



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

(Affiliated to Osmania University & Approved by AICTE, New Delhi)



### LABORATORY MANUAL

### CONTROL SYSTEMS LABORATORY

BE, V Semester (CBCS): 2020-21

NAME: \_\_\_\_\_

ROLL NO: \_\_\_\_\_

BRANCH: \_\_\_\_\_

SEM: \_\_\_\_\_

**DEPARTMENT OF ELECTRICAL AND ELECTRONCS ENGINEERING**

*Empowering youth- Architects of Future World*



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# **METHODIST COLLEGE OF ENGINEERING AND TECHNOLOGY**

## **VISION**

To produce ethical, socially conscious and innovative professionals who would contribute to sustainable technological development of the society.

## **MISSION**

To impart quality engineering education with latest technological developments and interdisciplinary skills to make students succeed in professional practice.

To encourage research culture among faculty and students by establishing state of art laboratories and exposing them to modern industrial and organizational practices.

To inculcate humane qualities like environmental consciousness, leadership, social values, professional ethics and engage in independent and lifelong learning for sustainable contribution to the society.

**DEPARTMENT  
OF  
ELECTRICAL AND ELECTRONICS  
ENGINEERING**

**LABORATORY MANUAL  
CONTROL SYSTEMS LABORATORY**

**Prepared  
By**

Mr. K.Pulla Reddy,  
Assistant Professor



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# **METHODIST**

## **COLLEGE OF ENGINEERING AND TECHNOLOGY**

### **DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING**

#### **VISION**

To become a reputed centre for imparting quality education in Electrical and Electronics Engineering with human values, ethics and social responsibility.

#### **MISSION**

- To impart fundamental knowledge of Electrical, Electronics and Computational Technology.
- To develop professional skills through hands-on experience aligned to industry needs.
- To undertake research in sunrise areas of Electrical and Electronics Engineering.
- To motivate and facilitate individual and team activities to enhance personality skills.



# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### PROGRAM EDUCATIONAL OBJECTIVES

BE-Electrical Engineering graduates shall be able to:

- **PEO1.** Utilize domain knowledge required for analyzing and resolving practical Electrical Engineering problems.
- **PEO2.** Willing to undertake inter-disciplinary projects, demonstrate the professional skills and flair for investigation.
- **PEO3.** Imbibe the state of the art technologies in the ever transforming technical scenario.
- **PEO4.** Exhibit social and professional ethics for sustainable development of the society.



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## COLLEGE OF ENGINEERING AND TECHNOLOGY

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#### PROGRAM OUTCOMES

Engineering Graduates will have ability to:

- **PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of electrical and electronics engineering problems.
- **PO2. Problem analysis:** Identify, formulate, review research literature, and analyze complex electrical and electronics engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3. Design/development of solutions:** Design solutions for complex electrical and electronics engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **PO4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex electrical and electronics engineering activities with an understanding of the limitations.
- **PO6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional electrical and electronics engineering practice.
- **PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- **PO8 Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the electrical and electronics engineering practice.
- **PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- **PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- **PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- **PO12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

## **PROGRAM SPECIFIC OUTCOMES**

At the end of BE program Electrical and Electronics Engineering graduates will be able to:

- **PSO1.** Provide effective solutions in the fields of Power Electronics, Power Systems and Electrical Machines using MATLAB/MULTISIM.
- **PSO2.** Design and Develop various Electrical and Electronics Systems, particularly Renewable Energy Systems.
- **PSO3.** Demonstrate the overall knowledge and contribute for the betterment of the society.



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## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### I. PREREQUISITE(S):

Level	Credits	Semester	Prerequisites
UG	1	1	Power Electronics

#### II. SCHEME OF INSTRUCTIONS

Lectures	Tutorials	Practical	Credits
0	0	2	1

#### III. SCHEME OF EVALUATION & GRADING

S. No	Component				Duration		Maximum Marks	
<b>Continuous Internal Evaluation (CIE)</b>								
1.	Internal Examination – I and II				1 hour each		25	
<b>CIE (Total)</b>						<b>25</b>		
2.	<b>Semester End Examination</b> (University Examination)				3 hours		<b>50</b>	
				<b>TOTAL</b>		<b>75</b>		
<b>% Marks Range</b>	$\geq 90$	80 to < 90	70 to < 80	60 to < 70	50 to < 60	40 to < 50	< 40	Absent
<b>Grade</b>	S	A	B	C	D	E	F	Ab
<b>Grade Point</b>	10	9	8	7	6	5	0	-





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## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### COURSE OUTCOMES

After completing this course the student will be able to:

CO No.	Course Outcome	Taxonomy Level
653.1	To develop transfer function of various control system plants practically by conducting the experiments.	Apply
653.2	Understand Performance of P, PI and PID Controllers.	Understand
653.3	Analyze the concepts to A.C and D.C position control system.	Analyze
653.4	Design of lag and lead compensation networks.	Create
653.5	Apply the concepts of control systems in developing Program using MATLAB.	Apply
653.6	Determine the time response of second order system.	Evaluate

#### MAPPING OF COs WITH POs & PSOs

Correlation Level: High – 3; Medium – 2; Low – 1

PO / CO	PO 1	PO 2	PO 3	P O4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS 01	PS 02	PS 03
C653.1	3	1	-	-	-	-	3	3	-		3	-	1	3	2
C653.2	3	2	-	-	-	-	-	3	-	-	3	-	2	2	2
C653.3	3	2	-	-	-	-	-	3	-	-	3	-	1	1	2
C653.4	3	2	-	-	-	-	-	3	-	-	3	-	3	2	1
C653.5	3	-	3	-	-	3	-	3	--	-	3	-	1	3	2
C653.6	3	-	3	-	3	-	-	3	3	-	3	-	3	2	1
C653	3	1.7 5	3		3	3		3	3		3		1.8 3	2.16	1.66



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### LABORATORY CODE OF CONDUCT

1. Students should report to the labs concerned as per the scheduled time table.
2. Students, who report late to the labs will not be permitted to perform the experiment scheduled for the day.
3. Students to bring a 100 pages note book to enter the readings /observations while performing the experiment.
4. After completion of the experiment, certification of the staff in-charge concerned, in the observation book is necessary.
5. Staff member in-charge shall evaluate for 25 marks, each experiment, based on continuous evaluation which will be entered in the continuous internal evaluation sheet.
6. The record of observations, along with the detailed procedure of the experiment performed in the immediate previous session should be submitted for certification by the staff member in-charge.
7. Not more than three students in a group would be permitted to perform the experiment on the equipment-based lab set up. However only one student is permitted per computer system for computer-based labs.
8. The group-wise division made at the start of the semester should be adhered to, and no mix up with any other group would be allowed.
9. The components required, pertaining to the experiment should be collected from the stores in-charge, after duly filling in the requisition form / log register.
10. After the completion of the experiment, students should disconnect the setup made by them, and return all the components / instruments taken for the purpose, in order.
11. Any damage of the equipment or burn-out of components will be charged at cost as a penalty or the total group of students would be dismissed from the lab for the semester/year.
12. Students should be present in the lab for the total time duration, as scheduled.
13. Students are required to prepare thoroughly, before coming to Laboratory to perform the experiment.
14. Procedure sheets / data sheets provided to the students, if any, should be maintained neatly and returned after the completion of the experiment.



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#### DO'S AND DON'TS IN THE LABORATORY

##### Do's

1. Proper dress has to be maintained while entering in the Lab. (with apron & shoes)
2. Students should carry observation notes and record completed in all aspects.
3. Correct specifications of the equipment have to be mentioned in the circuit diagram.
4. Student should be aware of operating equipment.
5. Students should be at their concerned experiment table, unnecessary moment is restricted.
6. After completing the connections Students should verify the circuits by the Lab Instructor.
7. The reading must be shown to the Lecturer In-Charge for verification.
8. Students must ensure that all switches are in the OFF position, all the connections are removed.
9. All patch cords and stools should be placed at their original positions.

##### Don'ts

1. Don't come late to the Lab.
2. Don't enter into the Lab with Golden rings, bracelets and bangles.
3. Don't make or remove the connections with power ON.
4. Don't switch ON the supply without verifying by the Staff Member.
5. Don't switch OFF the machine with load.
6. Don't leave the lab without the permission of the Lecturer In-Charge.

##### Before Leaving Lab:

- Place the seating stools under the lab bench.
- Turn off the power to all instruments.
- Return all the equipment to lab assistant.
- Turn off the main power switch to the lab bench.
- Please check the laboratory notice board regularly for updates.



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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERIN

## CONTENTS

Sl. No.	Name of Experiment	Page No.
1	Characteristics of D.C. and AC. Servomotors.	
2	Characteristics of synchro.	
3	Frequency response of second order system.	
4	Step response of second order system.	
5	D.C. Position control system.	
6	A.C. Position control system	
7	Performance of P, PI and PID Controller on system response.	
8	Design of lag and lead compensation.	
9	ON - OFF temperature control systems.	
10	Simulation of control system concepts using MATLAB.	
<b>Additional Experiments</b>		
11	Simulation of Root locus plot using MATLAB.	
12	Test for Controllability and Observability by using MATLAB.	

## **Expt No.1. (a) CHARACTERISTICS OF DC SERVOMOTOR**

**Aim:** To obtain Torque – Speed characteristics of DC Servomotor.

**Apparatus:** DC Servomotor kit

Patch chords

Multi-meter

**Theory:**

A feedback control system consists of several components such as error detectors, power amplifiers, actuators, sensors etc. along with the process being controlled.

A DC servo motor is used as an actuator to drive a load. Due to less rotor inertia, they have a high ratio of starting torque to inertia. Depending upon the speed control technique applied, (i.e., due to variable armature supply or field supply) DC servomotors are of two types known as armature controlled and field controlled DC servo motors.

DC motors are constructed using rare earth permanent magnets which have high residual flux density & high coercivity. As no field winding is used, field copper losses are zero resulting in higher efficiency. As armature reaction is negligible, speed is directly proportional to armature current in the winding for a given torque and speed torque characteristics of this motor is flat over wide range. Servo motors are used widely in position control systems. A servo mechanism is one, in which the controlled variable is a mechanical position, or the rate of change of position, i.e., velocity or acceleration.

**Description of the setup:**

This setup consists of a DC Servomotor whose characteristic is to be studied. A variable DC supply is provided to vary the speed of the DC motor. A speed sensor is attached to the motor shaft. A tachometer is provided to read the motor speed in rpm. A pulley is attached to the shaft of the DC Servomotor for mechanical loading arrangement. Another pulley is attached to the motor assembly to suspend the load.

**Speed variation and speed measurement:**

A variable DC voltage from 1V to 12V with 1A is generated using LM 317 metal pack voltage regulator. This source of voltage is used to vary the speed of the motor. The speed sensor must be connected from motor assembly to the instrument by the socket provided in the front panel. The speed sensor, sense the speed of the motor and generates AC signal whose frequency is proportional to the rpm. The signal conditioner converts frequency into voltage, corresponding to rpm. The digital panel meter displays the speed in rpm at the front panel of the instrument. The speed of the motor can be suddenly brought to zero by switching off the variable DC power supply through the switch ON / OFF provided at the front panel.

**Torque measurement:**

In order to measure the torque produced by the DC Servomotor, a variable load arrangement on the DC Servomotor is available. The shaft of the DC Servomotor is provided with the pulley. Another pulley is provided to suspend the load through it. The motor is loaded by adding the weights through the thread and pulley system.

**Related Formulae:**

$$T = K.I_a \quad K \text{ is the torque constant}$$

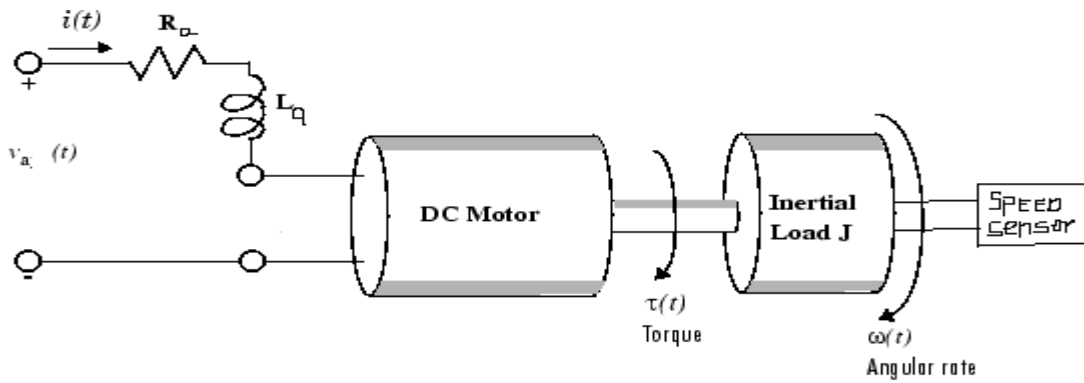


Fig.1. (a)

**Procedure:**

**NO LOAD CHARACTERISTICS**

- 1) Connect the motor to corresponding terminals.
- 2) Connect the speed sensor to the socket provided.
- 3) Switch on the power supply.
- 4) Slowly vary the motor voltage in steps till rated voltage is reached, note the speed.
- 5) Draw the graph between voltage and speed.

**LOAD CHARACTERISTICS**

- 1) Connect the motor to corresponding terminals.
- 2) Connect the speed sensor to the socket provided.
- 3) Switch on the power supply.
- 4) Keep the motor voltage to 12V.
- 5) Now slowly load the motor by adding 50gms.
- 6) Tabulate current (I), Speed (N), Weight (W) and calculate the Torque.
- 7) Repeat steps 5&6 for by increasing the loading up to 250gms in steps of 50gms.
- 8) Experiment procedure may be repeated for reduced voltage cases.

**Tabular Form:**

**NO LOAD CHARACTERISTICS:**

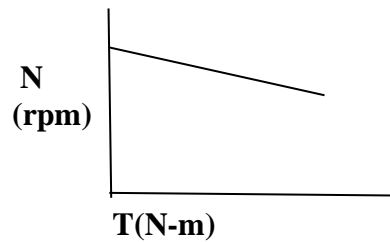
Sl. No	Voltage	Speed
1		
2		
3		
4		
5		
6		

**LOAD CHARACTERISTICS:**

V=-----volts

Sl.No	Voltage(V) (Volts)	Current (I <sub>a</sub> ) Amps	Speed (N) RPM	Weight (W) Kg	Torque (T) =9.81WR N-m
1					
2					
3					
4					
5					
6					

**Expected graph:**



**Result:**

**Viva Questions:**

- 1) Define and explain the term servomechanism.
- 2) Why are electric motors mostly used as actuators?
- 3) How  $k_b$  &  $K_T$  are equal? Which can be measured with better accuracy?
- 4) Give the demerits of field control scheme, when applied to large and medium sized motors.
- 5) Write the applications of DC Servomotor?
- 6) Determine the mathematical model of the DC servo motor and hence its transfer function.

## **Expt No.1. (b) CHARACTERISTICS OF AN AC SERVOMOTOR**

**Aim:** To obtain Torque – Speed characteristics of an AC Servo Motor.

**Apparatus:** AC Servomotor kit  
Patch chords  
Multimeter

### **Theory:**

AC Servo motors are two phase induction motors with certain special design features. The stator of the motor consists of two phases with distributed windings displaced by 90 electrical degrees. The two phases of such a motor are termed as reference and control phase. The voltages applied to the windings of these two phases are not balanced. Generally, voltages of 90 degrees phase difference are applied to each of these stator phases. In the normal mode of operation, a fixed voltage is impressed on reference phase and variable voltage is impressed on control phase. Both the control winding and reference winding are similar and we can interchange them. The rotor of the AC Servomotor is built with high resistance, so that its  $X/R$  (Inductive reactance/Resistance) ratio is small which results in linear speed-torque characteristics.

The advantages of AC Servo motors are its compact size, high torque, variable speed, easy maintenance and long life. The Servo motors are best suited for low power applications. The power consumed by an AC Servo motor usually varies from fraction of a watt up to only a few hundred watts.

### **Description of the setup:**

This setup consists of an AC Servomotor whose characteristics are to be studied. The AC Servo motor is coupled to a DC Servo motor. DC Servomotor is used to load the AC Servomotor. A variable DC supply is provided to load the AC Servomotor by the potentiometer  $P_2$ . A speed sensor is attached to the motor shaft through the coupler. A tachometer is provided to read the motor speed in rpm. An arrangement is made to apply the fixed voltage to the reference winding  $W_R$  and variable voltage to control winding  $W_c$  by potentiometer  $P_1$ . An ammeter is also provided to read the armature current,  $I_a$  of the DC Servomotor.

### **Speed variation and speed measurement:**

A variable AC voltage is applied to the control winding by varying the potentiometer  $P_1$ . This voltage is used to vary the speed of the motor. The speed sensor is connected from the motor assembly to the control circuit. The speed sensor senses the speed of the motor and generates an AC signal whose frequency is proportional to the rpm. The signal conditioner converts this frequency into a voltage corresponding to the speed(in rpm). The digital panel meter displays the speed in rpm at the front panel of the instrument. The speed of the motor can be suddenly brought to zero by switching off the variable ac power supply through the 'On / Off' switch connected to the control winding of the ac servomotor provided at the front panel.

### **Torque measurement:**

In order to measure the torque provided by the Servomotor, an arrangement to have variable load on the AC Servomotor, is provided. The shaft of the AC Servomotor is coupled to the DC Servomotor. When the servomotor is loaded, the current of DC Servomotor is displayed by the ammeter provided at the front panel, which is proportional to the amount of load applied.



## Related Formulae:

$$T = P \cdot 60 / (2\pi N) \text{ N-m}$$

Where  $P = E_b I_a$  Watts

$E_b$  is back-emf (V),  $I_a$  is armature current (A) &  $N$  is speed in rpm.

## Circuit diagram:

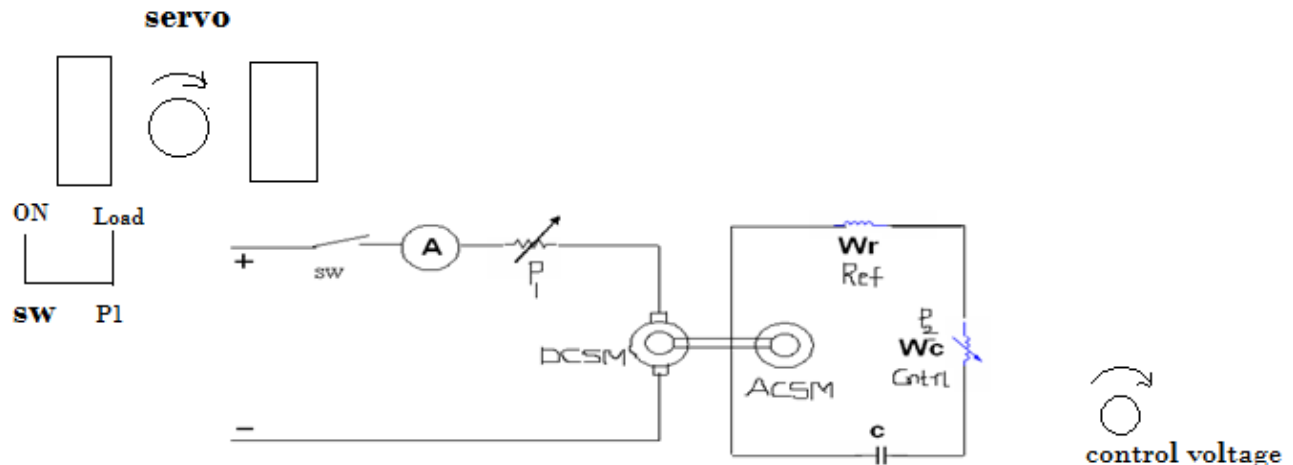


Fig.1. (b)

## Procedure:

### NO LOAD CHARACTERISTICS:

- 1) Keep potentiometers  $P_1$  &  $P_2$  in minimum position.
- 2) Switch ON the main supply.
- 3) Measure the reference winding ( $W_r$ ) voltage by multi-meter.
- 4) Slowly vary the control winding ( $W_c$ ) voltage and note the speed.
- 5) Draw the graph between control winding voltage and speed.

### LOAD CHARACTERISTICS:

- 1) Keep potentiometers  $P_1$  &  $P_2$  in minimum position.
- 2) Switch ON the main supply.
- 3) Measure the reference winding ( $W_r$ ) voltage by multi-meter.
- 4) Set the control winding voltage to 230V.
- 5) Switch ON the load slowly on the motor by varying  $P_1$  in Steps of RPM.
- 6) Tabulate the readings in the table.
- 7) Potentiometer  $P_1$  is brought back to minimum position and the load is switched off.
- 8) Set the control voltage,  $P_2$  to 200V and repeat the steps 5&6.
- 9) Plot the graphs of Speed Vs Torque, for the two control winding voltages set up.
- 10) Before switching OFF the power supply, ensure that the two potentiometers  $P_1$  &  $P_2$  are in minimum position.

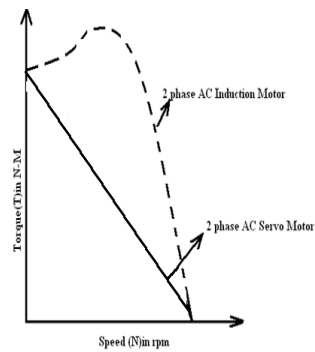
**NO LOAD CHARACTERISTICS:**

Sl. No	Voltage	Speed
1		
2		
3		
4		
5		
6		

**LOAD CHARACTERISTICS:**

Sl. No.	Armature Current ( $I_a$ ) Ampere	Speed (N) RPM	Back EMF ( $E_b$ ) Volt	Power (P) $= E_b \times I_a$ Watt	Torque (T) $= 60P/2\pi N$ N-m
1					
2					
3					
4					
5					

## Expected graph:



## **Result:**

### Viva Questions:

1. State the differences in construction of AC induction motor and AC servo motor.
2. What is the use of phase-shifting capacitor .
3. What kind of Slope of torque-speed characteristics is desirable in control systems?
4. Give the applications of AC servo motor.
5. Determine the mathematical model of an AC servo motor and its transfer function.

## Expt. No. 2 SYNCHRO TRANSMITTER RECEIVER PAIR

### Aim:

To study the “Synchrotransmitter” and “Synchro transmitter – Receiver” pair

### Apparatus:

Synchro transmitter - Receiver pair trainer kit  
Patch chords

### Circuit Diagram:

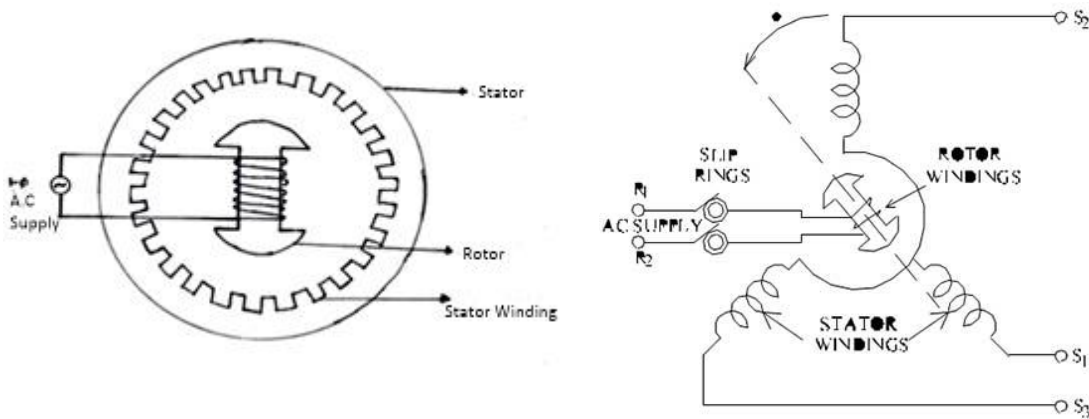


Fig.2. (a)

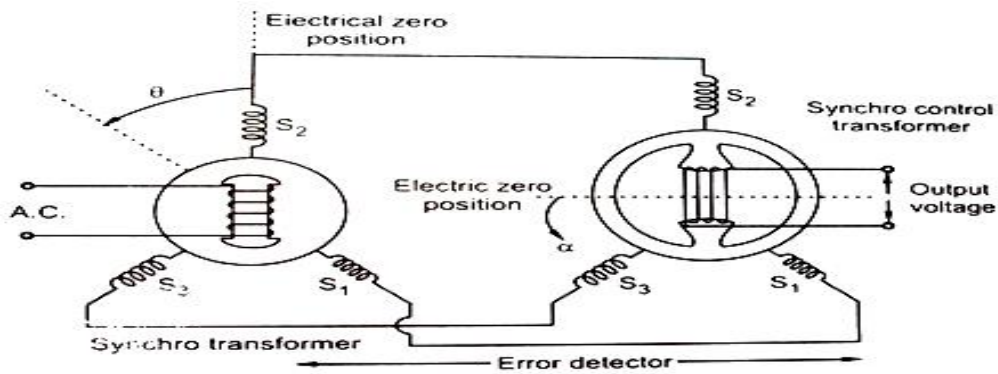


Fig.2. (b)

## **Theory:**

The term Synchro is a generic name for a family of inductive devices which can be connected in various ways to derive shaft angle measurements. These devices work on the principle of a rotating transformer which has two parts - synchro transmitter and synchro control transformer. This is mainly used as an error detector in feedback control systems, by comparing two angular displacements and giving an output voltage, proportional to the angular difference between the transmitter and receiver.

Synchro-transmitter,  $T_x$ : Its construction is similar to that of a three phase alternator, having laminated silicon steel slotted stator to accommodate a balanced concentric coil type three phase winding. Three identical star connected coils are placed in the stator displaced 120 degrees apart. Rotor is of dumb bell construction and a single phase ac voltage is applied to the rotor winding through slip rings.

Synchro receiver,  $T_r$ : It has almost the same constructional features as that of a synchro transmitter. Initially the winding,  $S_2$  of the stator of the transmitter is positioned for maximum coupling with the rotor winding.

There is a voltage imbalance between the windings of the stator that causes currents to flow through the closed circuit, producing torque that tends to rotate the rotor of the receiver to a new position where the voltage balance is again restored. This balance is restored only if the receiver turns through the same angle as the transmitter and also the direction of the rotation is the same as that of  $T_x$ . The  $T_x T_r$  pair thus serves to transmit information regarding angular position at one point to a remote point.

## **Procedure:**

### **SYNCHRO TRANSMITTER:**

1. Connect the main supply to the system with the help of cable provided. Do not interconnect  $S_1$ ,  $S_2$  and  $S_3$  to  $S_1^1$ ,  $S_2^1$ , and  $S_3^1$ .
2. Switch ON main supply for the unit and transmitter rotor supply.
3. Starting from zero position, note down the voltage between stator winding terminals i.e.,  $V_{S_1 S_2}$ ,  $V_{S_1 S_3}$ ,  $V_{S_2 S_3}$  in a sequential manner. Enter the readings in a tabular form and plot the graph of angular position Vs rotor voltages for all the 3-phases.
4. Note that zero position of the stator coincide with  $V_{S_3 S_1}$ , voltage equal to zero voltage. Do not disturb this condition.

### **SYNCHRO TRANSMITTER RECEIVER PAIR:**

1. Connect the main supply cable.
2. Connect  $S_1$ ,  $S_2$  and  $S_3$  terminals transmitter to  $S_1$ ,  $S_2$  and  $S_3$  of synchro receiver by patch chords provided respectively.
3. Switch ON rotor supply of both transmitter and receiver and also switch ON the main supply.

4. Move the pointer i.e. rotor position of synchro transmitter in steps of  $30^\circ$  and observe the rotor position. Observe that whenever transmitter rotor is rotated, the receiver rotor follows it for both the directions of rotations and their positions are in good agreement.
5. Enter the input angular position and output angular position in the tabular form and plot graph.

**Tabular Form:**

Synchro transmitter:

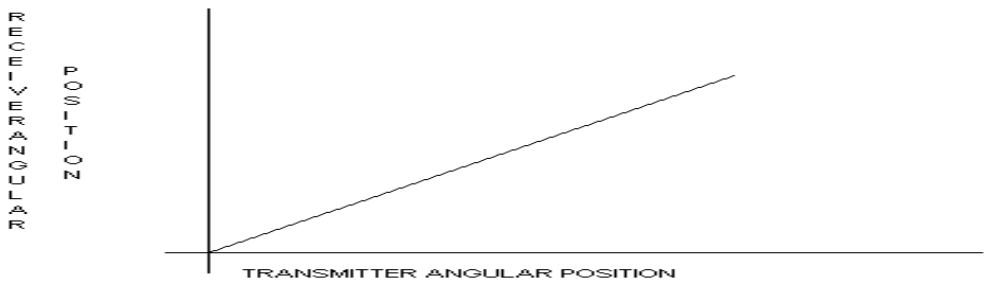
S.NO	Rotor position in degrees	$V_{S1S3}$	$V_{S1S2}$	$V_{S2S3}$
1				
2				
3				
4				
5				
6				

Synchro transmitter and receiver pair:

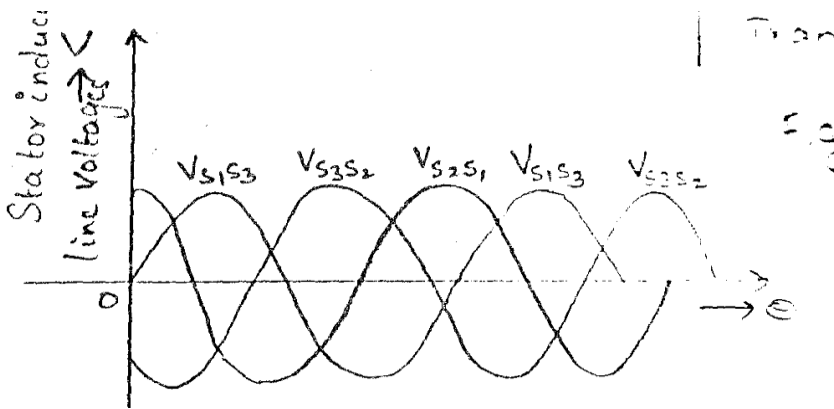
S.NO	Rotor position of transmitter in degrees	Rotor position of receiver in degrees
1		
2		
3		
4		
5		
6		

**Expected Graphs:**

Synchro transmitter



## Synchro transmitter and receiver pair



### Result:

### Viva Questions:

1. What are the different types of synchro?
2. What is the difference between each type of synchro?
3. Why shape of motor of transmitter different from that of a receiver?
4. What is the commercial name of synchro?
5. What are the various types of synchro errors?
6. Differentiate between potentiometer and a synchro.
7. Give few applications of synchro devices.

### Expt No.3. FREQUENCY RESPONSE OF FIRST ORDER SYSEM

**Aim:**To plot frequency response for the given first order system.

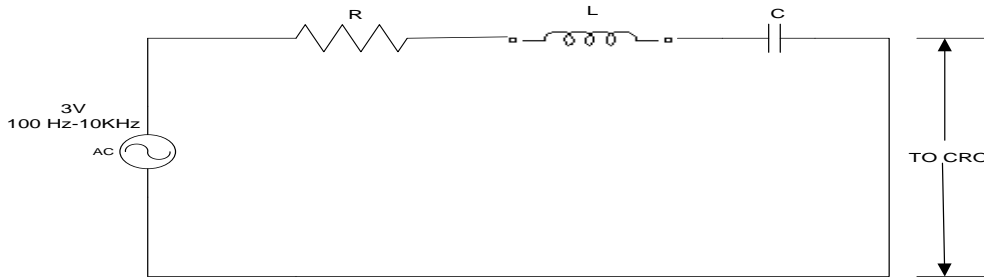
**Apparatus:**

Frequency response kit  
Patch chords.

**Theory:**

The frequency response is the steady state response of the system to a Sinusoidal signal. Consider a linear time invariant system, let  $x(t)$  is an input sinusoidal signal. Response is also sinusoidal signal of same frequency but with different magnitude of phase angle.

**Circuit Diagram:**



**Fig.3**

**Related Formulae:**

For RC filter,  $E_o(s)/E_i(s) = G(S) = 1/1+Ts$

Sinusoidal Transfer Function Magnitude,  $G(j\omega) = 1/\sqrt{1+ \omega^2 T^2}$ ,

Phase  $\angle \tan^{-1} \omega t = M \angle \theta$

Gain in dB =  $20 \log_{10} |V_o/V_i|$  dB

**Procedure:**

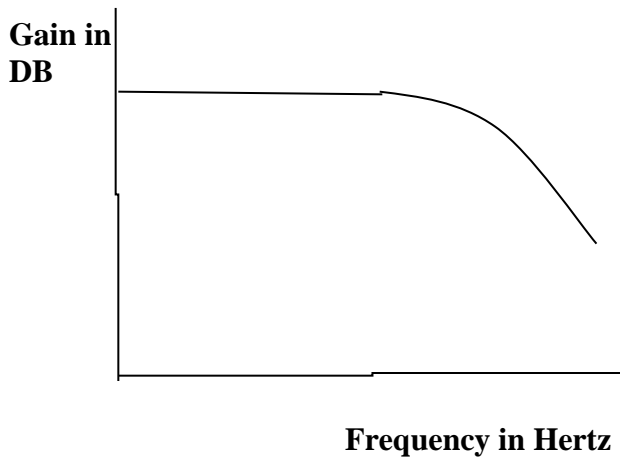
1. Connect the circuit as shown.
2. Switch on the apparatus.
3. Set the signal generator to sine wave. Adjust the amplitude of the sine wave signal to a suitable voltage.
4. Enter various readings in the table for the frequency from 100Hz to 10 KHz in steps.
5. Plot a graph of Gain in dB Vs frequency,  $\omega$  in radians.



**Tabular Form:**

S.No	Frequency(Hz)	$\omega = 2\pi f$ (rad)	Input Voltage (Vi)	Output Voltage (Vo)	Gain Vo/Vi	Gain in dB $=20\text{Log}_{10}\text{gain}$

**Expected graph:**



**Result:**

**Viva Questions:**

- 1) What is the order of a system?
- 2) What is the type of a system?
- 3) Analyze the response of first order system for step signal & find the steady state error for the first order system.
- 4) Define the transient and steady state responses.
- 5) Define the time response of the system.
- 6) If  $s = \sigma + j\omega$ , then how is  $s = j\omega$  for frequency response.

## Expt No.4. TIME RESPONSE OF SECOND ORDER SYSTEM

Aim: To obtain the time response of a second order system and to study the time domain specifications of the second order system modelled by an RLC circuit.

### Apparatus:

Step response of second order system kit  
Function generator  
CRO  
Connecting wires

### Theory:

The time response of the system is the output of the closed loop system as a function of time. It is denoted by  $C(t)$ . The time response can be obtained by solving the differential equation governing the system. Alternatively, the response  $C(t)$  can be obtained from the transfer function of the system and the input applied to the system.

The desired performance characteristics of control systems are specified in terms of time domain specifications. Systems with energy storage elements cannot respond instantaneously and will exhibit transient responses, wherever they are subjected to input or disturbances.

**STEP SIGNAL:** The step signal is a signal whose value changes from zero to  $A$  at  $t=0$  and remains constant at  $A$  for  $t>0$ . A special case of step signal is unit step in which  $A$  is unity.

$$r(t) = A u(t).$$

Where,  $u(t) = 1; t > 0.$

$$u(t) = 0; t < 0.$$

### Circuit diagram:

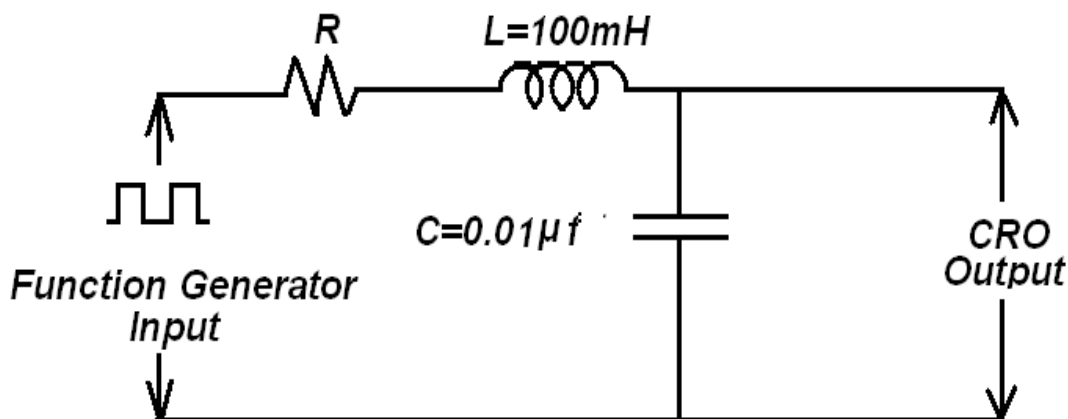


Fig.4

**Related Formulae:**

$$\text{Delay time} = (1+0.7\xi)/W_n$$

$$\text{Rise time} = (180^\circ - \theta)/W_d \text{ or } (\Pi - \theta)/W_d$$

$$\text{Peak time} = \Pi/W_d \text{ or } \pi/W_d$$

**Procedure:**

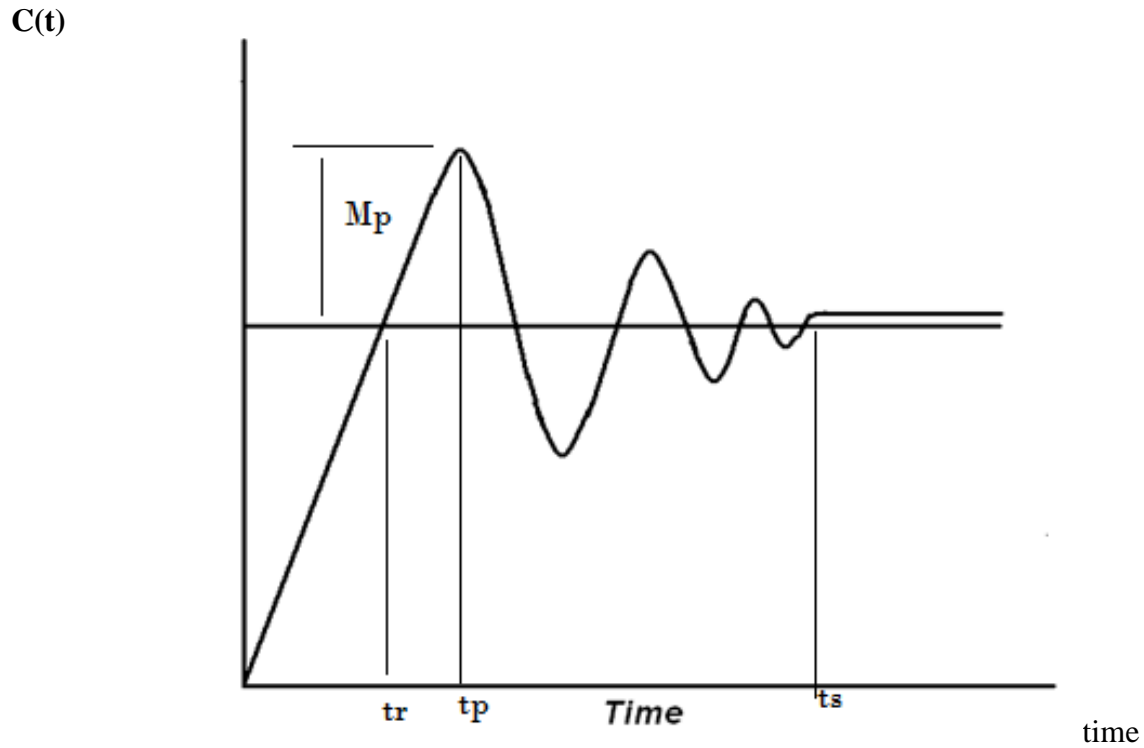
1. Connect the circuit as per circuit diagram
2. Connect the output to CRO
3. Note down the rise time, delay time, peak time, settling time and max overshoot
4. Adjust the value of resistance to obtain a critical damped and over damped system response and tabulate the various specifications of unit step response.

**Tabular form:**

Sl.no	Zeta $\xi$	Delay time $T_d$ (s)	Rise time $T_r$ (s)	Peak time $T_p$ (s)	Settling time $T_s$ (s)	%over shoot $M_p$
1						
2						
3						
4						
5						

**Expected graph:**

**Output Response Vs time**



**Fig.4**

**Result:**

**Viva Questions:**

- 1) Define Transient response and steady state response.
- 2) Define first order and second order control systems with examples.
- 3) Write the time domain specifications of second order system.
- 4) Define delay time and rise time.
- 5) Define peak time, settling time and peak overshoot.

## Expt No.5. DC POSITION CONTROL SYSTEM

**Aim:** To study a DC position control system.

**Apparatus:** DC position control kit  
Patch chords

**Theory:**

The position control systems have innumerable applications, namely machine tool position control, constant tension control of sheet rolls in paper mills, radar tracking systems, roll stabilization of slips positioning of heavy guns on the tanks for defense applications etc.

With  $S_1$  in upward position and the step change in input shaft, the output shaft exhibits an oscillator behavior, when the amplifier gain is high. This happens because of the system elements which are capable of storing energy i.e., capacitance, inductance, inertia of moving components like rotor of motor, load, gear train etc. Energy storing elements tend to produce overshoots and undershoot in the system. To avoid this, various stabilizing techniques are used. In this set up, output Derivative feedback is used for stabilizing the system. The Tacho-generator which is coupled to the motor generates an output voltage which is proportional to the rate of change of output angle.

For regenerative feedback, the damping of the system is reduced and energy stored in the moving elements cannot be readily dissipated. This increases tendency for induced oscillations and the system becomes unstable.

If  $\theta_1$  &  $\theta_2$  are the output (controlled) and derived (reference) positions respectively measured and compared by a potentiometer pair whose output voltage is proportional to the error in angular position  $\theta_E = \theta_1 - \theta_2$ . The error voltage is amplified and applied to servomotor which positions the load and output pot such that the error is reduced to zero.

P1 is the input potentiometer. P2 is the output position sensing potentiometer. If P1 is disturbed and wiper is moved in the upward direction (more positive) then IC1 gets a positive error signal. This signal is voltage amplified and then power amplified by the servo amplifier, which sets the motor in to rotation. If P1 is moved in the downward direction, servo amplifier output is made negative and the dc servomotor is rotated in the opposite direction bringing the P2 wiper contact to a lower position until the motor stops again. As soon as  $\theta_1$  becomes equal to  $\theta_2$ , null indicator meter also indicates almost zero. That is how any variation in the desired input  $\theta_1$  is transferred to the output position  $\theta_2$  along with the load.

## Circuit diagram:

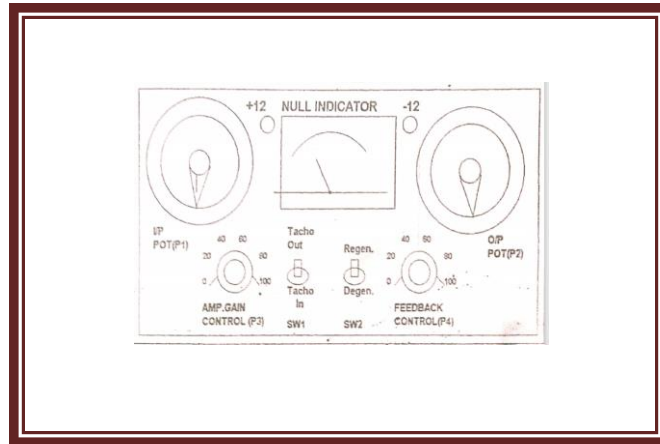


Fig.5

## Procedure:

- 1) Set the switches SW<sub>3</sub>, SW<sub>4</sub> in downward position i.e., switch them ON. And then switch on the main panel.
- 2) Ensure that SW<sub>1</sub> is in upward position & SW<sub>2</sub> is in downward position.
- 3) Set the input potentiometer P<sub>1</sub> in 10 Degree position.
- 4) Potentiometer P<sub>3</sub> (Amplifier gain adjust) should be in mid position.
- 5) Now, Switch ON the main unit.

## Operation without feedback (SW<sub>1</sub> in off position i.e., tacho-out)

Now slowly advance the input potentiometer in steps of 30 degrees and note down the output. When the input is disturbed, the null indicator will show some indication but when the output reaches desired position, again the null indicator indicates almost zero.

## Operation with stabilizing feedback (sw1 in down position, tacho- in)

Now set the SW<sub>1</sub> switch in lower position i.e., tacho-in position, SW<sub>2</sub> must be in downward position i.e., degenerative mode. Keep P<sub>4</sub> in fully anticlockwise direction.

Now take P<sub>1</sub> to 180 degree position and effect the step input change in one direction, output again indicates oscillations. Now advance the pot P<sub>4</sub> in clockwise direction the output now is observed to follow the input in a smooth fashion without oscillation. If the P<sub>4</sub> pot is too much advanced, the output now follows input in a sluggish fashion indicating an over damped system. Now take the pot P<sub>1</sub> to 180 degree position.

**Tabular Form:**

**Without feedback**

Sl. No	Gain	I/P Angular Position	O/P Angular Position	Error

**With feedback**

S.No	Gain	I/P Angular Position	O/P Angular Position	Error

**Precautions:**

1. Try not to rotate the output potentiometer by hand.
2. When the system is not being used, keep switches, SW3 and SW4 in OFF position (i.e. upward position) to avoid heating and possible damage of the power stage.
3. Do not operate the system with regenerative feedback

**Result:**

**Viva Questions:**

1. What are the various applications of position control systems?
2. What is degenerative and regenerative feedback?
3. Why should not a system be operated in regenerative feedback mode?
4. What is the principle of tachogenerator? Determine its transfer function.
5. What is the function of output potentiometer?



## Expt No.6. AC POSITION CONTROL SYSTEM

**Aim:**To study an AC position control system.

**Apparatus:**

AC position control kit  
Patch chords

**Theory:**

In an AC position control system, all the signals are sinusoidal quantities. For example, even though the reference input (R) and controlled output (C) are constants, the actuating signal is a sinusoidal function whose amplitude is proportional to the difference between (R&C). The power amplifier output activates the control winding of the AC servomotor. The other (reference winding) is activated by means of a fixed AC voltage. The load to be positioned is coupled to the output shaft of the output servomotor and gear train combination. The same shaft is also coupled to the output potentiometer.

This position control system works to make the output shaft position identical to the input shaft position. When the output shaft is being positioned, the mechanical load is also moved to a new desired position thus making error voltage always zero. The system works to make the error voltage zero after disturbance.

**Circuit Diagram:**

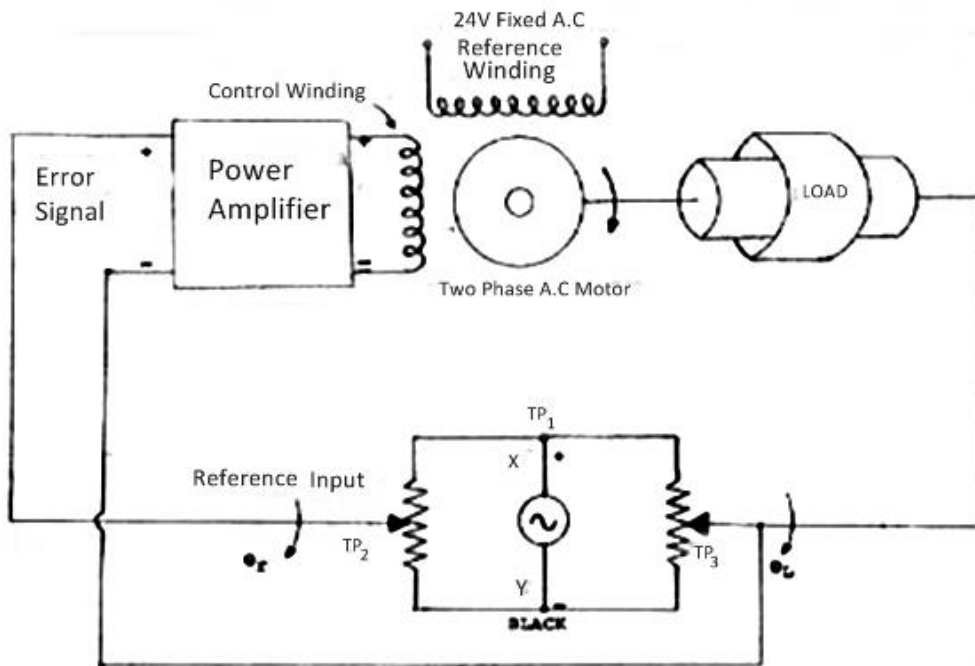


Fig.6

**Procedure:**

- 1) Switch on the ac mains supply.
- 2) Set SW<sub>1</sub>, SW<sub>2</sub>, & SW<sub>3</sub> to ON position.
- 3) Observe that the input and output potentiometers come in alignment.
- 4) Keep the gain potentiometer at its maximum gain position. (Full clockwise position).

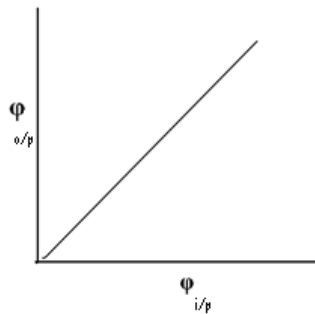
- 5) Take the input potentiometer very near to the zero position. The output potentiometer will also follow the input potentiometer till the null indicator indicates null position.
- 6) Enter the observations in the tabular column.
- 7) Keep the gain potentiometer in mid position i.e., 50 percentage.
- 8) Enter the observations in the tabular column.

**Tabular Form:**

100% gain			
Sl.No	I/P Angular Position	O/P Angular Position	Error
1			
2			
3			
4			
5			

50% gain			
Sl No	I/P Angular Position	O/P Angular Position	Error
1			
2			
3			
4			
5			

**Expected graph:**



**Result:**

**Viva Questions:**

1. What are basic features of the AC servomotor?
2. What are the applications of AC position control systems?
3. What is the effect of small (x/r) ratio of motor?
4. What is the importance of a null detector in AC position control system?
5. What will happen if the gain increases?

## Expt No.7. SPEED CONTROL OF DC SERVO MOTOR USING PID CONTROLLER

**Aim:** To study the speed control of DC servo motor using PID controller

**Apparatus:**

Speed control of DC servo motor using PID controller kit  
Patch chords

**Theory:**

In feedback control systems a controller may be introduced to modify the error signal and to achieve better control action. The controllers will modify the transient response and steady state error of the system.

### P CONTROLLER

The P controller produces an output signal which is proportional to error signal. The drawback in P controller action is that it produces a constant steady state error.

### PI CONTROLLER

The PI controller produces an output signal consisting of two terms **one proportional to error signal and the other to the integral of error signal.**

### PID CONTROLLER

The proportional controller stabilizes the gain but produces a steady state error. **The integral controller reduces or eliminates the steady state error.** The derivative control reduces the rate of change of error. The combined effect of all the three cannot be judged from the parameters  $K_p$ ,  $K_i$  and  $K_d$ .

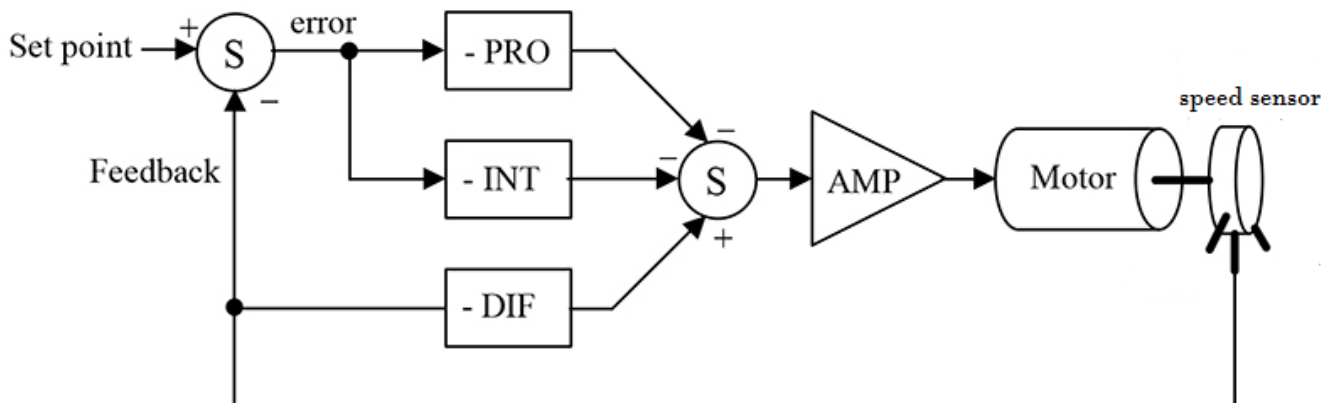


Fig.7

Procedure:

WITHOUT ANY CONTROLLER

- Initially set the required speed 900 rpm on DC motor and run the motor.
- Now disturb the speed by applying the load on the motor and note down the speed.

WITH PROPORTIONAL CONTROLLER

- Initially set the required speed 900 rpm on DC motor and run the motor.
- Set 25% gain on P controller and include it in the circuit by switching P.
- Now disturb the speed by applying the load on the motor and note down the speed.
- Switch off P and set different values of gain on P controller and repeat the steps
- Draw the graph between gain Vs error.

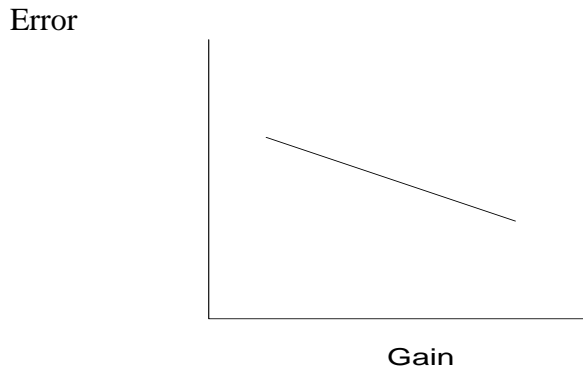
WITH PI CONTROLLER

- Initially set the required speed 900 rpm on DC motor and run the motor.
- Set 50% gain on P controller and 25% include it in the circuit by switching P, I switches.
- Now disturb the speed by applying the load on the motor and note down the speed.
- Switch off the P, I switches and set different values of gain on P controller and I controller and repeat the steps
- Draw the graph between gain Vs error

WITH PID CONTROLLER

- Initially set the required speed 900 rpm on DC motor and run the motor.
- Set 50% gain on P controller and 25% include it in the circuit by switching P, I switches.
- Now disturb the speed by applying the load on the motor and note down the speed.
- Switch off the P, I, D switches and set different values of gain on P, I, D controller and repeat the steps
- Draw the graph between gain Vs error

EXPECTED GRAPH:



Result:

Viva Questions:

1. What are the applications of DC servo motors?
2. What are the types of controllers?
3. Define P and PI controllers.
4. Define PD and PID controllers.
5. Write the transfer function of PID controller?

## Expt no.8.(a) STUDY OF LAG COMPENSATION NETWORK

**Aim:** To study a lag compensation network.

**Apparatus:**

Lag-compensation network kit  
Connecting wires

**Theory:**

There are two situations in which compensators are required. When the system is unstable, compensator is required to stabilize it as well as to achieve a specific performance, and also when the system is stable, but desired performance is not met. Thus, compensator improves both steady state and transient behavior of the system.

A compensation network in which the phase of the output signal ( $E_o$ ) lags that of the input signal ( $E_i$ ) is called a lag compensator. The figure which corresponds to the circuit diagram is the passive RC circuit implementation of a lag compensator.

Referring to the circuit diagram, the transfer function between the output and input is

$$E_o(s) / E_i(s) = (R_2 + 1/CS) / (R_1 + R_2 + 1/CS) = R_2CS + 1 / (R_1 + R_2)CS + 1$$

Letting  $R_2C = \tau$

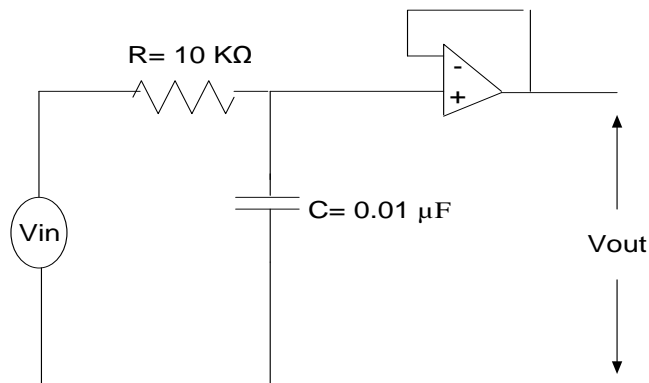
And  $(R_1 + R_2) / R_2 = \beta$

$\beta > 1, \tau > 0$

Thus the transfer function becomes

$$E_o(s) / E_i(s) = (\tau s + 1) / (\beta \tau s + 1)$$

**Circuit diagram:**



**Fig.8(a)**

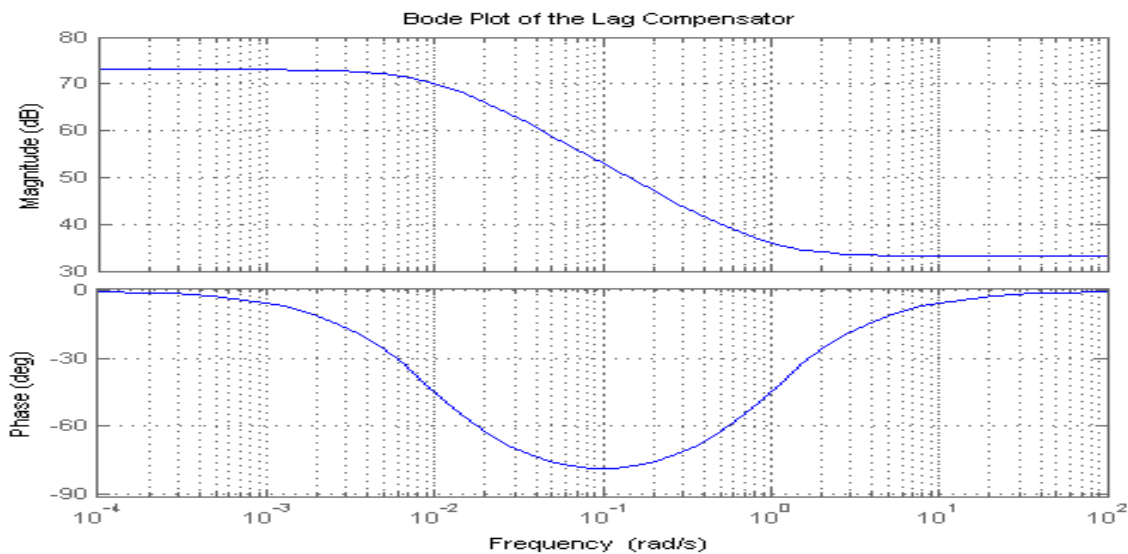
**Procedure:**

- 1) Make the connections as per the circuit diagram
- 2) Adjust frequency to 100Hz. Set the amplitude to 3V (peak to peak).
- 3) Note down the amplitude of  $E_o$  w.r.t input  $E_i$ .
- 4) Vary the frequency of the input gradually in steps of 100Hz to 10 KHz and obtain the amplitude  $E_o$  and the phase difference at each frequency and tabulate the results.
- 5) Plot the magnitude ratio and phase difference w.r.t to  $\omega$ .
- 6) Indicate the maximum phase difference and the corresponding frequency and the amplitude ratios.

**Tabular Form:**

S. No.	Frequency	$V_i$	$V_o$	Phase difference	Gain in dB = $20 \text{Log}(V_o/V_i)$
1					
2					
3					
4					
5					

**Expected graph:**



**Result:**

**Viva Questions:**

- 1) Under which case a lag compensator is required and what is the condition for designing it?
- 2) What is feedback compensation?
- 3) Why is lag-compensator called a low pass filter?
- 4) What is the effect of Lag compensator on stability?
- 5) What are the applications of lag compensator?



## Expt no.8(b) STUDY OF LEAD COMPENSATION NETWORK

**Aim:** To study a lead compensation network

**Apparatus:**

Lead-compensation network  
Connecting wires

**Theory:**

Compensation is the process of improving the system performance by incorporating additional components in the system.

A compensator in which the phase of the output signal ( $E_o$ ) leads that of the input signal ( $E_i$ ) is called a lead compensator. The lead compensator essentially yields an appreciable improvement in transient response and a small improvement in the steady state accuracy. The primary function of all lead compensators 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. The phase lead controller is nothing but the high pass filter.

The circuit diagram is the passive RC circuit implementation of a lead compensator.

The transfer function is:

$$E_o(s) / E_i(s) = R_2 / (R_2 + (R_1 / (1 + R_1 C S))) = R_2 (1 + R_1 C S) / (R_1 + R_2 + R_1 R_2 C S) =$$

$$(R_2 / (R_1 + R_2)) ((R_1 C S + 1) / (R_1 R_2 / (R_1 + R_2) C S + 1))$$

$$\text{Letting } R_2 / (R_1 + R_2) = \alpha \text{ and } R_1 C = \tau$$

Thus the transfer function becomes

$$E_o(s) / E_i(s) = (\tau s + 1) / (\alpha \tau s + 1)$$

**Circuit diagram:**

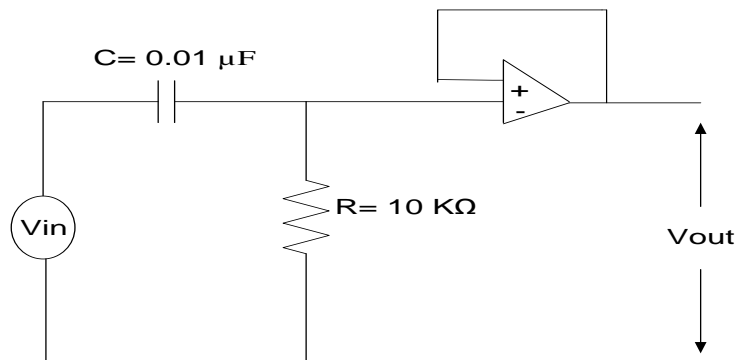


Fig.8.(b)

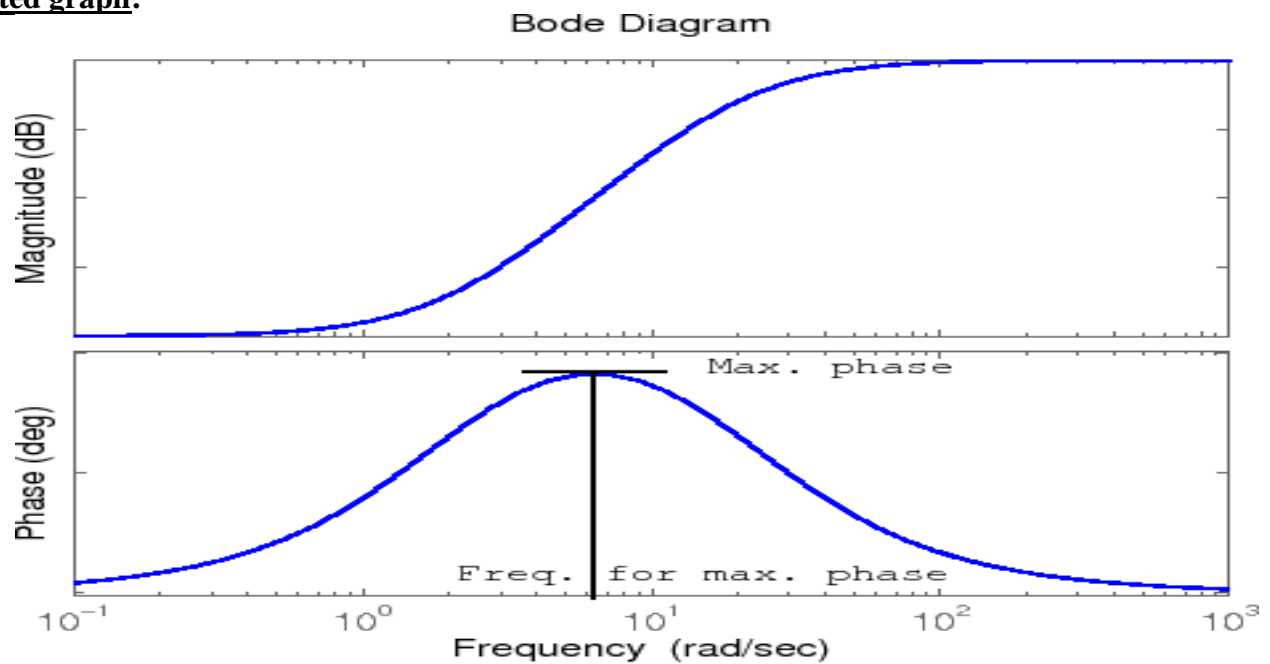
**Procedure:**

- 1) Make the connections as per the circuit diagram
- 2) Adjust frequency to 100Hz. Set the amplitude to 3V (peak to peak).
- 3) Note down the amplitude of  $E_o$  w.r.t input  $E_i$ .
- 4) Vary the frequency of the input gradually in steps of 100Hz to 10 KHz and obtain the amplitude  $E_o$  and the phase difference at each frequency and tabulate the results.
- 5) Plot the magnitude ratio and phase difference w.r.t to  $\omega$ .
- 6) Indicate the maximum phase difference and the corresponding frequency and the amplitude ratios.

**Tabular form:**

S. No.	Frequency	$V_i$	$V_o$	Phase difference	Gain in dB = $20 \text{Log}(V_o/V_i)$
1					
2					
3					
4					
5					

**Expected graph:**



**Result:**

**Viva Questions:**

1. What is the significance of compensation in control systems?
2. Under which case is a phase lead compensator required?
3. Why lead compensator is known as the high pass filter?
4. What are the applications of lead compensation network?
5. What is the effect of stability by varying a lead compensation network?

## 9. TEMPERATURE CONTROL USING PID CONTROLLER

### Experiment No.9(a). To study phenomenon of offset for proportional controller

Aim: To study phenomenon of offset for proportional controller when the load on the process is varied.

Apparatus: Temperature control trainer kit  
Heater socket

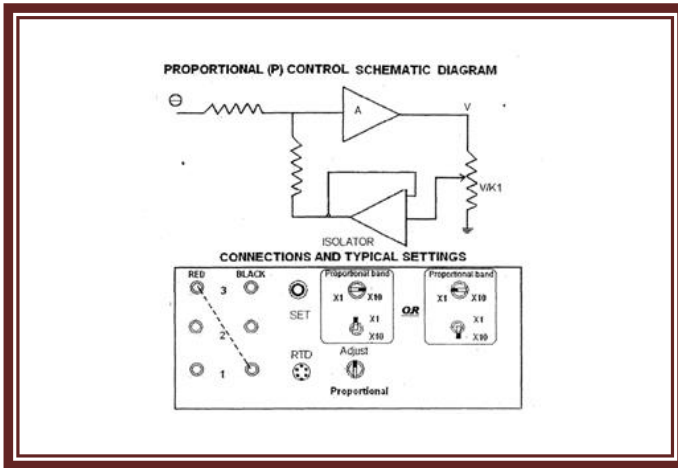
Theory:

Proportional action is a mode of controller action in which there is a continuous linear relation between values of deviation and manipulated variable. Thus the action of the controlled variable is repeated and amplified in the action of the final control element.

Procedure:

1. Established the connection between the conditioning unit and the model process with the help of cables provided.
2. Refer figure 6. and connect Red 3 and Black 1 with the help of patch chord.
3. Set the “ SET” potentiometer at the position of 18 Ohms corresponds to 45 degree centigrade of temperature.
4. Set the proportional band control to 10% i.e.  $K_1=10$
5. Now turn ON the power supply and also turn ON the fan. Place the fan regulator at low position.
6. Wait until the deviation indicator stabilizes at some point. Record the deviation readings at interval of 15 seconds.
7. Now suddenly increase the fan speed to high by moving fan control to high position.
8. Now note down the deviation meter reading when the pointer stabilizes.  
Record the deviation meter readings. The difference between the two readings i.e. step 8 and step 6 is the offset (steady state error).
9. Now you may increase the gain to 100 i.e. proportional band to 1% and  
Repeat the steps 5 to 8  
In this expt. You will observe that the offset error is reduced.
10. Draw the graph of Time v/s deviation.
11. You may perform experiments with various gain settings.

Circuit diagram:



Tabular form:

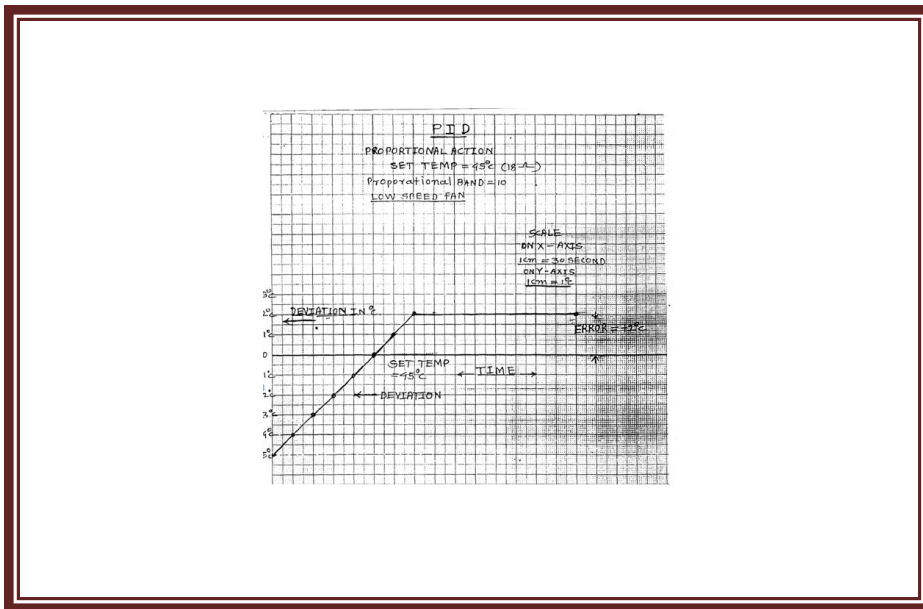
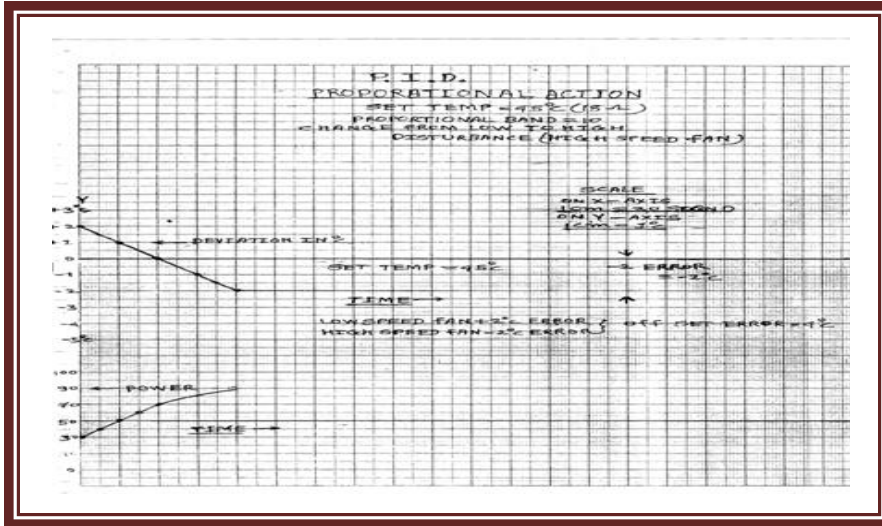
Low Disturbance (Fan Low speed)

Sl no	Time in Seconds	Deviation Degree C
1		
2		
3		
4		
5		

High Disturbance (Fan high speed)

Sl no	Time in seconds	Deviation Degree C
1		
2		
3		
4		
5		

Expected graph:



## Experiment No.9(b). (P+I)

Aim:To show the effect of integral action in eliminating the offset. To observe that the integral action has destabilizing effect on the process when load changes occur.

Apparatus: Temperature control trainer kit  
Heater socket

### Theory:

Integral action is a mode of control action in which the value of the manipulated variable is changed at a rate proportional to the deviation. Thus if the deviation is doubled over a previous value, the final control element is moved twice as fast. The integral action adjustment is the integral time. For a step change of deviation, the integral time is the time required to add and increment the response equal to the original step change of response. Integral action is seldom used. The integral action is generally used in association with proportional action. As a result of integral action the offset error is almost reduced to zero. But the transient response is adversely affected. In other words the integral action has a destabilizing effect on the process under the conditions of load variations.

### Procedure:

1. Establish the connections as per fig.5 with the help of patch chords. Get the indicated settings for the various controls.
  - a) SET= 18 ohms (i.e.45 degree centigrade)
  - b) PB= 10%
  - c) Coarse control for integral action= 10seconds.
  - d) Fine control = Midway.
2. Turn on the fan with control on low position.
3. Wait until the process stabilizes with almost zero deviation.
4. Now suddenly increase the fan speed to high position with the help of a stop watch record the deviation meter readings at an interval of 15seconds. Continue the process until the deviation meter almost stabilizes at zero deviation. There might be negligible error( around 0.2 degree centigrade or so)
5. You can observe that the integral action gives zero offset but transient response is hampered.

### Circuit

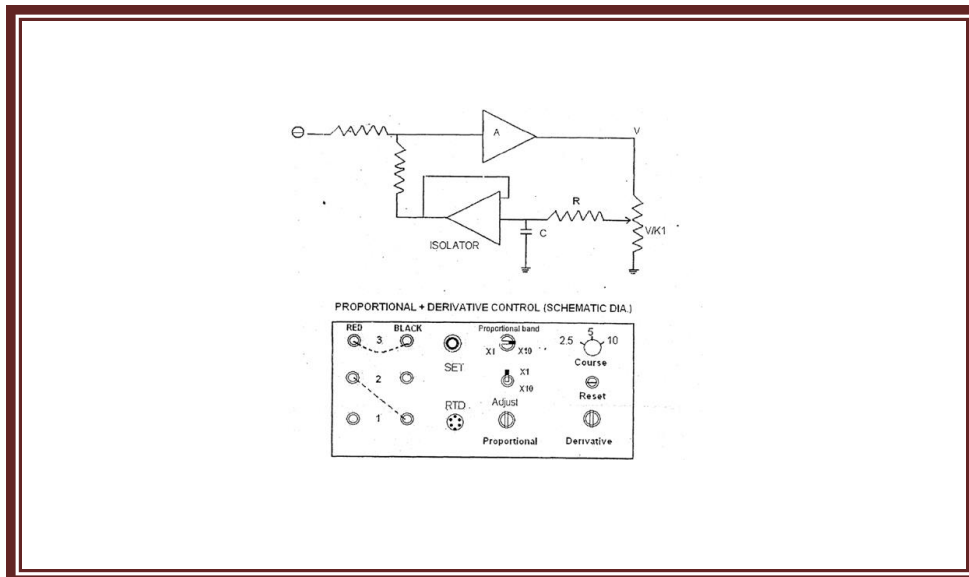


diagram:

Tabular form:

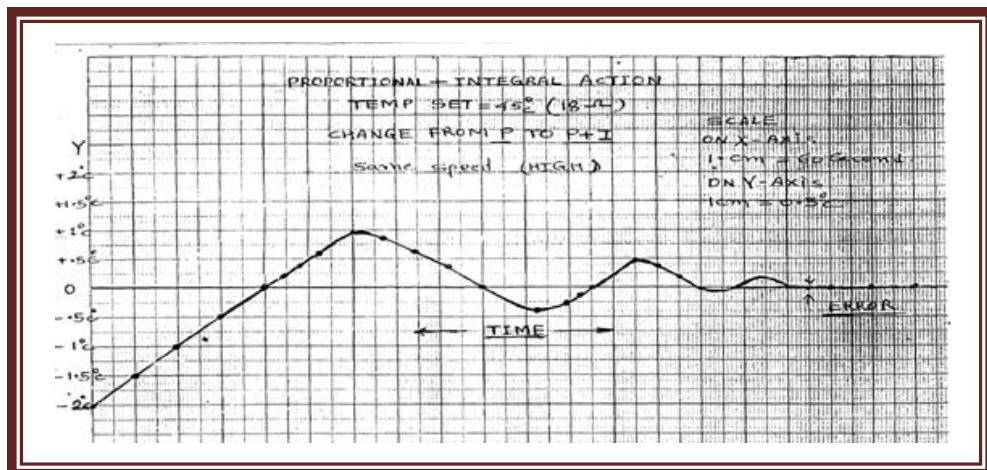
**Low Disturbance (Fan Low speed)**

Sl no	Time in seconds	Deviation Degree C
1		
2		
3		
4		
5		

**High Disturbance (Fan high speed)**

Sl no	Time in seconds	Deviation Degree C
1		
2		
3		
4		
5		

Expected graph:





## Experiment No.9(c). (P+D)

Aim: To observe the stabilizing effect of the derivative action.

Apparatus: Temperature control trainer kit  
Heater socket

Procedure:

1. Establish the connections as per fig.8 with the help of patch chords. Get the indicated settings for the various controls.

- a) SET= 18 ohms i.e.45 degree centigrade)
- b) PB= 10%
- c) Coarse control for derivative action= 5 seconds.
- d) Fine control = Midway.

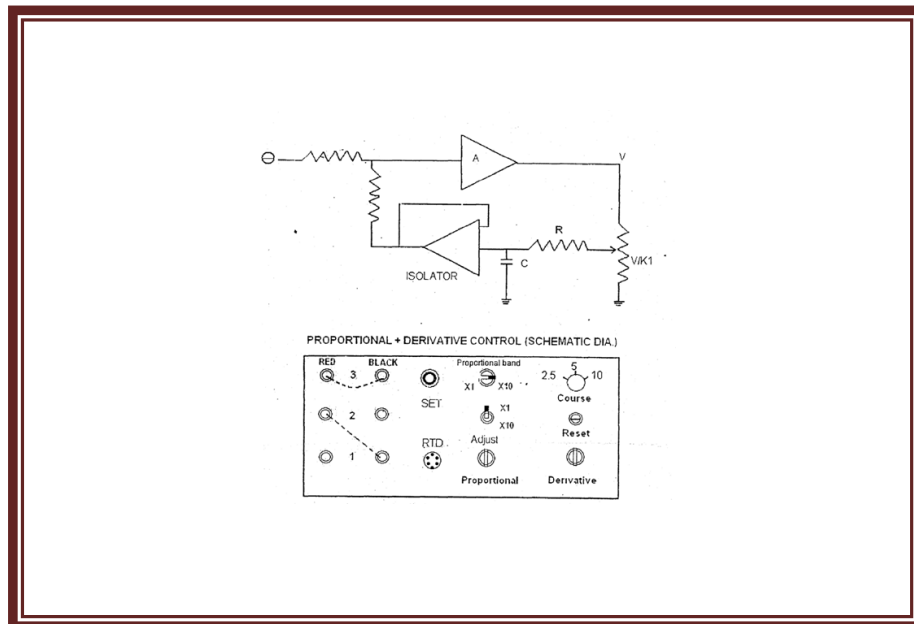
2. Turn on the fan with control on low position.

3. Wait until the process stabilizes .

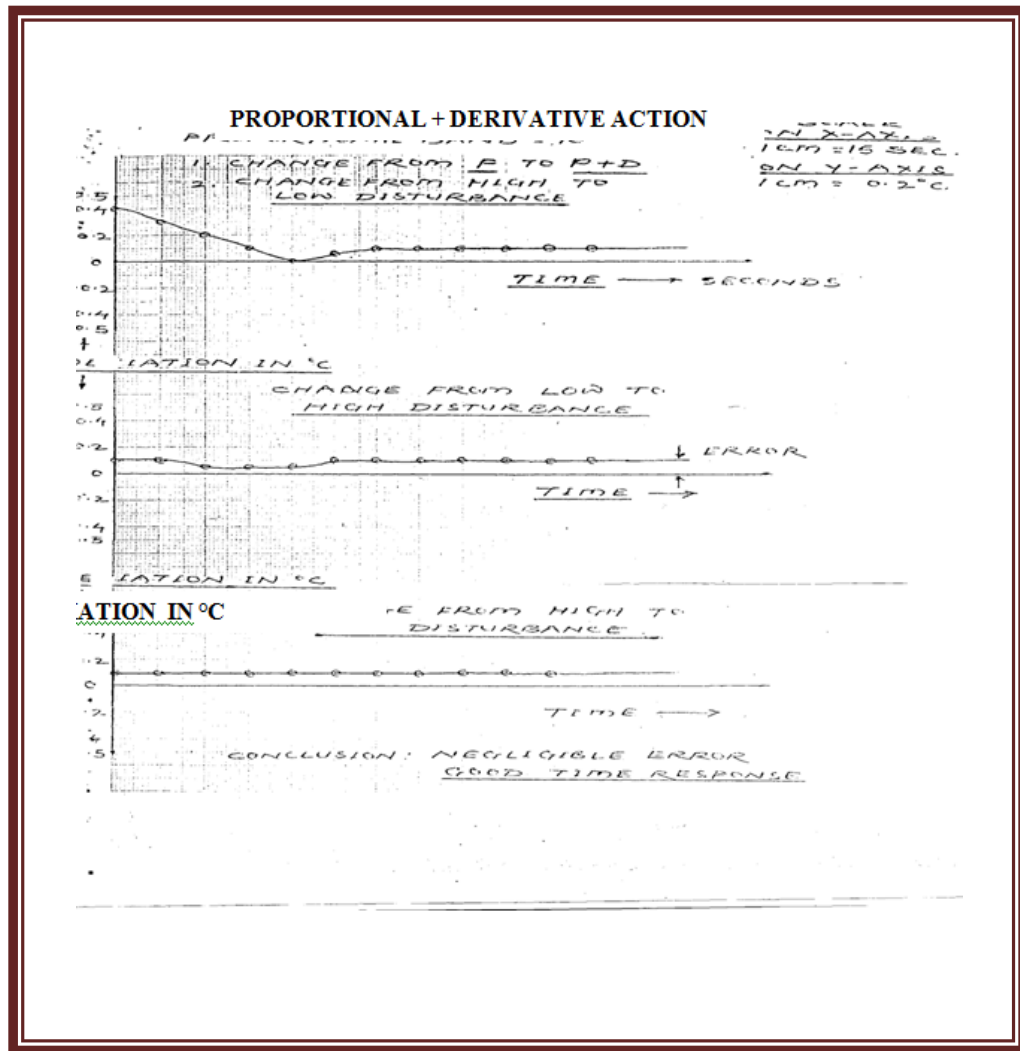
4. Now introduce the load change by moving the fan control to high position. With the help of a stop watch record the deviation meter readings at an interval of 5 to 10seconds.You may observe that the process comes to almost zero deviation point quickly. In fact in this process the performance of P+D and P+I+D are almost identical.

5. You may perform experiments for other settings of derivative time and PB.

Circuit diagram:



Expected graph:



Result:

## Experiment No.9(d). (P+I+D)

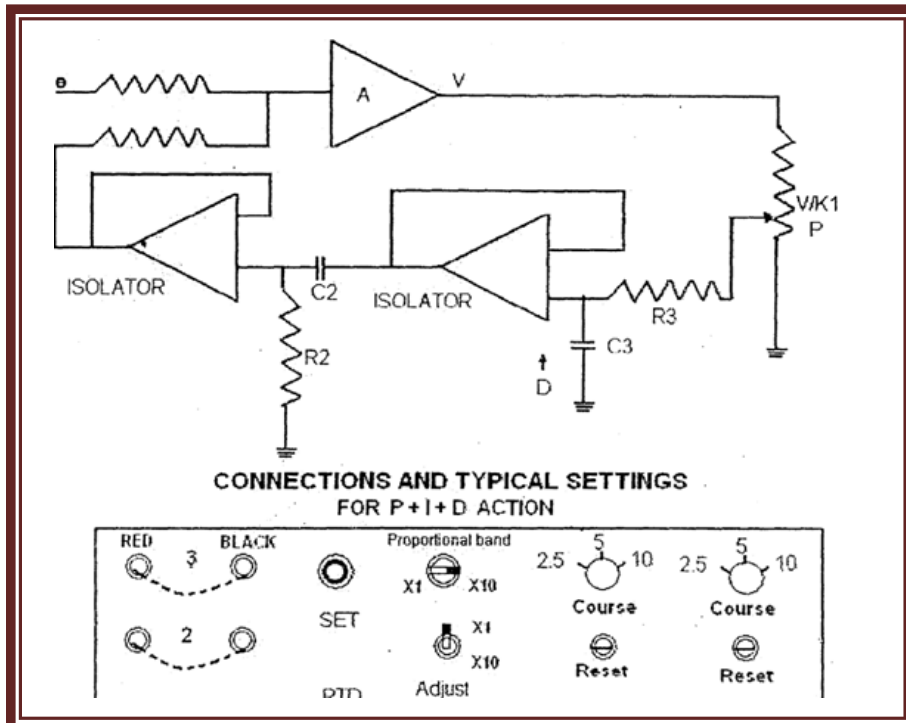
**Aim:-** To study the performance of P+I+D action.

**Apparatus:** Temperature control trainer kit  
Heater socket

### Procedure:

1. Establish the connections as per fig.9 with the help of patch chords. Get the Indicated settings for the various controls.
2. Turn on the fan with control on low position.
3. Wait until the process stabilizes.
4. Now introduce the load change by moving the fan control to high position. With the help of a stop watch record the deviation meter readings at an interval of 5 to 10seconds. You may observe that the process comes to almost zero deviation point quickly. Thus the transient response is improved and offset is also avoided.
5. You may perform experiments with various other settings. Also study the response of the system by change in set point by moving SET from 17 to 25 ohms.

### Circuit diagram:



## **PRECAUTIONS:**

1. Operate SET control pot in a gentle fashion.
2. Study all the controls carefully before using the equipment.
3. “ADJUST” control is adjusted in proportional mode to get 50% of output power when deviation is zero. Then the adjust control is not disturbed in the entire expt.
4. Make or break the connection only after turning OFF the mains supply.

**Note:-** Heater lamps are of Philips make with reflector 3 Nos. with 100/150 watts.

5. During winter season in view of low ambient temp. Adjust the process for low temperatures and vice versa for summer season.

## **Result:**

## **Viva questions:**

1. What are the applications of DC servo motors?
2. What are the types of controllers?
3. Define P and PI controllers.
4. Define PD and PID controllers.
5. Write the transfer function of PID controller?

## MATLAB

MATLAB (Matrix laboratory) is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization and programming.

MATLAB is developed by Math Works.

It allows matrix manipulations; plotting of functions and data; implementation of algorithms; creation of user interfaces; interfacing with programs written in other languages, including C, C++, Java, and Fortran; analyze data; develop algorithms; and create models and applications.

It has numerous built-in commands and math functions that will in mathematical calculations, generating plots and performing numerical methods.

MATLAB Power of Computational Mathematics.

MATLAB is used in every facet of computational mathematics. Following are some of the commonly used applications of MATLAB for mathematical calculations:

- Dealing with Matrices and Arrays
- 2-D and 3-D Plotting and graphics
- Linear Algebra
- Algebraic Equations
- Non-linear Functions
- Statistics
- Data Analysis
- Calculus and Differential Equations
- Numerical Calculations
- Integration
- Transforms
- Curve Fitting
- Various other special functions

Features of MATLAB

Following are the basic features of MATLAB:

- It is a high-level language for numerical computation, visualization and application development.
- It also provides an interactive environment for iterative exploration, design and problem solving.
- It provides vast library of mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration and solving ordinary differential equations.
- It provides built-in graphics for visualizing data and tools for creating custom plots.
- MATLAB's programming interface gives development tools for improving code quality and maintainability and maximizing performance.
- It provides tools for building applications with custom graphical interfaces.
- It provides functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET and Microsoft Excel.

## Uses of MATLAB

MATLAB is widely used as a computational tool in science and engineering encompassing the fields of physics, chemistry, math and all engineering streams. It is used in a range of applications including:

- Signal Processing and Communications
- Image and Video Processing
- Control Systems
- Test and Measurement
- Computational Finance
- Computational Biology

### **‘The MATLAB environment**

*Note:* From now on, an instruction to press a certain key will be denoted by <>, e.g., pressing the enter key will be denoted as <enter>. Commands that should be typed at the prompt, will be written in courier font.

The MATLAB environment (on most computer systems) consists of menus, buttons and a writing area similar to an ordinary word processor. There are plenty of help functions. The writing area at the start of MATLAB, is written for MATLAB, start the program in the command window by typing its name at the prompt. The command window is also useful to use MATLAB as a scientific calculator or as a graphing tool. For longer programs, it is more convenient to write the program code in a separate window, and then run it in the command window.

Type commands immediately after this prompt in the command window which looks like >>. After the command for MATLAB to perform, press <enter>. To *interrupt a command* that MATLAB is running, type <ctrl> + <c>.

The commands typed in the command window are stored by MATLAB and can be viewed in the *Command History* window. To repeat a command already used, simply double-click on the command in the history window, or use the <up arrow> at the command prompt to iterate through the commands used until desired command to repeat is reached.

## Expt.No.10. Simulation of control system concepts using MATLAB

### (a) Stability Analysis of Linear Time Invariant Systems

#### (Bode plot) using MATLAB

#### Aim:

To obtain the **Bode plot** for a given transfer function using MATLAB.

#### Apparatus: PC with windows 7

MATLAB tool

#### Theory:

In any frequency response we plot magnitude  $M$  and angle  $\phi$  against input frequency ' $\omega$ '. When  $\omega$  is varied from 0 to  $\infty$ , there is a wide range of variations in  $M$  and  $\phi$  so it becomes difficult to accommodate all such variations with linear scale hence we use logarithmic scale. Thus in bode plot logarithmic values of magnitude are to be plotted against logarithmic values of frequencies.

Bode plot consists of two plots:

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

#### Program:

```
numf=[10]           %numerator of the forward transfer function
denf=[1 4 8 0]      %denominator of the forward transfer function
gs=tf(numf,denf)    %forward transfer function
numb=[1]            %numerator of the backward transfer function
denb=[1]            %denominator of the backward transfer function
hs=tf(numb,denb)    %backward transfer function
cs=feedback(gs,hs)  %closed loop transfer function(of gs and hs)
bode(cs)            %bode plot of the closed loop transfer function
margin(cs)          %gain and phase margins of the closed loop
                    %transfer function
Clpoles=pole(cs)
```

## Output

```
>> numf=[10]
denf=[1 4 8 0]
gs=tf(numf,denf)
numb=[1]
denb=[1]
hs=tf(numb,denb)
cs=feedback(gs,hs)
```

```
numf =
    10
denf =
     1     4     8     0
```

```
Transfer function:
    10
```

```
-----
s^3 + 4 s^2 + 8 s
```

```
numb =
     1
```

```
denb =
     1
```

```
Transfer function:
     1
```

```
Transfer function:
    10
```

```
-----
s^3 + 4 s^2 + 8 s + 10
```

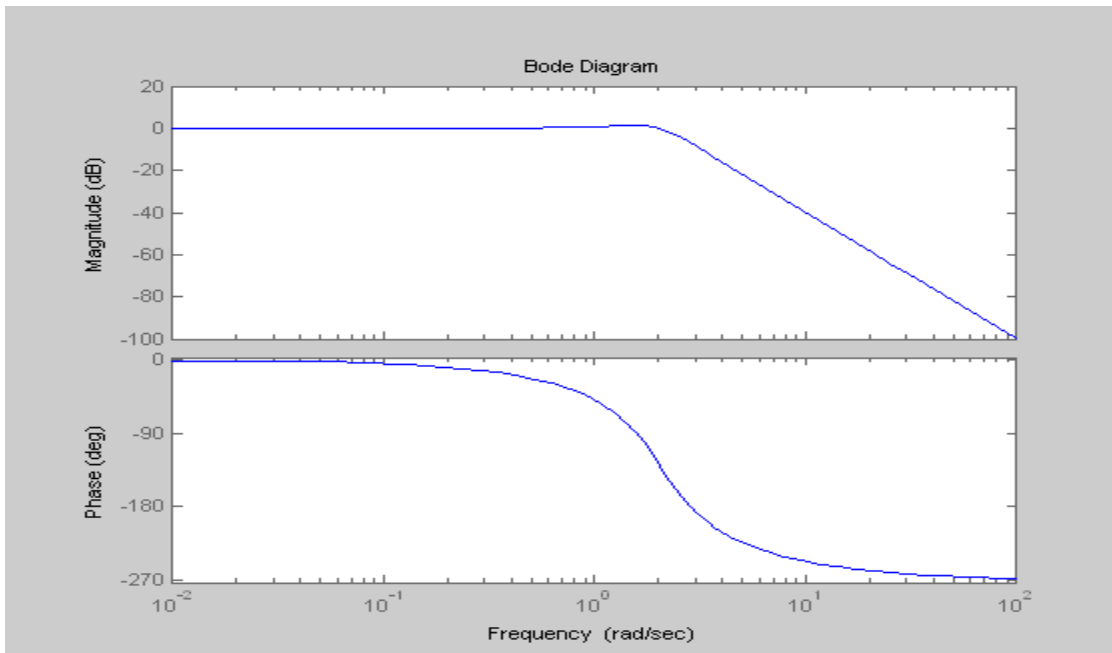
```
>> clpoles=pole(cs)
```

```
clpoles =

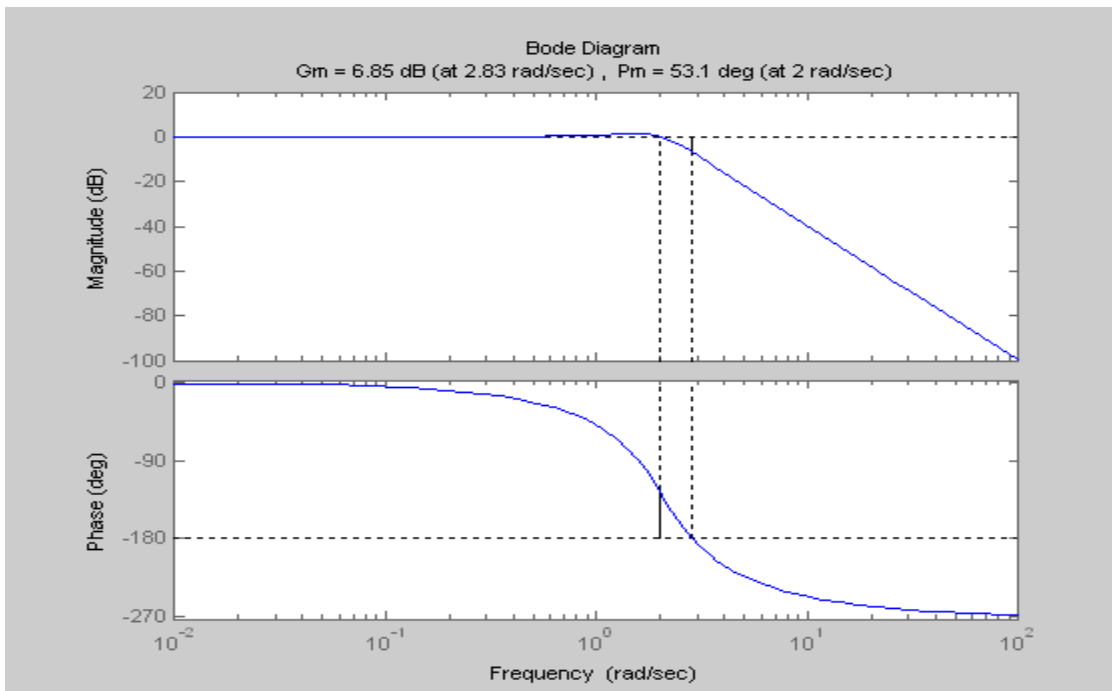
-2.4026
-0.7987 + 1.8773i
-0.7987 - 1.8773i
```

Because the poles are less than zero, the given system is stable.  
Bode (cs)





`margin(cs)`



**Result:**

**Viva Questions:**

1. What is MATLAB?
2. What are the advantages of MATLAB software?
3. Define Gain margin and phase margin?
4. What are the advantages of Bode plot?

# Expt.No.10 (b) Stability Analysis of Linear Time Invariant Systems

## (Nyquist-plot) using MATLAB

### Aim:

To obtain the Nyquist plot for a given transfer function using MATLAB.

Apparatus: PC with windows 7

MATLAB tool

### Theory:

The Nyquist method handles the system with time delay without the necessity of approximation and hence yields exact results about both absolute and relative stability of the system.

### **Program**

```
numf=[10]           %numerator of the forward transfer function
denf=[1 4 8 0]     %denominator of the forward transfer function
gs=tf(numf,denf)   %forward transfer function
numb=[1]           %numerator of the backward transfer function
denb=[1]           %denominator of the backward transfer function
hs=tf(numb,denb)   %backward transfer function
cs=feedback(gs,hs) %closed loop transfer function(of gs and hs)
nyquist(cs)        %nyquist plot of the closed loop transfer
function%
```

```
Clpoles=pole(cs)
```

### Output

```
>> numf=[10]
denf=[1 4 8 0]
gs=tf(numf,denf)
numb=[1]
denb=[1]
hs=tf(numb,denb)
cs=feedback(gs,hs)
```

```
numf =
    10
denf =
```

1 4 8 0  
Transfer function:  
10

-----  
 $s^3 + 4s^2 + 8s$

numb =

1

denb =

1

Transfer function:

1

Transfer function:  
10

-----  
 $s^3 + 4s^2 + 8s + 10$

>> clpoles=pole(cs)

clpoles =

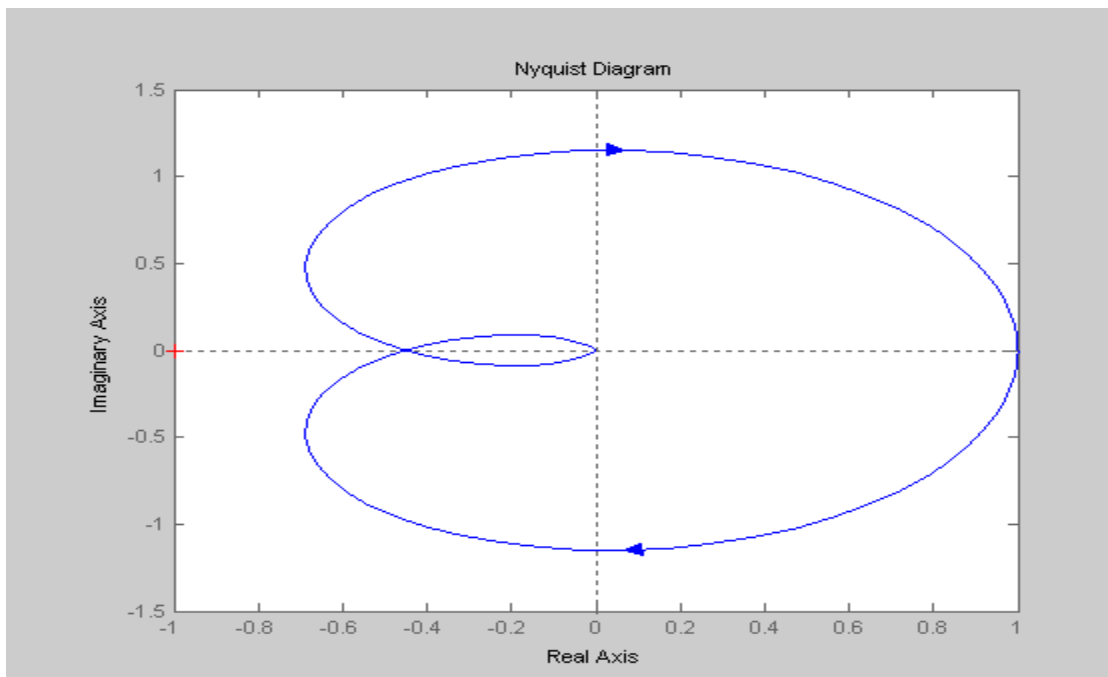
-2.4026

-0.7987 + 1.8773i

-0.7987 - 1.8773i

Because the poles are less than zero, the given system is stable.

nyquist(cs)



**Result:**

**Viva Questions:**

1. What is MATLAB?
2. What are the advantages of MATLAB software?
3. What are the advantages of Nyquist plot?
4. Define Nyquist plot?

## Expt.no.11. Root locus plot using MATLAB

### Aim:

To obtain the **root locus plot** for a given transfer function using MATLAB.

Apparatus: PC with windows 7

MATLAB tool

### Theory:

Root locus is a 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. The parameter which is usually varied is the gain but any other parameters may be varied.

### Program

```
numf=[10]           %numerator of the forward transfer function
denf=[1 4 8 0]      %denominator of the forward transfer function
gs=tf(numf,denf)    %forward transfer function
numb=[1]            %numerator of the backward transfer function
denb=[1]            %denominator of the backward transfer function
hs=tf(numb,denb)    %backward transfer function
cs=feedback(gs,hs)  %closed loop transfer function(of gs and hs)
rlocus(cs)          %root locus of the closed loop transfer function
```

```
Clpoles=pole(cs)
```

### Output:

```
>> numf=[10]
denf=[1 4 8 0]
gs=tf(numf,denf)
numb=[1]
denb=[1]
hs=tf(numb,denb)
cs=feedback(gs,hs)
```

```
numf =
```

```
10
```

```
denf =
```

```
1 4 8 0
```

Transfer function:

$$10$$

$$\frac{10}{s^3 + 4s^2 + 8s}$$

numb =

$$1$$

denb =

$$1$$

Transfer function:

$$1$$

Transfer function:

$$10$$

$$\frac{10}{s^3 + 4s^2 + 8s + 10}$$

```
>> clpoles=pole(cs)
```

```
clpoles =
```

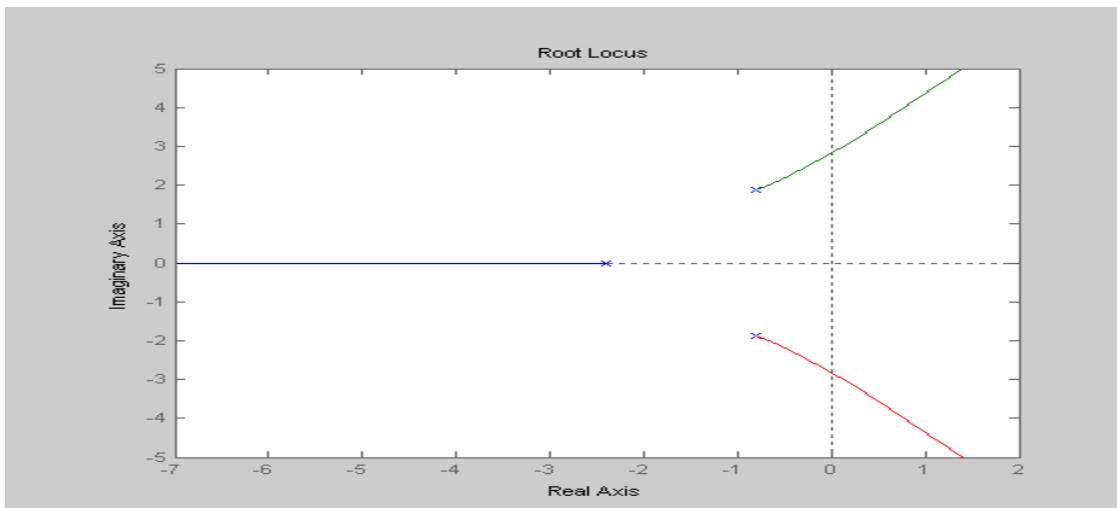
$$-2.4026$$

$$-0.7987 + 1.8773i$$

$$-0.7987 - 1.8773i$$

Because the poles are less than zero, the given system is stable.

```
locus(cs)
```



**Result:**

**Viva Questions:**

1. Define root locus or root loci?
2. What is MATLAB?
3. Define centroid and angle of asymptotes?
4. What are the advantages of MATLAB software?
5. What are the advantages of root locus?



## Expt.No.12.Test for Controllability and Observability , using MATLAB

### Aim:

To obtain the Controllability and Observability for a given state equations using MATLAB.

**Apparatus:** PC with windows 7

MATLAB tool

### Theory:

A control system is said to be **controllable** if the initial states of the control system are transferred (changed) to some other desired states by a controlled input in finite duration of time.

A control system is said to be **observable** if it is able to determine the initial states of the control system by observing the outputs in finite duration of time

### Program:

A=[-1 0 0;0 -2 0;0 0 -3];

B=[1;1,0];

C=[1 0 2];

D=[0];

M=ctrb (A,B)

Rank\_of\_M= rank(M)

System\_order=length(A)

N=(obsv(A,C))'

Rank\_of\_N=randk(N)

### Output

M= 1 -1 1

1 -2 4

0 0 0

Rank\_of\_M =2

System\_order=3

Sytem is not controllable

N= 1 -1 1

0 0 0

2 -6 18

Rank\_of\_N =2

System order=3

System is not observable

Result:

Viva Questions:

1. What is MATLAB?
2. Define controllability?
3. What are the advantages of MATLAB software?
4. Define Observability?
5. Condition for controllability and observability by using Kalman's test.