and } \beta = (R_1 + R_2) / R_2$$

$$R_2 = T / C = \text{_____ } \Omega$$

For lead circuit:

$$\text{Given } \Phi_m = \text{_____ degree}$$

$$1 - \sin \Phi_m$$

$$\alpha = \text{_____} = \text{_____}$$

$$1 + \sin \Phi_m$$

$$\omega_n = 1 / (T\sqrt{\alpha}) \text{ But } \omega_n = 2 \Pi f_n$$

$$T = 1 / (2 \Pi f_n \sqrt{\alpha}) = \text{_____ sec.}$$

$$\text{Also, } T = R_1 C \text{ and } \alpha = (R_1 + R_2) / R_2, R_1 = T / C, R_1 = \text{_____ } \Omega$$

11. Graphs / Outputs:

12. Results & Analysis:

Frequency in Hz	$V_{i(p-p)}$ in Volts	$V_{o(p-p)}$ in Volts	Gain in dB	Phase angle Φ_m	Φ_m

13. Outcome & Conclusions:

14. REMARKS:



EXPERIMENT NO:	Date Conducted	Marks
6b		

▪ **TITLE: LAG-LEAD COMPENSATOR NETWORK**

2. AIM: To draw the frequency response characteristics of the lag-lead compensator network and determination of its transfer function.

3. MATERIAL / EQUIPMENT REQUIRED:

- Computer system
- MATLAB

4. THEORY / HYPOTHESIS:

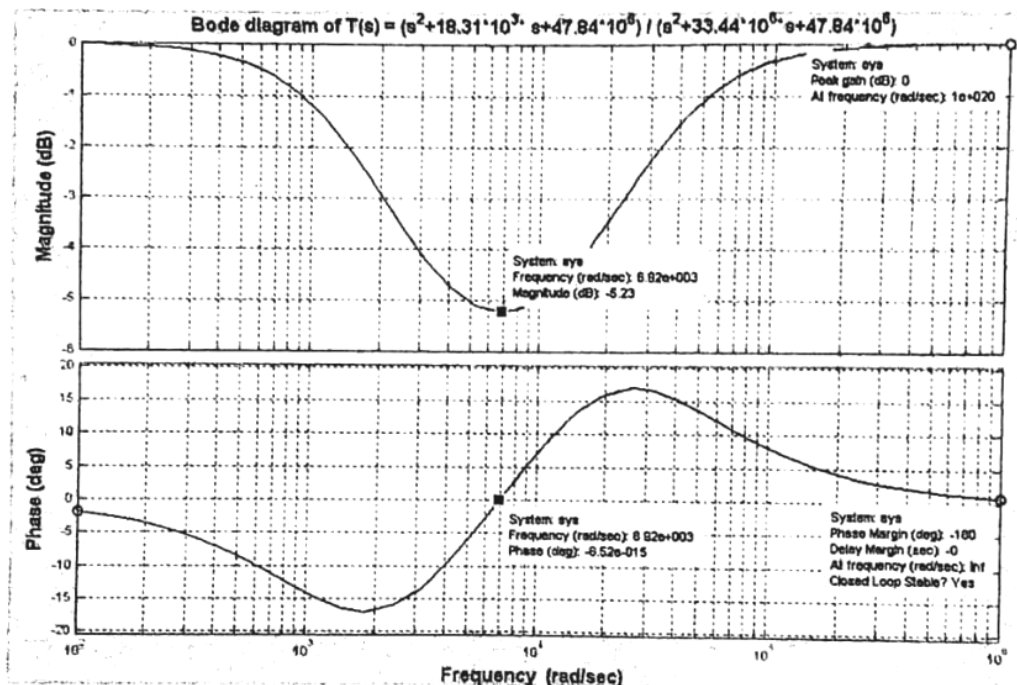
- Refer 6A experiment theory.


5. PROCEDURE / PROGRAMME / ACTIVITY:

LEAD-LAG NETWORK

```
%Bode plot for lead-lag network  
num = [ 1 18.31*10^3 47.84*10^6 ];  
den = [ 1 33.44*10^3 47.84*10^6 ];  
bode(num, den);  
grid;  
title('Bode diagram of T(s) = (s^2+ 18.31*10^3*s+47.84*10^6) /  
(s^2+33.44*10^6*s+47.84*10^6)');
```


6. GRAPHS / OUTPUTS:



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11. OUTCOME:

12. CONCLUSIONS:

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EXPERIMENT NO:	Date Conducted	Marks
7a		

2. TITLE:

- **STUDY OF P, PI, PD AND PID CONTROLLER**

3. LEARNING OBJECTIVES:

- Different types of controllers
- Able to identify steady state error.
- Able to know peak overshoot.

4. AIM:

- To study the effect of P, PI, PD and PID controller on the step response of a feedback control system (using control engineering trainer/process control simulator). Verify the same by simulation.

5. MATERIAL / EQUIPMENT REQUIRED:

S.no	Apparatus	Qty
1	Analog PID controller	01No
2	CRO and Probes	01Set
5	Patch cords	Few

- **THEORY / HYPOTHESIS:**

Introduction to PID controllers

A controller is a device which when introduced in feedback or forward path of system, controls the steady state and transient response as per the requirement. Such device converts input to the controller to some other form of error than proportional to error due to which steady state and transient response gets improved. In most of the practical systems, controller input is proportional to error generated. Such systems are called proportional to error mechanisms (P type)

Consider such second order system where controller input is error itself and proportional constant is $K=1$ as shown in the fig 7.40

$$G(s)H(s) = \omega_n^2 / s(s+2\xi\omega_n)$$

$$C(s)R(s) = \omega_n^2 / (s^2+2\xi\omega_n s+\omega_n^2)$$

for this system damping ration is ξ and natural frequency ω_n .

And for steady state error

$$K_p = \lim_{s \rightarrow 0} G(s)H(s) = \infty$$

and

$$K_v = \lim_{s \rightarrow 0} sG(s)H(s) = \omega_n / 2\xi$$

Now if transient response is to be improved, damping ratio must be changed.

- i) Less settling time ii) Less overshoot iii) Less rise time iv) smallest s.s error



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By increase in K_v i.e increase in system gain, s.s error can be reduced but due to high gain settling time and peak overshoot increases. This may lead to instability of system. So, compromise is made to keep steady state error and overshoot within acceptable limits by providing following different types of controllers.

- i) PD ----> Proportional+ Derivative Action.
- ii) PI -----> Proportional + Integral Action.
- iii) PID ----> Proportional + Derivative + Integral Action.
- iv) Rate feedback controller (output derivative controller)

PD type controller:

A controller in the forward path, which changes the controller input to the proportional plus derivative of error signal is called PD controller.

i.e Input to controller = $K e(t) + [T_d de(t) / dt]$

Taking laplace = $K E(s) + s T_d E(s) = E(s) [K + s T_d]$

The T.F of such controller is $[K + s T_d]$. This can be realised as shown in the fig. 7.41

Assuming $K=1$, we can write,

$$G(s) = [(1+sT_d) \omega_n^2] / [s(s+2\xi\omega_n)]$$

$$\text{and } C(s)/R(s) = [(1+sT_d) \omega_n^2] / \{s^2+s[2\xi\omega_n + \omega_n^2 T_d] + \omega_n^2\}$$

comparing denominator with standard form,

ω_n is same as in the previous P type controller.

$$\text{And } 2\xi'\omega_n = 2\xi\omega_n + \omega_n^2 T_d$$

$$\xi' = \xi + (\omega_n T_d / 2)$$

Because of this controller, damping ratio increases by factor $\omega_n T_d / 2$ while,

$$K_p = \lim_{s \rightarrow 0} G(s)H(s) = \infty$$

$$s \rightarrow 0$$

and

$$K_v = \lim_{s \rightarrow 0} sG(s)H(s) = \omega_n / 2\xi$$

$$s \rightarrow 0$$

As there is no change in coefficients, error also will remain same. Hence PD controller has following effects on system.

- i) It increases damping ratio.
- ii) ' ω_n ' for system remains unchanged.
- iii) TYPE of the system remains unchanged
- iv) It reduces peak overshoot.
- v) It reduces settling time.
- vi) Steady state error remains unchanged.

In general it improves transient part without affecting steady state.



PI type of controller:

A controller in the forward path, which changes the controller input to the proportional plus integral of the error signal is called PI controller.

i.e Input to controller = $K e(t) + K_i \int e(t) dt$

Taking Laplace = $KE(s) + (K_i/s) E(s) = E(s) [K + (K_i/s)]$

Therefore The T.F of such controller is $[K + (K_i/s)]$ and can be realised shown in the fig 7.42

Assuming $K=1$, we can write,

$$G(s) = [K + (K_i/s)] \omega_n^2 / [s(s + 2\xi\omega_n)] = (K_i + s)\omega_n^2 / s^2(s + 2\xi\omega_n)$$

i.e system becomes TYPE 2 in nature.

$$\text{And } C(s)/R(s) = (K_i + s)\omega_n^2 / (s^2 + 2\xi\omega_n s + s\omega_n^2 + K_i\omega_n^2)$$

i.e it becomes third order.

Now as order increases by one, system relatively becomes less stable as K_i must be designed in such a way that system will be remain in stable condition. Second order system is always stable. Hence transient response gets badly if controller is not designed properly.

While

$$K_p = \lim_{s \rightarrow 0} G(s)H(s) = \infty, e_{ss} = 0$$

$$s \rightarrow 0$$

and

$$K_v = \lim_{s \rightarrow 0} sG(s)H(s) = \infty, e_{ss} = 0$$

$$s \rightarrow 0$$

Hence as type is increased by one, error becomes zero for ramp type of inputs i.e. Steady state of system gets improved and system becomes more accurate in nature.

Hence PI controller has following effects:

- i) It increases order of the system.
- ii) It increases TYPE of the system.
- iii) Design of K_i must be proper to maintain stability of system. So it makes system relatively less stable.
- iv) Steady state error reduces tremendously for same type of inputs. i.e. In general this controller improves steady state part affecting the transient part.

PID type of controllers:

As PD improves transient and pi improves steady state, combination of two may be used to improve overall time response of the system. This can be shown in figure. 7.43


7. PROCEDURE / PROGRAMME / ACTIVITY:

• Proportional controller:

1. Connections are made as per the circuit diagram.
2. Set input amplitude to 1V (p-p) and frequency to lower value.
3. Note down the value of 'x' and 'y' from figure keeping the value in x-y mode.
4. Repeat above steps for different values of K_p .

• Proportional integral (PI) Controller :

1. Connections are made as per the circuit diagram.

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2. Set the input amplitude 2V (p-p) and frequency to lower value, $K_i=0$, $K_d=0$.
3. Set $K_p=1.6$ record the peak over shoot and steady state error.
4. Repeat above steps for different values of K_c in small steps

- **Proportional + integral + derivative (PID) Controller :**

1. Connections are made as per the circuit diagram and also connect o/p to summer block.
2. Set $K_p=1.6$, record the peak over shoot, $K_i=$ _____ and $K_d=0$, with input 1V (p-p) of lower frequency.
3. Repeat the above steps for different values of K_d in small steps.

- **Proportional Differential (PD) Controller :**

8. BLOCK / CIRCUIT / MODEL / REACTION DIAGRAM:

CIRCUIT DIAGRAM

BLOCK DIAGRAM



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9. OBSERVATION TABLE / LOOKUP TABLE / TRUTH TABLE:

• **P- Controller:**

Division	$K_p=0.002*\text{div}$	x	y	% Steady state error	% peak overshoot

• **PI- Controller:**

Division	$K_i=0.002 * \text{div} * \text{_____}$	x	y	% Steady state error	% peak overshoot

• **PID- Controller:**

Division	$K_i=0.002 * \text{div} * \text{_____}$	x	y	% Steady state error	% peak overshoot

• **PD- Controller:**

Division	$K_d=0.002 * \text{div} * \text{_____}$	x	y	% Steady state error	% peak overshoot



10. FORMULA / CALCULATIONS:

$$e_{ss} = \frac{(P-P)I/P-x}{(P-P)I/P}$$

$$\% \text{peak overshoot} = \frac{Y-X}{x} \times 100$$


11. GRAPHS / OUTPUTS:

12. RESULTS & ANALYSIS:

Controller Type	% Steady state error	% peak over shoot
P-Controller		
PI-Controller		
PD-Controller		
PID-Controller		

13. OUTCOME & CONCLUSIONS:

14. REMARKS:

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7b		

▪ **TITLE: STUDY OF P, PI, PD AND PID CONTROLLER**

2. LEARNING OBJECTIVES:

- Understanding of step response of different controller.
- Understanding of effect of damping factor.
- Ability to use MATLAB command.

3. AIM: To Simulate P, PI, PD and PID controller using MAT LAB.

4. MATERIAL / EQUIPMENT REQUIRED:

- Computer system
- MATLAB

6. THEORY / HYPOTHESIS:

- Refer 7A experiment theory.

7. PROCEDURE / PROGRAMME / ACTIVITY:

• **P-Controller**

```
%unit step response of 2nd order system with P-controller
num=[0 0 100];
den=[.02 1 100];
step(num,den);
grid;
Title('Unit step response of 2nd order system with P-controller
T(s)=100/(.02*s^2+s+100)')
```

• **PI-Controller**

```
%unit step response of 2nd order system with PI-controller
num=[0 0 100 20];
den=[.02 1 100 20];
step(num,den);
grid;
Title('Unit step response of 2nd order system with PI-controller
T(s)=(100*s+20)/(.02*s^3+s^2+100s+20)')
```

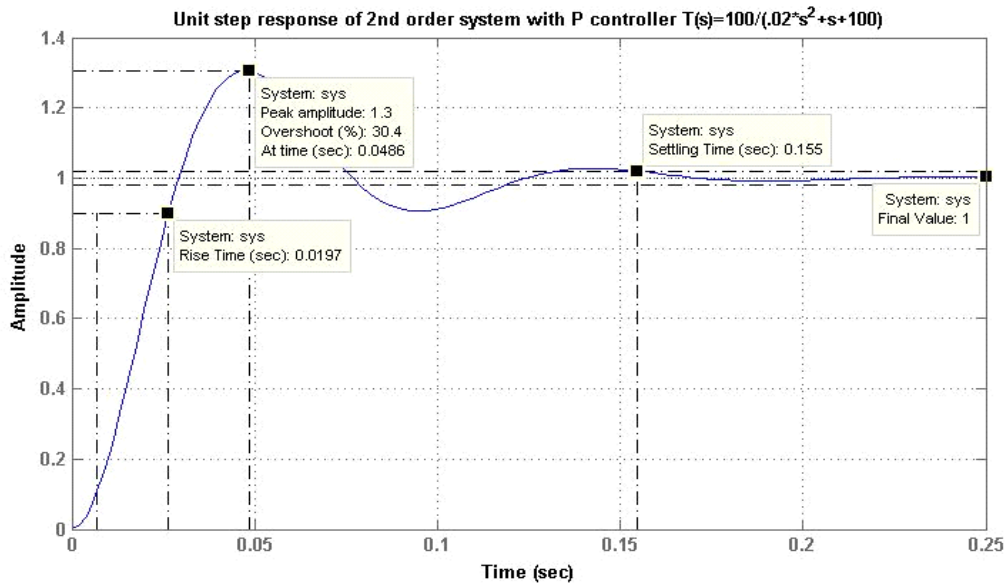
• **PID-Controller**

```
%unit step response of 2nd order system with PID-controller
num=[0 0.7 100 20];
den=[.02 1.7 100 20];
step(num,den);
grid;
Title('Unit step response of 2nd order system with PID-
controller T(S)=(.7S^2+100S+20)/(.02S^3+1.7S^2+100S+20)')
```

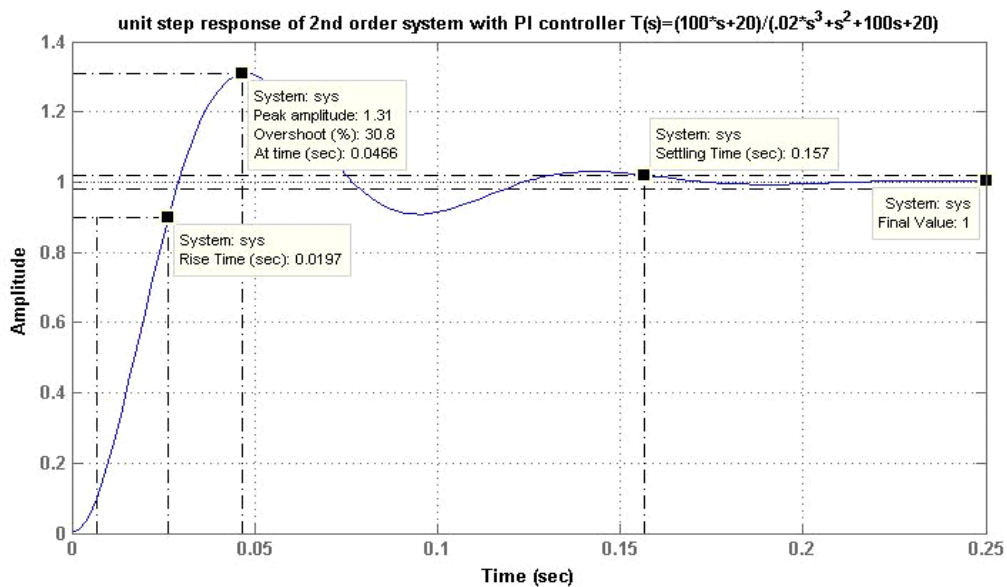


8. GRAPHS / OUTPUTS:

- P- Controller**

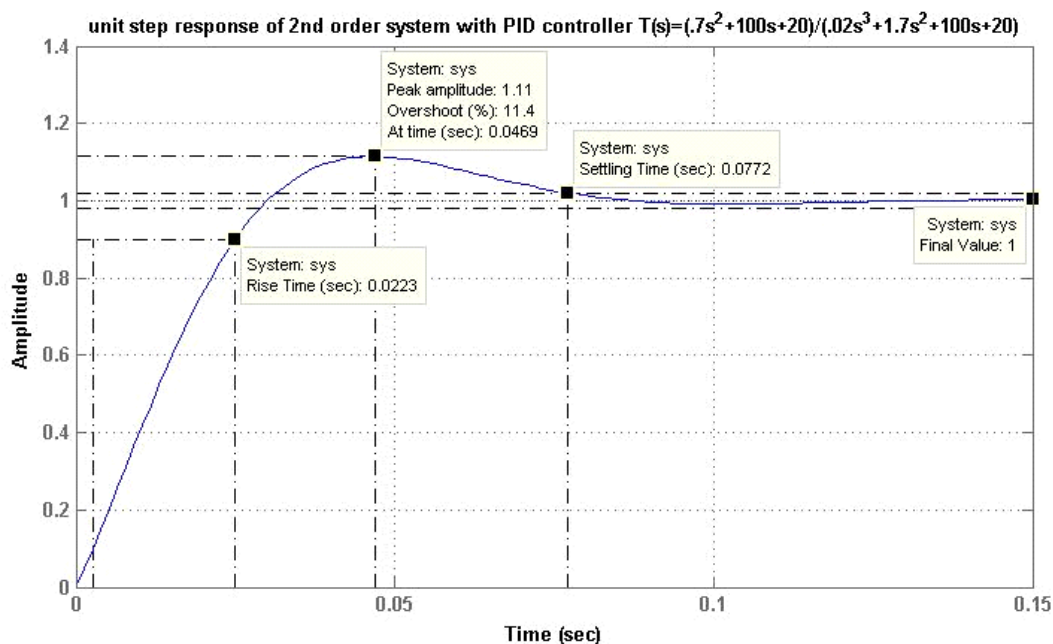


- PI-Controller:**





PID-Controller



9. RESULTS & ANALYSIS:

- **SIMULATION RESULTS:**

For P-Controller:

Rise time= _____ Sec
Settling time = _____ Sec
% Overshoot = _____ %

For PI-Controller:

Rise time = _____ Sec
Settling time = _____ Sec
% Overshoot = _____ %

For PID-Controller:

Rise time = _____ Sec
Settling time = _____ Sec
% Overshoot = _____ %

10. OUTCOME & CONCLUSIONS:

11. REMARKS:



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EXPERIMENT NO:	Date Conducted	Marks
8		

1. TITLE: TIME RESPONSE CHARACTERISTICS OF 2ND ORDER SYSTEM

2. LEARNING OBJECTIVES:

- To study the performance characteristics of second order systems using MATLAB.
- To study the effect of additional poles and zeroes on time response of second order system.
- To study the effect of pole location on stability.
- To study the system stability.

3. AIM:

- A) Simulation of a typical second order system and determination of step response and evaluation of time- domain specifications.
- B) Evaluation of the effect of additional poles and zeroes on time response of second order system.
- C) Evaluation of effect of pole location on stability.
- D) Effect of loop gain of a negative feedback system on stability.

4. MATERIAL / EQUIPMENT REQUIRED:

- Computer system
- MATLAB

5. THEORY / HYPOTHESIS:

DETERMINATION OF TRANSFER FUNCTION

Apply KVL to given network, we get

$$V_0(t) = (1/C) \int i dt$$

taking Laplace transform we get

$$V_s(s) = (1/SC) I(s) \dots\dots\dots(1)$$

$$V_i(t) = R_i * i(t) + L * [di(t)/dt] + (1/C) * \int i dt$$

Taking Laplace transform we get

$$V_i(s) = (R + sL + 1/SC) * I(s)$$


Hence T.F is given as

$$T.F = V_0(s) / V_i(s) = [(1/SC) * I(s)] / [R + sL + 1/SC]$$

$$= 1 / (s^2 LC + sRC + 1)$$

Dividing throughout by LC we get

$$V_0(s) / V_i(s) = (1/LC) / [s^2 + (R/L) * s + (1/LC)]$$

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6. PROCEDURE / PROGRAMME / ACTIVITY:

UNIT STEP RESPONSE UNDAMPED CASE

```
%unit step response
num=[0 0 10^10];
den=[1 0 10^10];
step(num,den);
grid;
title('Time response of second order system
T(s)=10^10/(s^2+10^10) zita=0')
```

UNIT STEP RESPONSE UNDER-DAMPED CASE

```
%unit step response
num=[0 0 10^10];
den=[1 40000 10^10];
step(num,den);
grid;
title('Time response of second order system
T(s)=10^10/(s^2+40000*s+10^10) zita=0.2')
```

UNIT STEP RESPONSE UNDER-DAMPED CASE

```
%unit step response
num=[0 0 10^10];
den=[1 100000 10^10];
step(num,den);
grid;
title('Time response of second order system
T(s)=10^10/(s^2+100000*s+10^10) zita=0.5')
```

UNIT STEP RESPONSE CRITICALLY-DAMPED CASE

```
%unit step response
num=[0 0 10^10];
den=[1 200000 10^10];
step(num,den);
grid;
title('Time response of second order system
T(s)=10^10/(s^2+200000*s+10^10) zita=1')
```

a) Simulation of a typical second order system and determination of step response and evaluation of time- domain specifications.

```
clc
% prg c(t)
num = 1;
den = [1 10 20];
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
```

B) Evaluation of the effect of additional poles and zeroes on time response of second order system.

```
%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)')
```

C) Evaluation of effect of pole location on stability.

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

7. OBSERVATION TABLE / LOOKUP TABLE / TRUTH TABLE:

8. FORMULA / CALCULATIONS:



9. GRAPHS / OUTPUTS:

12. RESULTS & ANALYSIS:

• **Simulation Results:**

For Under damped condition ($0 < \xi < 1$)

Rise time = _____ Sec

Settling time = _____ Sec

Peak overshoot = _____ %

For under damped condition ($0 < \xi < 1$)

Rise time = _____ Sec

Settling time = _____ Sec

Peak overshoot = _____ %

For critically damped condition ($\xi = 1$)

Rise time = _____ Sec

Settling time = _____ Sec

For Over damped condition ($1 < \xi < \infty$)

Rise time = _____ Sec

Settling time = _____ Sec

13. OUTCOME & CONCLUSIONS:

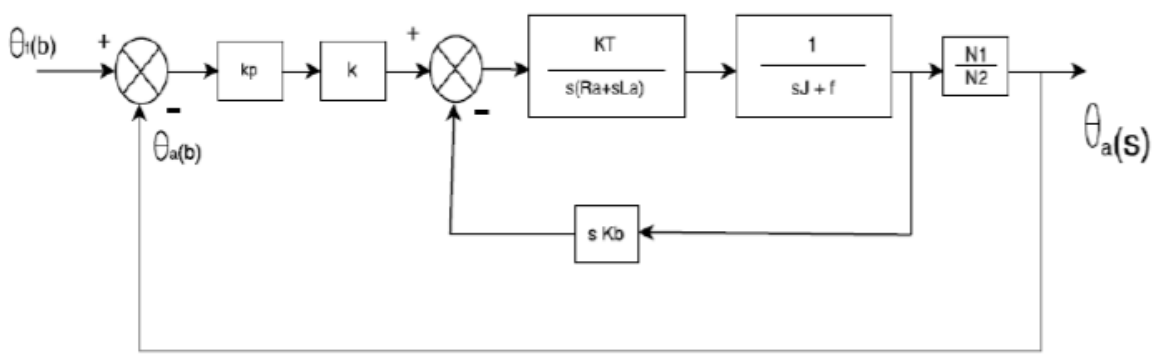
14. REMARKS:



EXPERIMENT NO:	Date Conducted	Marks
9		

1. TITLE: DC POSITION CONTROL SYSTEM

- 2. AIM:**
1. To obtain the step response of a DC Position control system using MAT LAB.
 2. To verify the effect of input wave form, loop gain system type on steady state Errors.
- 3. THEORY:** The DC Position Control System block diagram is given below.

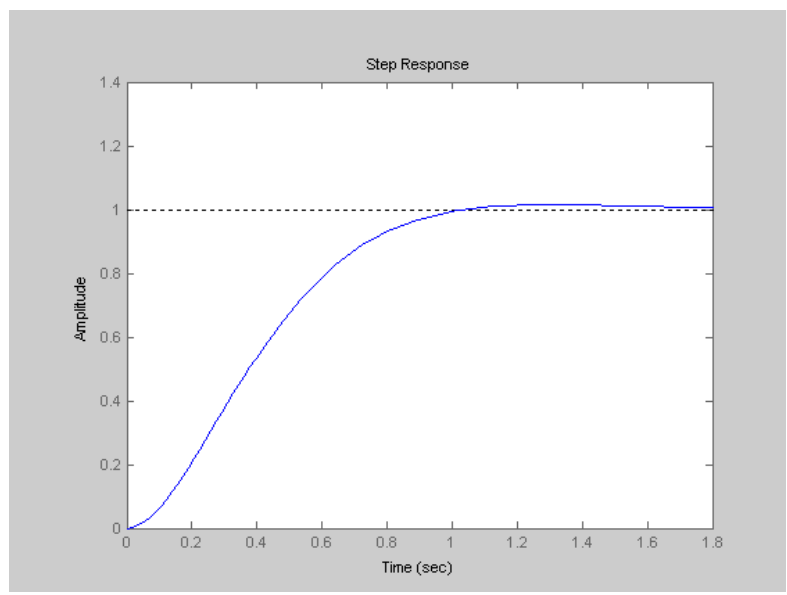


The Transfer Function can be written as:

$$TF = \frac{kb}{s[(Ra + sLa)(sJ + f) + kb kT] + kb}$$

Where, $kb = k kp kT \left(\frac{N1}{N2}\right) = \text{System Gain}$

Graph:

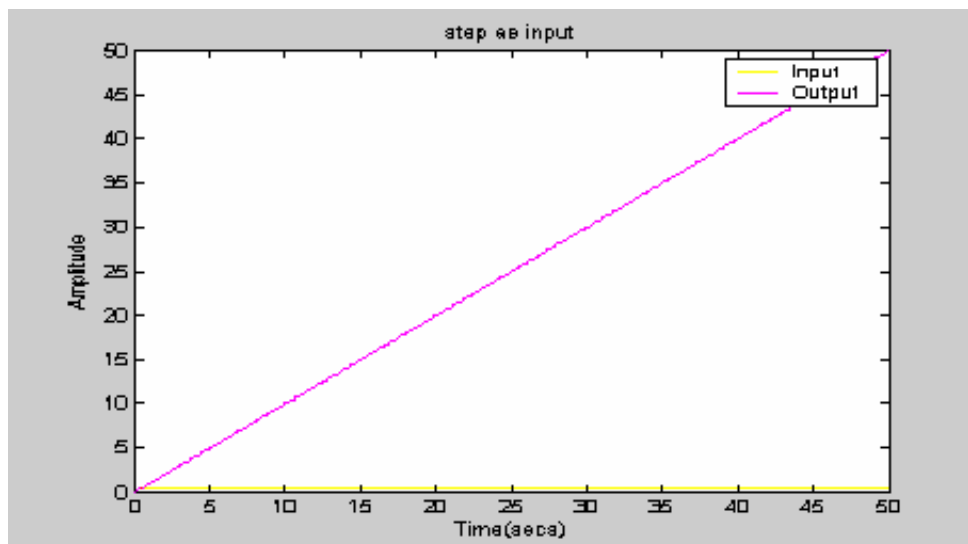




PROGRAM:

```
% DC position step response
num1=[      ];
den1=[      ];
sys=tf(num1,den1);
step(sys)
title('Dc position step response')
figure
```

<pre>% 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</pre>	<pre>% 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</pre>	<pre>% 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 ')</pre>
---	---	---





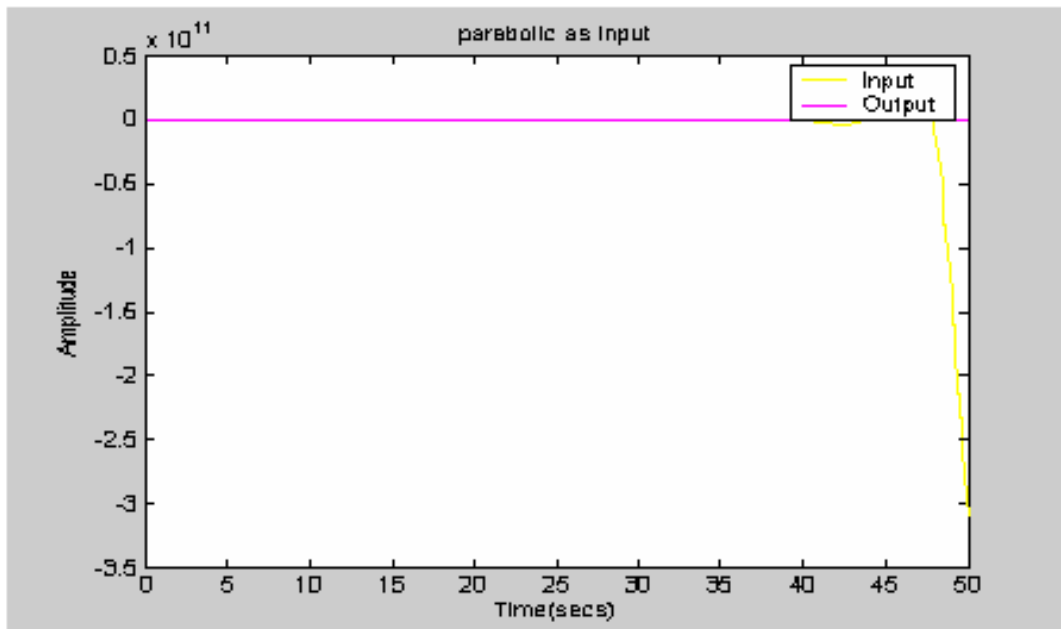
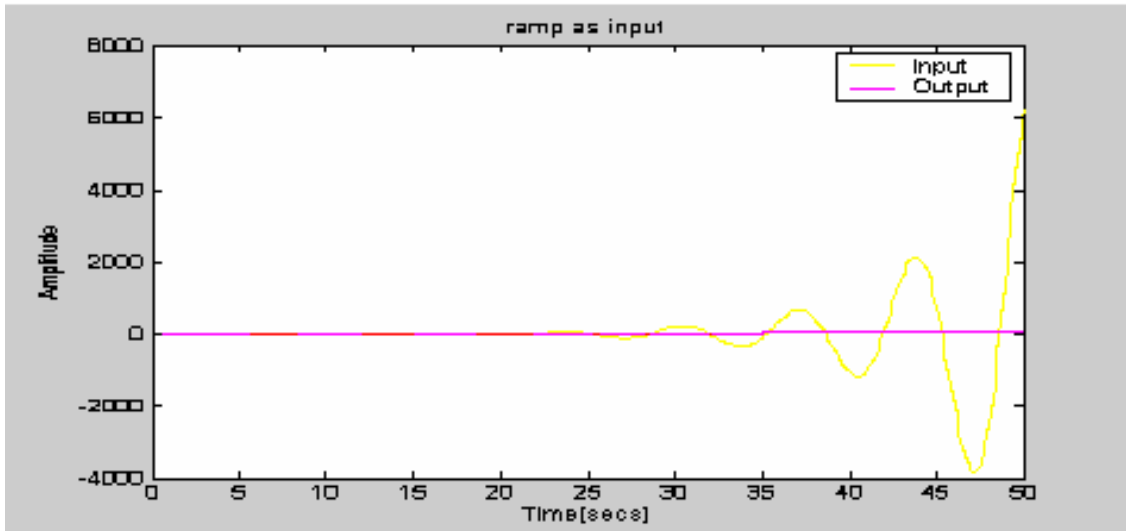
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EXPERIMENT NO:	Date Conducted	Marks
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1. TITLE: THE RELATION BETWEEN FREQUENCY RESPONSE AND TRANSIENT RESPONSE

2. AIM: To examine the relationship between open loop frequency response and stability, open loop frequency and closed loop transient response.

3. PROCEDURE / PROGRAMME / ACTIVITY:

% 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')

```

4. RESULTS & ANALYSIS:

5. OUTCOME & CONCLUSIONS:

6. REMARKS:



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1. TITLE:

- **BODE, NYQUIST AND ROOT LOCUS WITH RESPECT TO STABILITY.**

2. LEARNING OBJECTIVES:

- Understanding of Effect of open loop gain & zeros
- Understanding of stability analysis.

3. AIM: Using MATLAB/SCILAB

- a) Effect of open loop and zeroes on root locus contour
- b) Comparative study of Bode, Nyquist and Root locus with respect to Stability.

4. MATERIAL / EQUIPMENT REQUIRED:

- Computer system
- MATLAB

5. THEORY / HYPOTHESIS:

- **ROOT LOCUS**

We have seen that the stability of any closed loop system depends on the locations of the roots of the characteristic equation i.e the locations of closed loop poles. Nature of the transient response is closely related to the location of the poles in the s -plane. It is advantageous to know how the closed loop poles move in the s -plane if some parameters of the system are varied. The knowledge of such movement of the closed loop poles with small changes in the parameters of the system greatly helps in the design of any closed loop system.

Such movement of the poles can be known by the Root Locus method, introduced by W.R.Evans in 1948. This is graphical method, in which movement of poles in the s -plane is sketched when a particular parameter of system is varied from zero to infinity. Note that the parameter is usually the gain but any other parameter may be varied. But for root locus method, gain is assumed to be a parameter which is to be varied from zero to infinity.

- **BODE PLOT**

Basic of any frequency response is to plot magnitude M and angle Φ against input frequency ' ω '. When ' ω ' is varied from 0 to ∞ there is wide range of variations in M and Φ and hence it becomes difficult to accommodate all such variations with linear scale. Hence H.W. Bode suggested the method in which logarithmic values of Magnitude are to be plotted against logarithmic values of frequencies. Such plots are called Logarithmic plots which allows us to show wide range of variations in magnitude on a single paper.

In general Bode plot consists of two parts.

- 1) Magnitude expressed in logarithmic values against logarithmic values of frequency called Magnitude plot.
- 2) Phase angle in degrees against logarithmic values of frequency called phase angle plot.



• NYQUIST PLOT ANALYSIS

The concept of Nyquist plot is based on the polar plot which can be conveniently applied to the stability analysis of any kind of system. The concept is little bit difficult to understand and hence we will divide the discussion in following sections to unfold the Nyquist plot, step by step.

- a. Pole-Zero configuration from Nyquist plot point of view.
- b. Concept of encirclement and number of encirclements.
- c. Analytic function and its singularities.
- d. Mapping theorem or principle of argument.
- e. Nyquist stability criterion.


7. PROCEDURE / PROGRAMME / ACTIVITY:

```
%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
```

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COMPARATIVE STUDY OF BODEPLOT, ROOT LOCUS, NYQUIST PLOT WITH RESPECT TO STABILITY

```

%comparative study of bodeplot, root locus, nyquist plot with
respect to stability
num=[0 0 1 4];
den=[1,2,2,0];

%set the "grid" for plots to 2 rows and 2 columns. place
%the first plot at location 1.
subplot(2,2,1);
bode(num,den);
title('bode plot');

subplot(2,2,3);
rlocus(num,den);
title('root locus');

subplot(2,2,4);
nyquist(num,den);
title('nyquist plot');

```

11. GRAPHS / OUTPUTS:

12. RESULTS & ANALYSIS:

13. OUTCOME & CONCLUSIONS:

14. REMARKS: