LABORATORY MANUAL

CONTROL SYSTEMS LABORATORY

II B. Tech II – SEM (EEE)

Prepared by

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ASSISTANT PROFESSOR

NAME OF THE LABORATORY	**:**	**CONTROL SYSTSEMS LAB**
COURSE CODE	**:**	**EE408PC**
YEAR/SEM	**:**	**II B. Tech II – SEM**
DEPARTMENT	**:**	**EEE**

Department of Electrical & Electronics Engineering
MALLA REDDY ENGINEERING COLLEGE & MANAGEMENT SCIENCES
(Approved by the AICTE, New Delhi and affiliated to JNTU, Hyderabad)
Kistapur Hamlet of Medchal, Hyderabad, R.R. Dist. - 501401

VISION OF THE INSTITUTE

The aspiration is to emerge as a premier institution in technical education to produce competent engineers and management professionals contributing to Industry and Society.

MISSION OF THE INSTITUTE (MI)

The aspirations are fulfilled and continue to be fulfilled:

MI-1: By providing the student supporting systems:

To impart updated pedagogical techniques with supportive learning environment and state-of-the-art facilities.

MI-2: By training the students as per the industry needs:

To cultivate a culture of interdisciplinary approach, problem solving, innovative ecosystem, and entrepreneurship by facilitating critical thinking, teamwork, and research-driven activities with hands-on learning.

MI-3: By educating the students about society's needs:

To instill ethical, social, and environmental values through community engagement resulting in sustainable development of society.

VISION OF THE EEE-DEPARTMENT

The aspiration is to produce competent Electrical and Electronics Engineering Graduates capable of making valuable contributions in the field of Electrical and Electronics Engineering.

Mission of the Department:

MD-1:

Student Support Systems:

To equip students with advanced learning skills in Electrical and Electronics Engineering, while providing them with the necessary professional competencies to overcome future challenges.

MD-2:

Training the students as per the industry needs:

To facilitate the students to acquire interdisciplinary skills in renewable energy, electric vehicles, and power electronics applications through practical knowledge and innovative techniques to meet evolving global challenges.

MD-3:

Educating the students, the needs of society:
To develop professional ethics, self-confidence, and leadership qualities among students.

PROGRAM EDUCATIONAL OBJECTIVES (PEOS)

PEO 1: MREM B. Tech EEE graduates shall be able to apply technical knowledge in Electrical and Electronics Engineering, empowering them to pursue higher studies or succeed in their professional careers in the electrical Power Industry.

PEO 2: MREM B. Tech EEE graduates shall be able to design and implement complex electrical systems, meeting the electrical and electronics industry demands.

PEO 3: MREM B. Tech EEE graduates shall be able to handle societal and environmental problems with ethical values as demanded by society.

Program Specific Outcomes (PSOs):

PSO1: Provide efficient problem-solving techniques in the areas of Power Electronics, Power Systems, Control systems, and Electrical Machines using MATLAB/MULTISIM.

PSO2: Design and develop a wide range of Electrical and Electronics Systems, specifically emphasizing Electric Drives, Conventional Renewable Energy, and Automation to demonstrate overall knowledge and contribute to the betterment of society.

PO-1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO-2	**Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO-3	**Design/development of solutions:** Design solutions for complex 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.
PO-4	**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.
PO-5	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO-6	**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 engineering practice.
PO-7	**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.
PO-8	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO-9	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO-10	**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.
PO-11	**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.
PO-12	**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 (PSOs):

PSO1	Provide efficient problem-solving techniques in the areas of Power Electronics, Power Systems, Control systems, and Electrical Machines using MATLAB/MULTISIM.
PSO2	Design and develop a wide range of Electrical and Electronics Systems, specifically emphasizing Electric Drives, Conventional Renewable Energy, and Automation to demonstrate overall knowledge and contribute to the betterment of society.

GENERAL INSTRUCTIONS FOR LABORATORY CLASSES

DO ‘S

1. Without Prior permission do not enter into the Laboratory.
2. While entering into the LAB students should wear their ID cards.
3. The students should come with proper uniform.
4. Students should sign in the LOGIN REGISTER before entering into the laboratory.
5. Students should come with observation and record note book to the laboratory.
6. Students should maintain silence inside the laboratory.
7. Circuit connections must be checked by the lab-in charge before switching the supply

DONT ‘S

1. Students bringing the bags inside the laboratory.
2. Students wearing slippers/shoes insides the laboratory.
3. Students scribbling on the desk and mishandling the chairs.
4. Students using mobile phones inside the laboratory.
5. Students making noise inside the laboratory.
6. Students mishandle the devices.
7. Students write anything on the devices

Course Objectives:

- To understand the different ways of system representations such as Transfer function
- Representation and state space representations and to assess the system dynamic response
- To assess the system performance using time domain analysis and methods for improving it
- To assess the system performance using frequency domain analysis and techniques for
- improving the performance
- To design various controllers and compensators to improve system performance

Course Outcomes:

S. NO	Course Outcomes
C217.1	How to improve the system performance by selecting a suitable controller and/or a compensator for a specific application
C217.2	Apply various time domain and frequency domain techniques to assess the system performance
C217.3	Apply various control strategies to different applications (example: Power systems, electrical drives etc.)
C217.4	Test system controllability and observability using state space representation and applications of state space representation to various systems
C217.5	Discuss the need of software tools (MATLAB) to illustrate modeling and simulation of any system.

CO Mappings PO & PSO

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
C217.1	3	2	3	3	1							1	3	2
C217.2	3	2	2	3	1							1	3	2
C217.3	1	3	3	2	1							1	3	2
C217.4	3	2	3	3	1							1	2	2
C217.5	3	2	3	3	1							1	3	2
Average														

CONTENTS

CONTROL SYSTEMS LABORATORY (EE408PC)

EXPERIMENT 1:

TIME RESPONSE OF SECOND ORDER SYSTEM

Objective:

To compute the Time Response of a second order system (theoretically and practically).

- To Observe the characteristics of time response of a second order system in CRO
- To Calculate damping factor, delay time, rise time, peak time, peak over shoot, setting time and damped natural frequency.

1.1 APPARATUS REQUIRED:

S. No.	Apparatus	Range	Quantity
1	Decade Resistance Box	(0-100) Ω	01
2	Decade Capacitance Box	(0-50µ) f	01
3	Decade Inductance Box	(0-1) H	01
4	Function Generator	(0-2M) Hz	01
5	Digital Multimeter	(0-10) A	01
6	CRO	(0-2M) Hz Dual Trace Oscilloscope	01
7	BNC Adaptors	---	01
8	Patch cords	---	Some

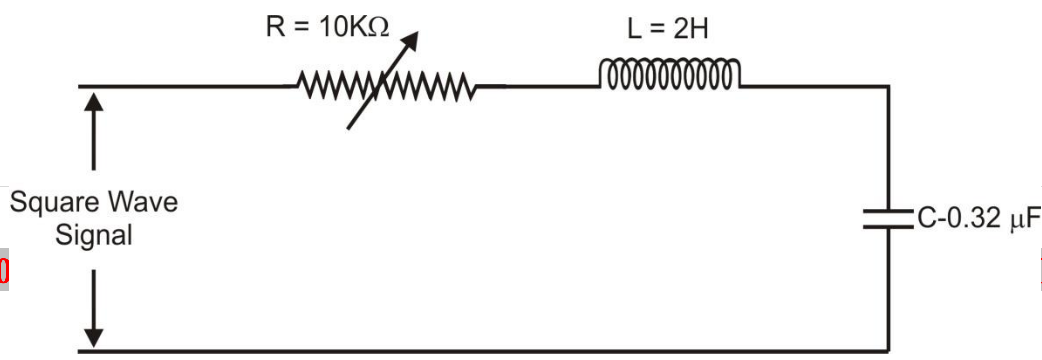
1.2 PRECAUTIONS*:*

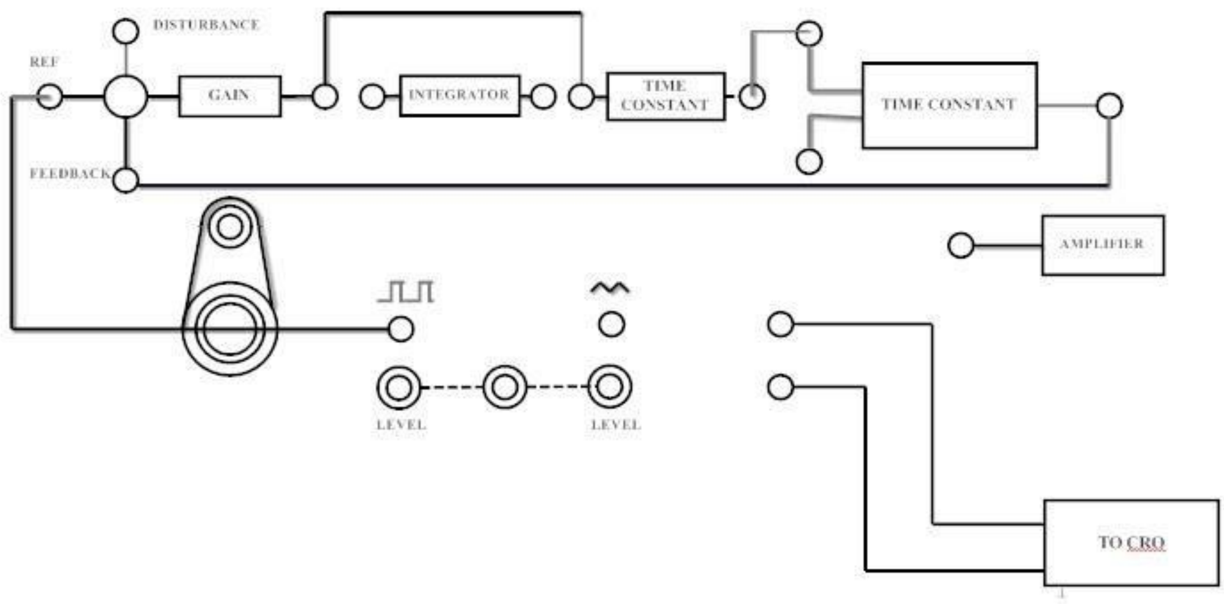
1. Energize the circuit after thorough checking of lab in-charge

2. Student should not operate the main power panel

3. De-energize the circuit after completion of experiment

1.3 CIRCUIT DIAGRAM:





1.4 PROCEDURE:

1. Switch ON the Main supply and observe the signal source output by varying potentiometer
2. Apply Square wave or step input by varying amplitude potentiometer.
3. Make sure signal source is connected before the input of the second order system.
4. Now select square wave signal. Draw the input square wave signal.
5. Connect the output of square wave signal source to second order system using RLC.
6. Adjust the resistance value in the RLC circuit for different damping factors.
7. For different values of damping factor, observe second order response.
8. Verify time response specifications theoretically and practically.

Note: Use 3 pin grounded main supply to the unit avoid line interference. Use proper CRO probes to see the output wave forms.

For all these cases note down the time response specifications and compare them with theoretical values.

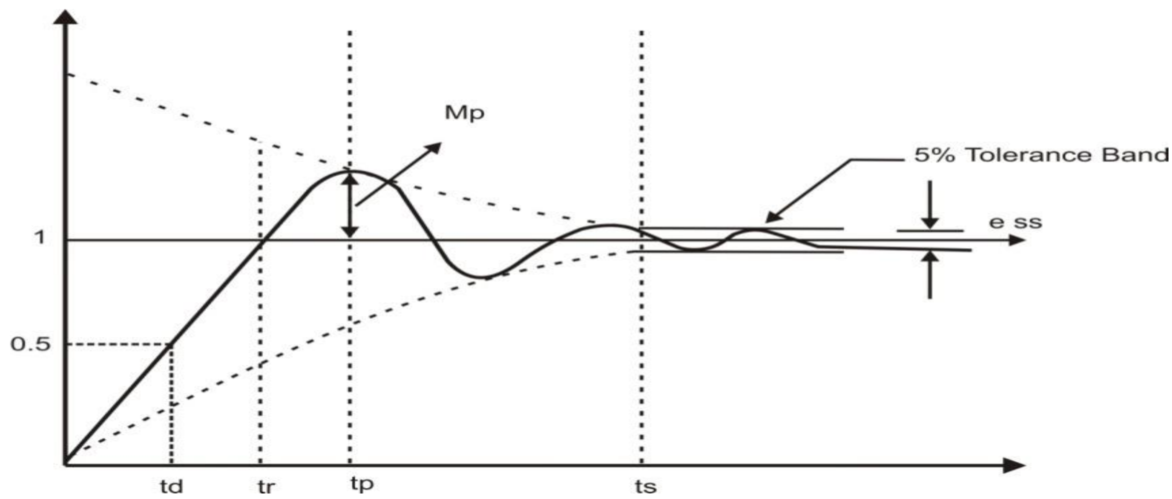
1.5 OBSERVATION TABLE:

S. No	R in Ohm	L in Henry	C in Micro Farad	δ (Damping Factor)	td	tr	Mp	t_p	t_s	ess
1	500	2	0.32							
2	1000	2	0.32							
3	1500	2	0.32							
4	2000	2	0.32							
	–	–	–							
	–	–	–							
	–	–	–							
	–	–	–							
	–	–	–							
	–	–	–							
	10000	2	0.32							

Time domain specification	Theoretical	Practical
Rise time (t_r)		
Peak time (t_p)		

Delay time (t_d)		
Setting time (t_s)		
Peak over shoot (M_P)		

1.6 MODEL GRAPH:



THEORY:

The time response has utmost importance for the design and analysis of control systems because these are inherently time domain systems where time is independent variable. During the analysis of response, the variation of output with respect to time can be studied and it is known as time response. To obtain satisfactory performance of the system with respect to time must be within the specified limits. From time response analysis and corresponding results, the stability of system, accuracy of system and complete evaluation can be studied easily.

Due to the application of an excitation to a system, the response of the system is known as time response and it is a function of time.

The two parts of response of any system:

1. Transient response
2. Steady-state response.

Transient response: The part of the time response which goes to zero after large interval of time is known as transient response.

Steady state response: The part of response that means even after the transients have died out is said to be steady state response. The total response of a system is sum of transient response and steady state response: C(t)=Ctr(t)+Css (t)

TIME DOMAIN SPECIFICATIONS:

1. Delay Time
2. Rise Time
3. Peak Time
4. Peak Overshoot
5. Settling time

Delay Time

It is the time required for the response to reach half of its final value from the zero instant. It isdenoted by td

Rise Time

It is the time required for the response to rise from 0% to 100% of its final value. This is applicable forthe under-damped systems.

For the over-damped systems, consider the duration from 10% to 90% of the final value.Rise time is denoted by tr.

Peak Time

It is the time required for the response to reach the peak value for the first time. Itis denoted by tp.

Peak Overshoot

Peak overshoot Mp is defined as the deviation of the response at peak time from the final value ofresponse.

Settling time

It is the time required for the response to reach the steady state and stay within the specified tolerancebands around the final value. In general, the tolerance bands are 2% and 5%.

The settling time is denoted by t_s.

TIME RESPONSE OF SECOND ORDER CONTROL SYSTEM:

A second order control system is one wherein the highest power of ‘s’ in the denominator of its transfer function equals 2.

Transfer function is given by:

Transfer function of given circuit is $V_o/V_i = (1/LC) / (s^2+(R/L)\,s+(1/LC))$

Normal frequency, $\omega_n = 1 / \sqrt{(LC)}$

Damping factor, $\xi = (R/2)\sqrt{(C/L)}$

Rise time, $t_r = [\Pi-\tan^{-1}(\sqrt{(1-\xi^2)}/\xi)] / (\omega_n \sqrt{(1-\xi^2)})$

Peak time, $t_p = \Pi / (\omega_n \sqrt{(1-\xi^2)})$

% Peak Overshoot = $e^{-\partial\Pi / \sqrt{(1-\xi^2)}} * 100$

Settling time, $t_s = 4 / (\xi\,\omega_n)$

Delay time, $t_d = t_r / 2$

ω_n—is called natural frequency of oscillations.

$\omega_d=\omega_n\sqrt{1-\delta^2}$ is called damping frequency oscillations.

δ-affects damping and called damping ratio.

$\delta\omega_n$ is called damping factor or actual damping or damping coefficients.

Theoretical Calculations:

1.7 RESULT: The characteristics of time response of a second order system are observed in CRO.

1.8 CONCLUSIONS: The values of damping factor, delay time, rise time, peak time, peak over shoot, setting time and damped natural frequency are calculated observed time response. The practical values are verified with theoretical calculated values.

1.9 PRE LAB-QUESTIONS:

1. What is Time Response?
2. Define Delay Time, Rise Time, Peak Time, Peak Over Shoot, Settling Time?

1.10 LAB ASSIGNMENT: -

1 Define type and order of a system?

2. Distinguish between Type and Order of a system?

1.11 POST LAB QUESTIONS:

1. What is Steady State Error?
2. The damping ratio of system is 0.6 and the natural frequency of oscillation is 8 rad/ sec. Determine the rise time.
3. Define Positional Error Constant and Velocity Error Constant?

Viva Questions:

1. What is control system?
2. What are the Time domain specifications?
3. What is Rise time?

4. What is Delay time?
5. What is Characteristic Equation of second order system?
6. What is Maximum peak overshoot?
7. What is Settling Time?
8. What is Settling Time with 2% tolerance band?
9. What is the relation between rise time and band width?
10. What are various types of Control Systems?

EXPERIMENT 2:

CHARACTERISTICS OF SYNCHROS

2.1 OBJECTIVE:

I. To study i) Synchro Transmitter characteristics.

ii) Synchro Transmitter – Receiver Characteristics.

- To study the variation of voltages between stator winding terminals with change in rotor position of synchro transmitter
- To study the variation of Rotor position of synchro receiver with the change in rotor position of synchro transmitter.

2.2 Apparatus required:

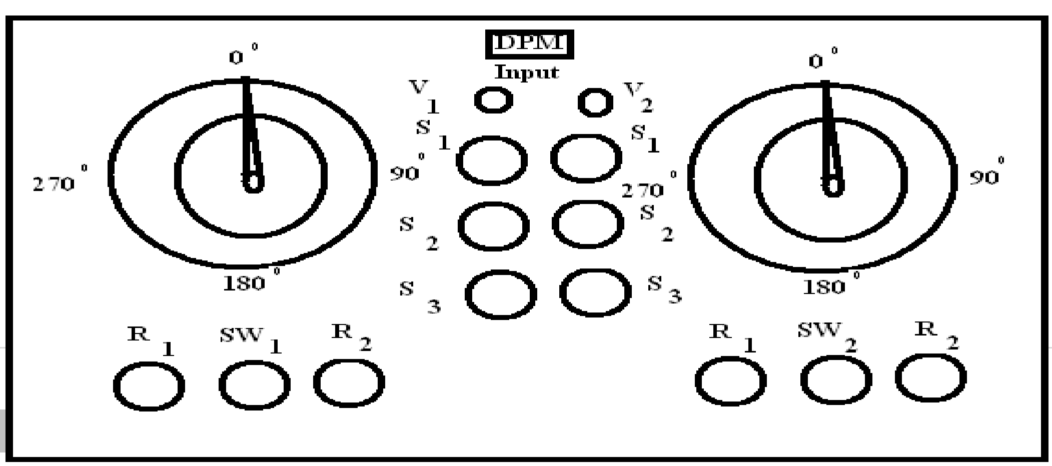
S. No.	Apparatus	Range	Quantity
1	Synchro Transmitter and Receiver Pair Kit	---	1
2	Multi-Meter	-----	1
2	Patch Cords	---	Some

2.3 PRECAUTIONS:

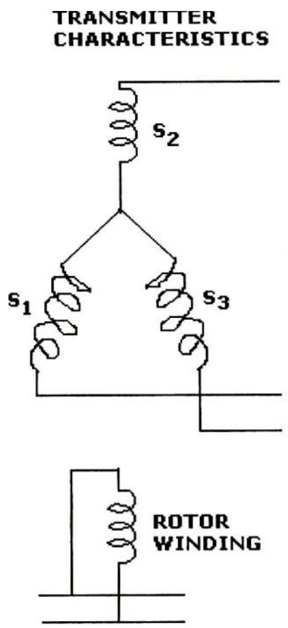
1. Energize the circuit after thorough checking of lab in-charge
2. Student should not operate the main power panel
3. De-energize the circuit after completion of experiment

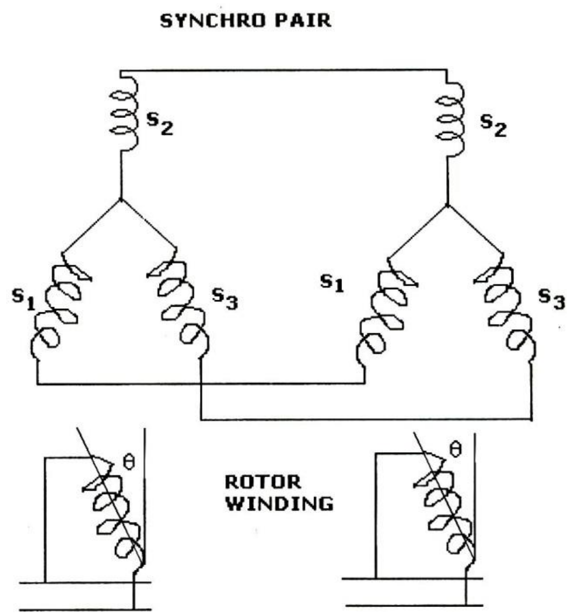
2.4 CIRCUIT DIAGRAM:

Front Panel view



Circuit Diagram:





2.5 Procedure:

Synchro Transmitter:

1) Connect the main supply to the system with the help of cable provided. Do not connect any patch cords to terminals marked S1, S2 and S3.
2) Switch ON the main supply for the unit.
3) Starting from zero position, note down the voltage between stator winding terminals i.e., VS1S2 & VS2S3 & VS3S1 in a sequential manner.
4) Enter reading in tabular columns and plot a graph of angular position of rotor voltage for all 3-phases.
5) Note that zero position of the stator rotor coincides with VS3 VS1 voltage equal to zero voltage. Do not disturb this condition.

Synchro Transmitter & Receiver Pair:

1) Connect the supply cable.
2) Connect the S1, S2 and S3 terminals of transmitter to S1, S2 and S3

terminals of synchro receiver by patch cords.

3) Switch ON SW1, SW2 and also switch ON the main supply.
4) Move the pointer i.e., rotor position of synchro transmitter in steps of 30^0 and observe the new rotor position.
5) Enter the input angular position and output angular position in the tabular form and plot a graph.

2.6 THEORY:

The term synchro is a generic name for a family of inductive devices which works on the principle of a rotating transformer basically they are electro- mechanical devices or electromagnetic transducers which produces an o/p voltage depending upon angular position of the rotor a synchro system is formed by inter connection. The basic synchro is usually called a synchro transmitter. Its construction is similar to that of a three-phase alternator. The stator (stationary member) is of laminated silicon steel and is slotted to accommodate a balanced three phase winding which is usually of concentric coil type f (three identical coils are placed in the stator with their axis 120 degree apart) and is Y connected. The rotor is a dumb bell shape type in construction and wound with a concentric coil. An a.c. voltage is applied to the rotor winding through slip rings. The system set up is consists of synchro transmitter and synchro receiver on a single rigid panel housed in MS cabinet plates, Rotor position of Tx and Rx is marked by graduated angular scale with pointer arrangement. AC input excitation supply for rotor of Tx and Rx is provided internally and panel switches are provided to make it On and Off independently. Test points for Tx and Rx stator and Rotor points are provided on panel.

2.7 TABULAR COLUMN:

Transmitter Characteristics:

Stator Voltages for 3-ϕ (V_{S1S3}, V_{S1S2}, V_{S2S3})

ROTOR VOLTAGE = V_R =				
S. No.	Position Rotor (in degree)	Stator / V_{S3S1}	Terminal V_{S1S2}	Voltage (rms) V_{S2} V_{S3}

1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

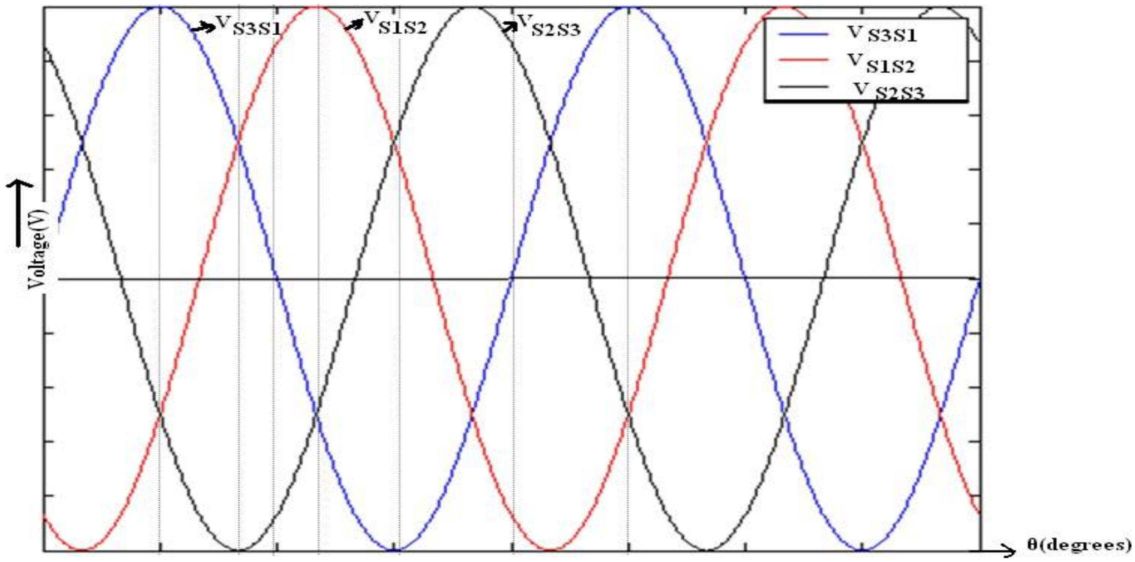
Transmitter-Receiver Characteristics:

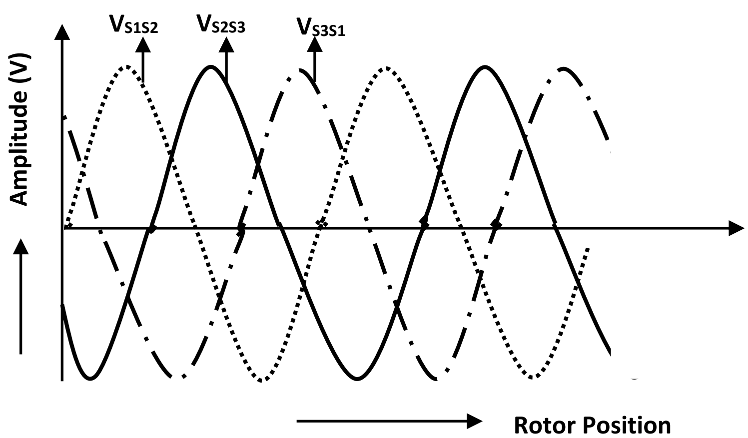
S. No.	Angular Position in Degrees Synchro Transmitter (Input)	Angular Position in Degrees Synchro Receiver (Output)

1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		

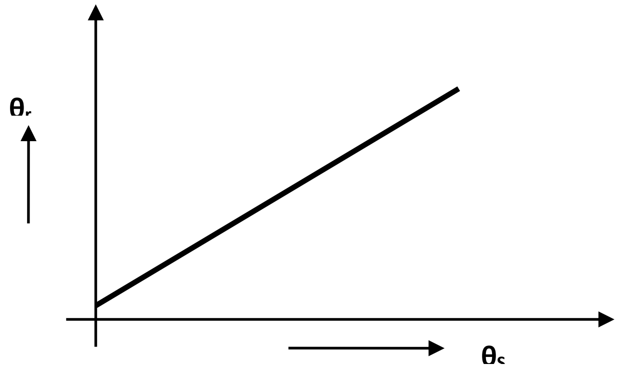
2.8 MODEL GRAPH:

Synchro Transmitter Characteristics:





Synchro Transmitter-Receiver Characteristics:



2.9 RESULT:

Hence, the synchro transmitter characteristics and synchro transmitter – Receiver characteristics are studied.

2.10 CONCLUTIONS:

The variation of voltages between stator winding terminals with change in rotor position of synchro transmitter is studied.

The variation of Rotor position of synchro receiver with the change in rotor position of synchro transmitter is studied.

2.11 PRE LAB-QUESTIONS:

1. Define the term "synchro."?
2. Name the two general classifications of synchro's?
3. List the different synchro characteristics and give a brief explanation of each?
4. Explain the operation of a basic synchro transmitter and receiver?
5. Name the two types of synchro identification code?

2.12 LAB ASSIGNMENTS:

1. To draw the characteristics of receiver?
2. How it will work in navy systems?
3. Explain what happens when the rotor leads on Synchro transmitter and synchro receiver are reversed?
4. Draw the five standard schematic symbols for synchro and identify all connections?

2.13 POST LAB QUESTIONS:

1. State the difference between a synchro transmitter and a synchro receiver?
2. Explain the operation of a simple synchro transmission system?
3. State the purposes of differential synchro's?
4. State the purposes and functions of multispeed synchro systems?

5. List the basic components that compose a torque synchro system?

Viva - Questions:

1. What is meant by synchro's?
2. What are the applications of synchro's?
3. What are the types of synchro's?
4. What are the uses of synchro's?
5. Synchro's is also called as?
6. What are the functional categories of synchro's?
7. Synchro resembles what electrical machine.
8. What is the effect of feedback on a given system?
9. Compare Stability versus feedback of a given system.
10. What are the examples of closed loop control system?

EXPERIMENT 3:

Programmable logic controller – Study and verification of truth tables of logic gates, simple Boolean expressions, and application of speed control of motor.

AIM:

Study and develop the ladder program using PLC for the following modules Logic gatesimulation, Boolean algebra

APPARATUS:

1. PLC Trainer Kit
2. Logic gate simulation module
3. Boolean algebra panel
4. DC motor Control using relays
5. Personnel Computer
6. Connecting wires

PROCEDURE:

(A) OR Logic:

1) connect S_1 to I_1, S_2 to I_2, S_3 to I_3
2) Connect the output Q_1 to Red indicator
3) Enter the program as

I1……………………

…………………

…………....

I2…………………………….Q1

I3…………………………….

4) Run the programmed
5) Press either S_1 or S_2 or S_3 and observe the status of output Q_1 for various input andverify truth table.

OR LOGIC:

A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

(A) AND Logic:

1) connect S_1 to I_1, S_2 to I_2, S_3 to I_3
2) Connect the output Q_1 to Red indicator
3) Enter the program as
   I1……… I2……}…… I3…………… Q1
4) Run the programmed
5) Press either S_1 or S_2 or S_3 and observe the status of output Q_1 for various input andverify truth table

AND LOGIC:

A	B	A+B
0	0	0
0	1	0
1	0	0
1	1	1

(B) NOT Logic:

1) connect S_1 to I_1
2) Connect the output Q_1 to Red indicator
3) Enter the program as I1 ....}.......... Q1
4) Run the programmed
5) Press either S_1 and observe the status of output Q_1 for various inputs and verify truthtable.

NOT LOGIC:

A	B
0	1
1	0

(C) NOR LOGIC:

1) connect S_1 to I_1, S_2 to I_2
2) Connect the output Q_1 to Red indicator
3) Enter the program as I1 .... M1
   I2..................................

   — M1....................... Q1

4) Run the programmed
5) Press either S_1 or S_2 or both and observe the status of output Q_1 for various input andverify truth table

NOR LOGIC:

A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

(D) NAND Logic:

1) connect S_1 to I_1, S_2 to I_2
2) Connect the output Q_1 to Red indicator
3) Enter the program as

   — I1.........................

   I2.........................}M1 M1

   ....

   Q1

4) Run the programmed and observe the output.

NAND LOGIC:

A	B	AB
0	0	1
0	1	1
1	0	1
1	1	0

(E) EX-OR Logic:

1) connect S_1 to I_1, S_2 to I_2
2) Connect the output Q_1 to Red indicator
3) Enter the program as }

   I1………………

   I2.................................. Q1

   I1…………………I2…………
4) Run the programmed and observe the output
5) Press either S_1 or S_2 or both and observe the status of output Q_1 for various input andverify truth table

EX-OR LOGIC:

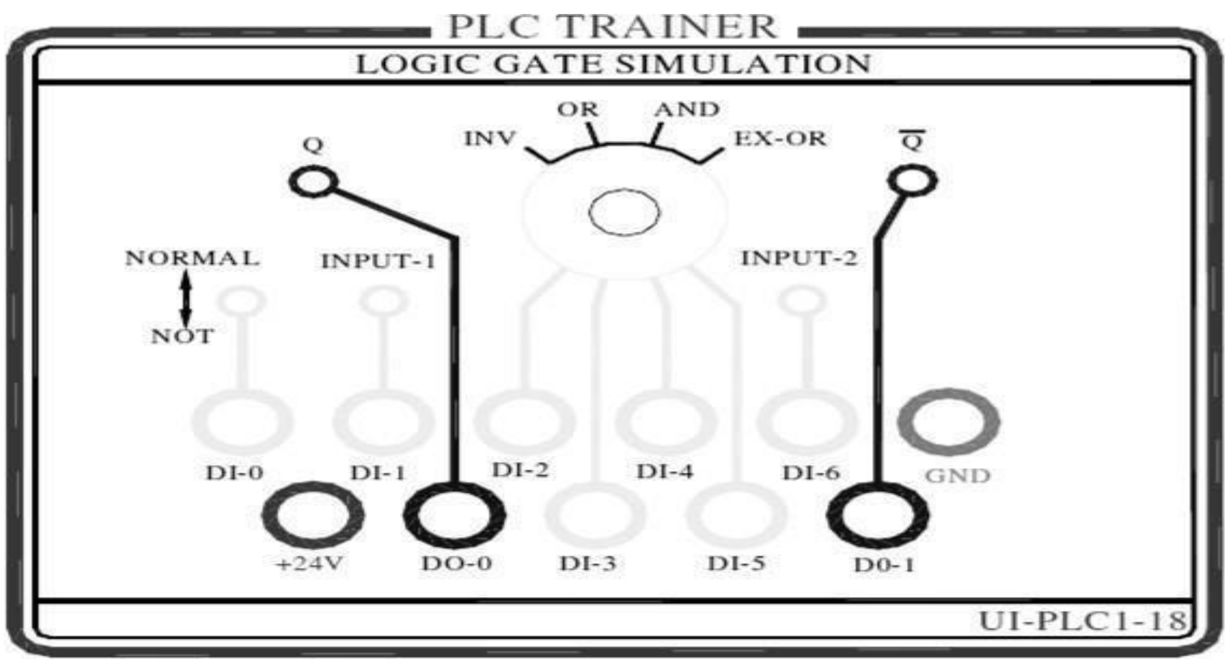
A	B	A (+) B
0	0	0
0	1	1
1	0	1
1	1	0

THEORY:

A Programmable Logic Controller, or PLC, is a ruggedized computer used for industrial automation. These controllers can automate a specific process, machine function, or even an entire production line. The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters.

Depending on the inputs and outputs, a PLC can monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application.

CIRCUIT DIAGRAM: Fig – 3.2 Boolean algebra Module



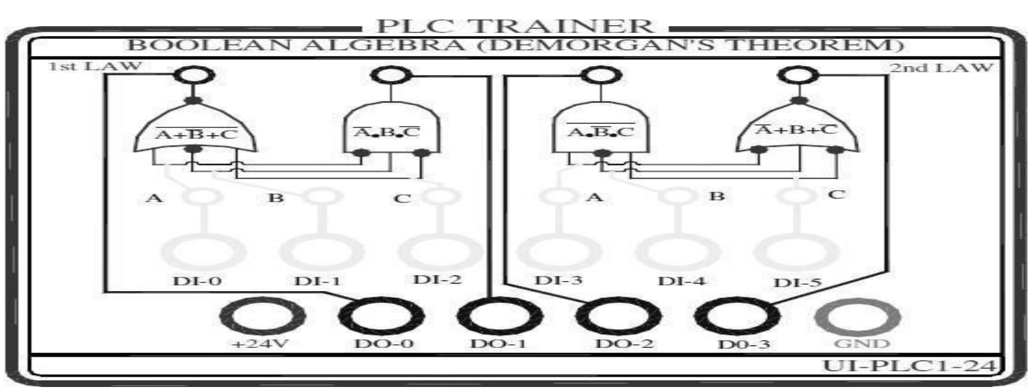


Fig – 3.2 Boolean algebra Module

INV gate

Q	
0	1
1	0

AND gate:

X	Y	X.Y
0	0	0
0	1	0
1	0	0
1	1	1

OR gate:

X	Y	X+Y
0	0	0
0	1	1
1	0	1
1	1	1

EX-NOR gate:

X	Y	X®Y= +XY
0	0	1
0	1	0
1	0	0
1	1	1

DE Morgan's Ist Law

A	B	C		A. C
0	0	0	0	0
0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
1	0	0	0	0
1	0	1	1	1
1	1	0	0	0
1	1	1	0	0

DE Morgan's IInd Law

A	B	C		A +C
0	0	0	1	1
0	0	1	1	1
0	1	0	0	0

0	**1**	**1**	**1**	**1**
1	**0**	**0**	**1**	**1**
1	**0**	**1**	**1**	**1**
1	**1**	**0**	**1**	**1**
1	**1**	**1**	**1**	**1**

PROCEDURE:

1 Press the start button
2 Click on the program folder
3 Click on the WPL soft
4 Execute WPL2
5 After the 'RUN' operation what operated next is the WPL window will show up.
6 After WPL soft is activated, we are to undertake the creating of new documents.
7 After the setting is completed, three windows will show up: one is the ladder diagram modewindow, the other is the command mode window and the third one is the SFC editing mode.
8 Users are to choose the editing mode of their interests to proceed with the program editing.
9 The ladder diagram mode :(after the diagram is edited, convert the ladder diagram to thecommand mode and the SFC diagram through compiling)
10 The command mode (after the command is edited, convert it to the ladder and the SFC diagramthrough compiling)
11 The SFC mode: (after the SFC diagram is edited convert it to the command code through compiling and to convert it to the ladder diagram, users have to go through the command code compiling in order to achieve the ladder diagram conversion.)
12 When WPL soft is activated, the first image to show up is; there are five selections on the function panel: File (F), communication(C), option (o), window (W), Help (H).
13 Click on 'New' under ''File'', and the following image will show up; there will be

some other selections listed on the function panel: Edit (E), Compile (P), Comment (L), Search(S), and View(V).

RESULT:

VIVA QUESTIONS:

1. Where in the PLC memory is each timer storing its data?
2. How does the operation of an OFF -delay timer differ from that of an on-delay timer?
3. How does each type of timer get reset back to zero?

EXPERIMENT 4:

EFFECT OF FEEDBACK ON DC SERVO MOTOR

AIM: -*To study the effect of feedback on DC Servo Motor by its Torque-Speed characteristics*

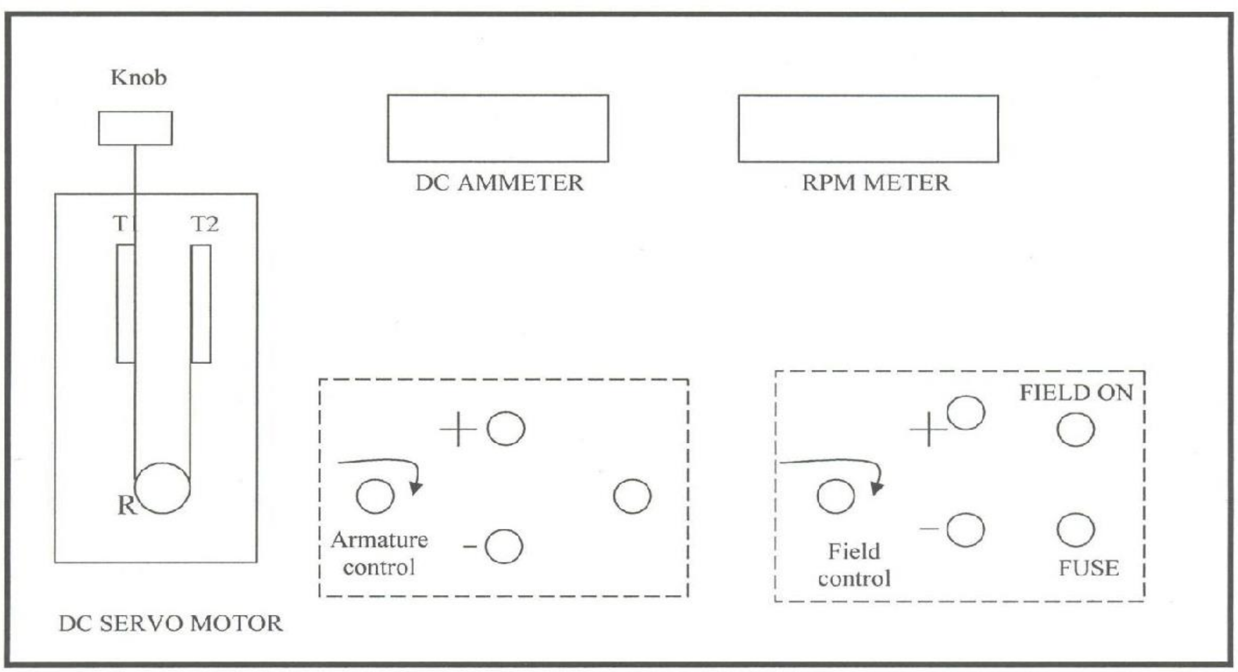
APPARATUS: -

1. DC Servo Motor Kit
2. Patch Chords
3. Multimeter
4. Connecting Leads

PRECAUTIONS: -

1. Potentiometers of Field control and Armature control must be always in minimum position (i.e., extreme anti- clock wise direction) before switching ON the equipment.
2. Spring balance unit should be properly fixed to the main unit.
3. If field on indication LED is not glowing then immediately switch OFF the instrument and start again.

BLOCK DIAGRAM: -



PROCEDURE: -

1. Before switch ON the instrument, please see that armature control potentiometer and field control potentiometer are at minimum position so that the armature voltage applied to the armature from zero volts onwards and field voltage applied to the field from 25V onwards.
2. Switch ON the instrument, observe that the field on indication LED glows, if not then immediately switch OFF the instrument. Please note that for all DC motors field voltage to be given initially before applying the armature voltage. Initially DC ammeter and RPM meter indicates ZERO reading.
3. Connect the ammeter to the terminal of field voltage Adjust spring balance so that there is minimum load on the DC Servo Motor. You may fix knob at any particular place to apply a fixed load on the DC Servo Motor.
4. Adjust armature control potentiometer so that $\mathbf{V_a}$ = 10V and field control potentiometer so that $\mathbf{V_f}$ = 20V by using digital ammeter.
5. Note down $\mathbf{T_1}$, $\mathbf{T_2}$, Armature Current (Ia) and Speed.
6. Keeping $\mathbf{V_a}$ = 10V, $\mathbf{V_f}$ = 20V, adjust $\mathbf{T_1}$ up to 500 gm in suitable steps and note down the readings as in step 6.
7. Now repeat the step 7 for $\mathbf{V_a}$ = 15, 20 and 25 by keeping $\mathbf{V_f}$ at 20V.
8. You may repeat the steps 7 & 8 for $\mathbf{V_f}$ = 15V, 10V.

THEORY: -

The types of DC Servo Motors are (i) Series Motor (ii) Shunt Motor (iii) Permanent Magnet Motor. A DC Servo Motor can be controlled by varying either the field current or the armature current. DC Servo Motors offers higher efficiency than that of AC Servo Motors of same size, but radio interference is a problem in some applications.

Most of the DC Servo Motors used in low power applications are of the PM type. The ease of controllable speed along with the linear torque-speed characteristics makes the DC Servo Motor ideal for servo mechanism applications. The torque-speed curve is quite similar to that of the AC Servo Motor. These motors are available in 6, 12 and 24 V models making them applicable to solid-state circuitry. By comparison, the DC Servo Motor has some advantages over AC Servo Motor.

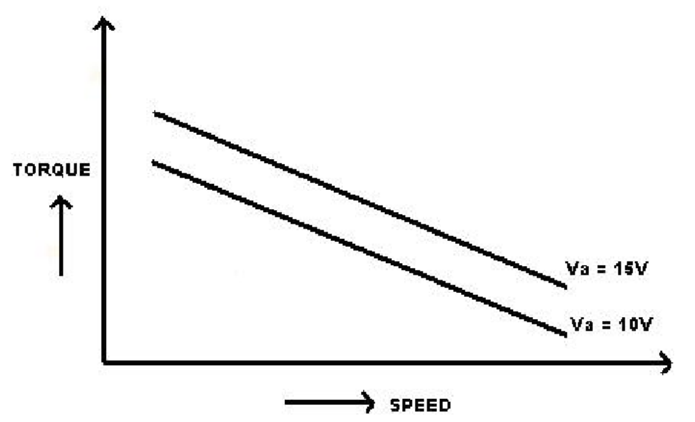
The DC Servo Motor inertia is greater than that of the AC Servo motor. This greater inertia is due to the wound armature and commutator, which produces a heavier rotor. The DC Servo Motor does not require any standby power whereas the AC Servo Motor continuously draws power for its main (reference) winding. Such DC Servo Motors are popular in compact systems such as pneumatic control and robotics systems and in automatic control machines. DC Servo Motors in some modern servomechanism may be one of the brushes less types, which lend themselves to easy computer control Alone the same lines, the stepping motor has become a valuable type to be used as a servo motor.

<u>TABLE: -</u>

Field Voltage (**V_f**) = 20 V

S. No.		**T_1 (gms)**	**T_2 (gms)**	**$T = T_1 - T_1$**	**Torque = T * 3.5**	**Speed (rpm)**	**I_a (mA)**
Va =10 V	*1*						
	2						
	3						
Va =15 V	*1*						
	2						
	3						

MODEL Graph:



RESULT: -*Hence the effect of Feedback on DC Servomotor has been studied with the help of Torque-sped characteristics.*

Viva-Voice Questions

1. Draw the speed torque characteristics of D.C Servo motor?
2. What are the applications of D.C Servo motor?
3. What are the types of D.C. Servo motor?
4. Write the formula for the torque in case of D.C. servo motor?
5. Compare ac and dc servo motors
6. Define Motor classifications?
7. where it is used?
8. Explain Working Principle of D.C servo Motor?
9. Draw the Ckt of D.C servo Motor?
10. How it is useful to do this experiment
11. What is the overall efficiency of D.C servo Motor?

EXPERIMENT 5:

TRANSFER FUNCTION OF DC MOTOR

5.1 OBJECTIVE: To determine the transfer function of armature-controlled DC Motor.

To study the DC motor and DC generator characteristics DC motor speed-torque characteristics Step response of DC motor

5.2 RESOURCES:

DC Motor (armature controlled) set up, consisting the following;

1) AC IN: Terminals to Connect 230v AC Mains Supply.
2) MCB: 2 Pole / 6A MCB to Turn OFF/ON AC Supply to the controller.
3) ARMATURE: V_A Potentiometer to vary the Armature voltage from 0-200V.

   : OFF/ON Switch for Armature voltage with soft start.

   : 0-200V Variable DC. For Arm. (1-Φ, 1/2 control bridge rectifier)

   : 0-230V Variable AC. to find Inductance of Field Coil (AC Voltage Control)
4) FIELD: V_F Potentiometer to vary the Field voltage from 100V-200V.

   : 100-200V Variable DC supply

   : 220V/2A Rectified DC Supply for field supply of DC Motor or Generator.
5) DIGITAL VOLTMETER: To measure AC/DC Voltage with AC/DC selector switch.
6) DIGITAL AMMETER: To measure AC/DC Current with AC/DC selectorswitch
7) CONTROLLER: Unit to vary the Arm. Volt. & Field Voltages.
8) TACHOMETER : Digital contact type for measure the speed of DCMotor.

9) DC MOTOR: 0.5 HP / 220V / 1500 RPM with mech. loading arrangement.

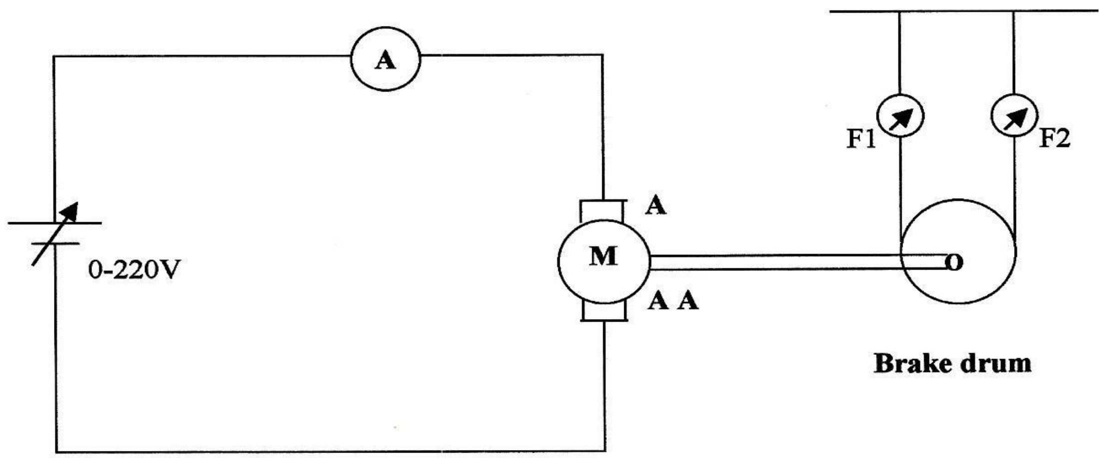
DC MOTOR:

Armature Resistance	R_A	-	15Ω
Armature Inductance	L_A	-	135mH
Field Resistance	R_F	-	255 Ω
Field Inductance	L_F	-	21H
Moment of Inertia	J	-	0.024Kg-m^2
Friction Co-efficient	B	-	0.8

5.3 CIRCUIT DIAGRAM:

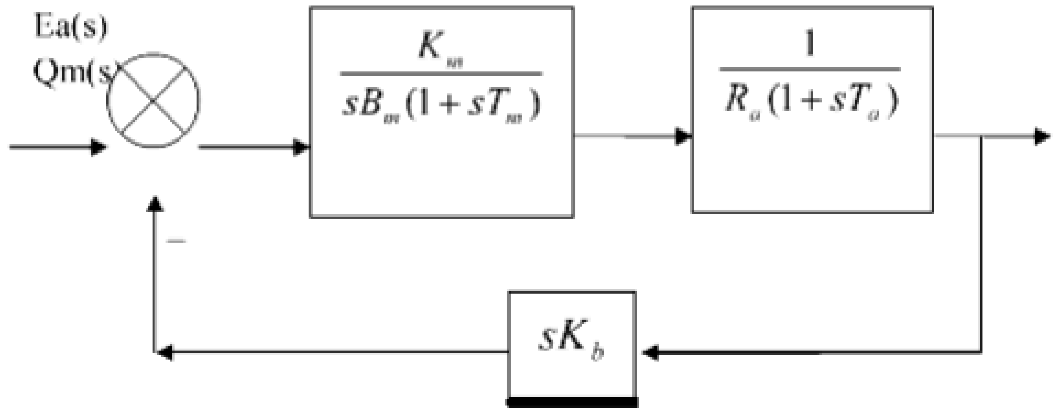
ARMATURE CONTROLLED DC MOTOR

Load Test on DC Motor:-



1. Circuit connections are make as per the circuit diagram.
2. Connect 220V fixed DC supply to the field of DC motor and Brake drum belt should be loosened.
3. Start the motor by applying 0-220V variable DC supply from the controller till the motor rotates at its rated speed.
4. Note down meter readings which indicates no load reading.
5. Apply load in steps upto rated current of the motor and note down corresponding I_L, N, F_1 and F_2 readings.

Block Diagram:

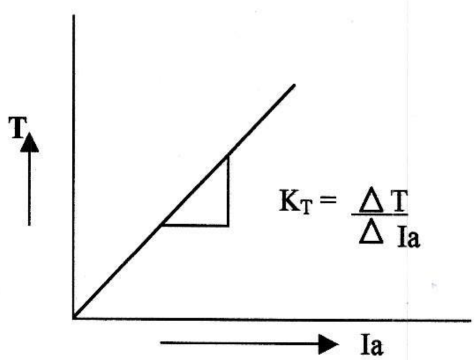


Switch OFF the armature DC supply using Armature supply ON/OFF switch and them switch OFF the MCB.

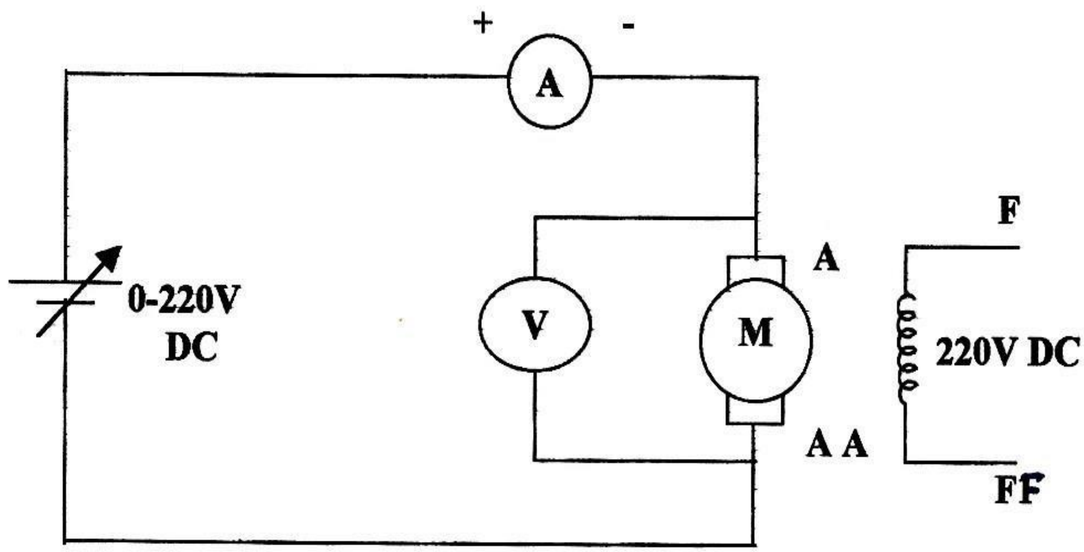
Radius: R= 6.5 cm

TABLE

Sl. No.	I_L	F_1	F_2	*N rpm*	*T= (F1 ~ F2) 6.5 X9.81N-cm*



Speed Control by Armature Voltage Control



1. Circuit connections are mode as per the circuit diagram.

2. Connect 220V fixed DC supply to the motor field keep the armature control pot at its minimum position and switch at OFF position.

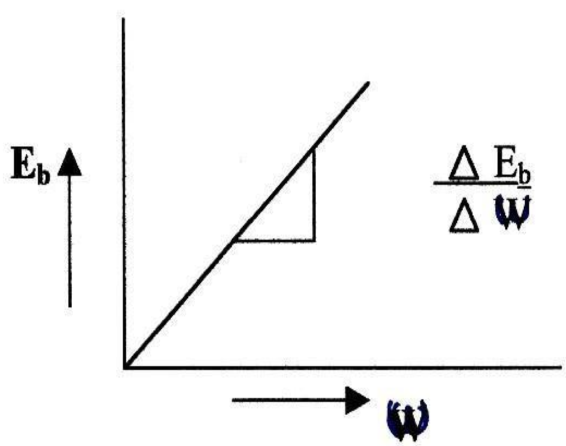
3. Switch ON the MCB, Switch ON the armature control switch. Vary the armature voltage and note down the speed and the corresponding meter readings.

4. Repeat the same for different armature voltages.

Switch OFF the Armature control switch and then the mains MCB.

Sl. No.	Ia	N	V	$E_b = V - I_a R_a$	$\omega = \frac{2\Pi N}{60}$

Draw the graph of back emf V/S speed.



Transfer Function of Armature Controlled DC Motor = $\dfrac{KT}{S\left[[R_a + SL_a][SJ_m + f_m] + K_T K_b\right]}$

R_a	=	Armature Resistance
L_a	=	Armature Inductance
I_a	=	Armature Current
E_b	=	Back emf
T	=	Torque developed
J	=	Moment of Inertia = 0.024 $Kg\text{-}m^2$
B	=	Frictional Co-efficient – 0.8
K_b	=	Back emf constant
K_T	=	Torque Constant

By Kirchoff's law

$$Ia\ Ra + La\ \frac{d\ Ia}{dt} + Eb = Va$$

Since flux is constant

Torque is proportional to Ia.

$$T_m \propto Ia$$
$$T_m \propto K_T\ Ia$$

Also for Mechanical System

$$J \frac{d\theta m^2}{dt^2} + B \frac{d\theta m}{dt} = Tm$$

Also Back emf Eb α to angular velocity of shaft

$$Eb = Kb \frac{d\theta m}{dt}$$

Dynamic Equation	Laplace Equipment
$Tm = K_T\, Ia$ $Eb = Kb\, Wm$ $Va - Eb = Ra\, Ia + La \frac{dIa}{dt}$ $Tm = Jm \frac{d^2\theta_m}{dt2} + f_m \frac{d\theta m}{dt}$	$Tm\,(s) = K_T\, Ia\,(s)$ $Eb\,(S) = Kb\, Wm\,(s)$ $Va(s) - Eb(s) = Ra\, Ia\,(s) + Sl_a\, Ia\,(s)$ $T_m(s) = JmS^2\, \theta_m\,(s) + Sfm\, \theta_m(s)$

By solving the Laplace equation we obtain the transfer function as $\frac{\theta(s)}{V(s)}$

$$= \frac{K_T}{S\,(\,[Ra + SL_a]\,[SJ_m + f_m) + K_T\, Kb])}$$

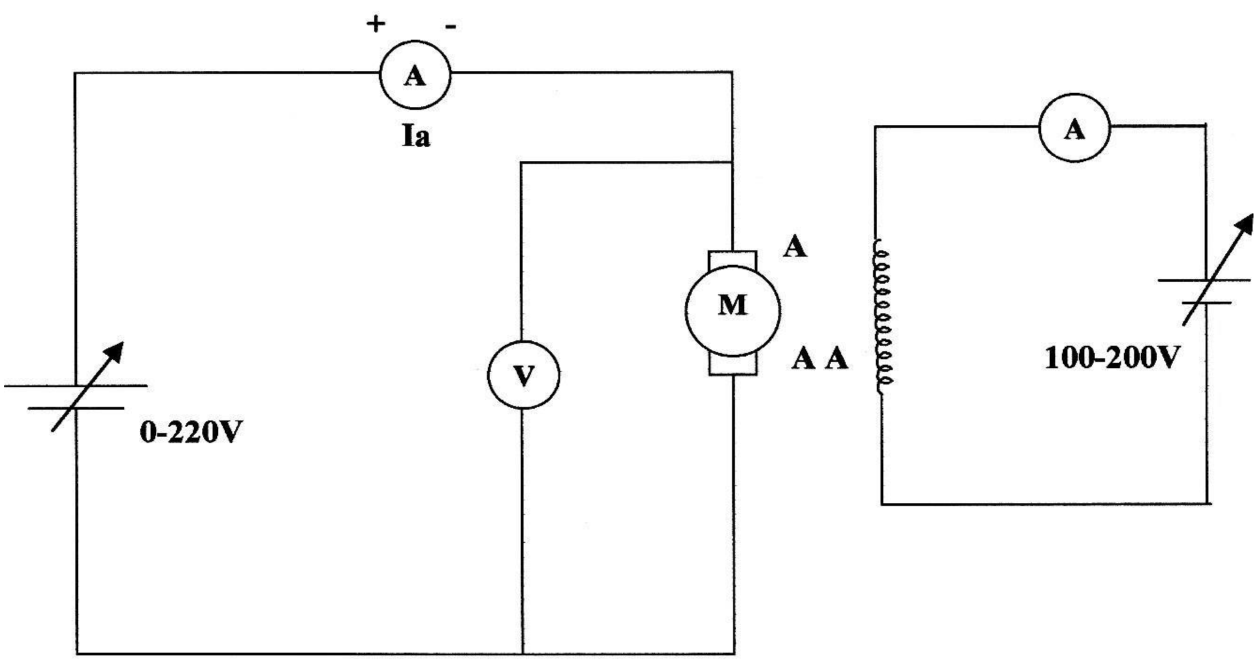
PROCEDURE:

1. Connect the patch cords.
2. Set motor switch ‘on’. Set ‘reset’ switch to ‘RESET’. SET ‘LOAD’ switch to 0.
3. Vary Ea (the voltage can be observed by using DC voltmeter) in small steps and take readings.

4. Eg (Generator voltmeter) can also be observed at DC voltmeter and Ia can be observed at DC Ammeter.
5. Obtain the slopes and compute Km (Motor gain constant) and Kg (generator gain constant) using the formulas.
6. Plot N(speed)vs Ea (armature voltage) and Eg (armature voltage) vs N(Speed)

TRANSFER FUNCTION OF FIELD CONTROLLED OF DC MOTOR

PROCEDURE: -



1. Make the connections as given in the circuit diagram.
2. Motor field voltage should be maximum and belt is loosened
3. Switch ON the supply to the controller unit. Switch ON the armature supply. Vary the armature voltage till the motor speed comes to rated speed and note down meter readings.
4. Vary the field supply till we obtain 20% above rated speed of motor and note down the readings.

TABLE

s.no	*E_a (Volts)*	*I_a (Amps)*	*N(RPM)*	*Eg (volts)*

STEP RESPONSE:

TABULAR COLUMN

1) Field Control Method: -

Sl. No.	I_f amps	I_a amps	N speed	V volts	$T = I_f I_a$

TRANSFER FUNCTION DERIVATION

Transfer function of a field control DC motor relates angular shift in the shaft and the field input voltage. The armature current I_a supplied is kept constant.

The field current I_f produces a flux in the motor which in turn produces a torque at the motor shaft. The moment of inertia and coefficient of viscs friction are J_m (kg/m2) and f_m (N-m / rad/see) respectively. The angular shaft in the motor shaft being θ_m radians or angular velocity 'ω' rad/sec.

PROCEDURE:

i. Set motor switch to ‘OFF’. set ‘RESET’ switch to ‘RESET’.
2. SET ‘LOAD’ switch to 0 position.
3. Connect Ea to the voltmeter and set it to 8V.
4. Switch ‘ON’ the motor and measure Eg and the speed in rpm. These are the steady state generator voltage Eg and steady state motor speed N respectively.
5. Set Es to 63.2% of Eg measured above. This is the generator voltage at which the counter will stop counting.
6. Switch off the motor. set ‘RESET’ switch to ‘READY’.
7. Now switch the motor. Record the counter ready as time in milliseconds.
8. Substitute the values of Km and Tm in the equation and write down motor transfer function.

Dynamic Equations	Laplace Equations
$T_m \propto I_f$	
$Tm = K_f I_f$	$T_m(s) = K_f I_f(s)$
$V_f = R_f I_f + L_f \frac{dI_f}{dt}$	$Vf(s) = Rf\, If(s) + SLf\, If(s)$
$Tm = I_m \frac{d^2\theta_m}{dt^2} + fm \frac{d\theta_m}{dt}$	$Tm(s) = S^2 J_m \Theta_m(s) + S f_m \theta_m(s)$
or	or
$Tm = Jm \frac{dw_m}{dt} + f_m w_m$	$T_m(s) = S I_m w_m(s) + F_m w_m(s)$

The overall Transferfunction of field control D C motor is

$$\text{Transfer function} = \frac{Kf}{S(R_f + SL_f)(SJ_m + f_m)}$$

CALCULATION:

From graph (K_f) =

Field resistance (Rf) =

Inductance (Lf) =

$$\text{Transfer function} = \frac{Kf}{S(R_f + SL_f)(SJm + f_m)}$$

TABULAR COLUMN:

S.NO	Ea (volts)	Eg (volts)	N (RPM)	Es=0.632 E volts	Time	

5.5 RESULT:

PRELAB QUESTIONS:

1. What are the different types of motors?
2. Explain the characteristics of shunt motor?
3. Explain the characteristics of series motor?

LAB ASSIGNMENTS:

1. To determine the transfer function of DC series motor using thyristor controller?
2. To determine the transfer function of DC shunt generator using thyristor controller?
3. To determine the transfer function of synchronous generator using thyristor controller?

POSTLAB QUESTIONS:

1. Explain the characteristics of compound motor?
2. To determine the transfer function of DC compound motor using thyristor controller

EXPERIMENT 6:

TRANSFER FUNCTION OF D.C GENERATOR

AIM: determine the transfer function of armature-controlled DC Generator.

APPARATUS:

S. No	Equipment	Range	No. of Required
1	1-Φ Variac	230V/ (0-270) V	1
2	Voltmeter	(0-300) V M.C	1
3	Ammeter	(0-1.5) A M.C (0-100) mA M. I	1 1
4	Rheostat	230 /1.7A (0-100) mA M. I	2 1
5	Connecting wires	-	-

This setup consists of the following units to conduct the above experiment

a. DC – Motor – Generator set – 0.5HP/220V / 1500 rpm.

b. Controller unit suitable for the above motor – Generator set with Digital meters
DC motor – Generator Set – 0.5HP/220V / 1500 rpm

PROCEDURE:

a) To Find E_G:

1. Give the connections as per the circuit diagram 1.
2. Keep the motor field rheostat at minimum position, armature rheostat at maximum position and generator field rheostat at maximum position.
3. Switch ON the D.C supply to the M-G set and start the motor with the help of a 3-point starter.
4. Adjust the speed of the M-G set to the rated value with the help of armature rheostat of the motor. If the rated speed is not reached, then adjust the field rheostat of the motor.
5. Now adjust the generator field rheostat in steps up to the rated voltage of the generator and at each step, note down the readings of the ammeter and the voltmeter.
6. Switch OFF the D.C supply to the M-G set by bringing all the devices to

initial positions.

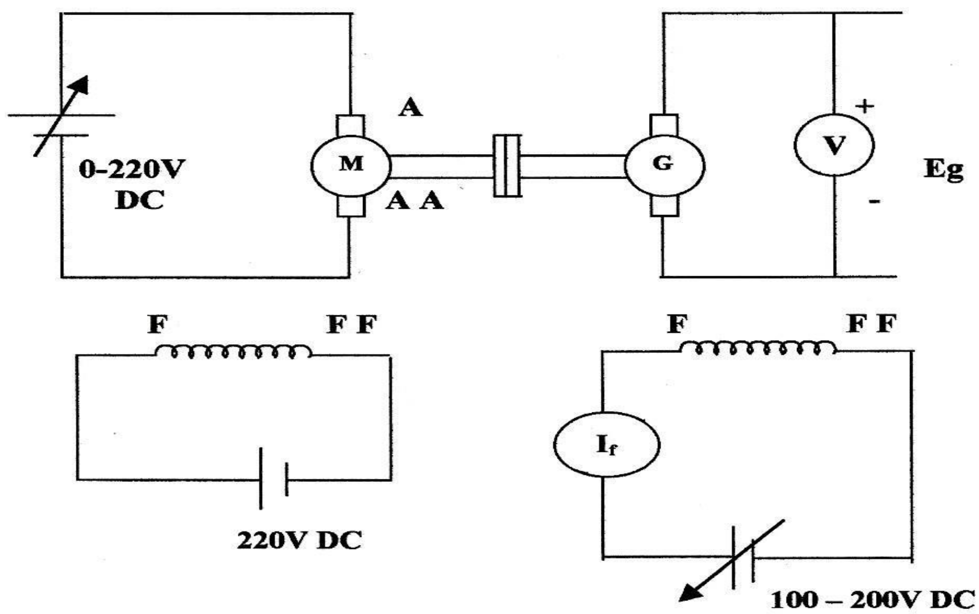
b) To find the Field Resistance of the Generator (Rfdc)

1. Connect the circuit as per the circuit diagram 2.
2. Switch ON the D.C supply to the field winding of the generator.
3. Vary the rheostat in steps to below the rated voltage of the generator and at each step note down the readings of the voltmeter and ammeter.
4. Switch OFF the D.C supply by bringing the rheostat to initial position.

CIRCUIT DIAGRAM:

To Find EG:

TRANSFER FUNCTION OF DC GENERATOR
(Separately Excited)



1. Make the connections as given in the circuit diagram
2. Connect 220V fixed DC supply to the Motor field
3. Connect 100-220V Variable DC supply to the Generator field
4. Connect 0-220V Variable DC supply to the armature.
5. Switch on the MCB keeping armature voltage control pot at its minimum position & ON/OFF switch at OFF position and also variable field voltage pot at its maximum position
6. Now switch ON the Armature control switch and vary the armature control potentiometer till the motor rotates at its rated speed.

7. Note down If and Eg and entered in the tabular column.

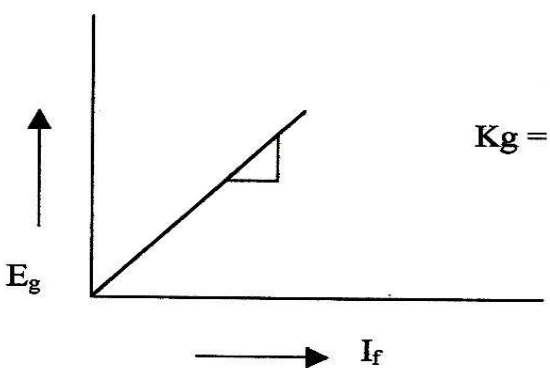
8. Now vary the generator field supply and note down Eg for different Igs and entered in the tabular column.

9. Draw the graph of Eg volts v/s I_f.

Sl. No.	If Amps	Eg Volts

$$\text{Transfer function} = \frac{K_g / L_f}{S_f R_f/L_f}$$

$$= \frac{K_g / L_f}{S + \frac{R_f}{L_f}}$$



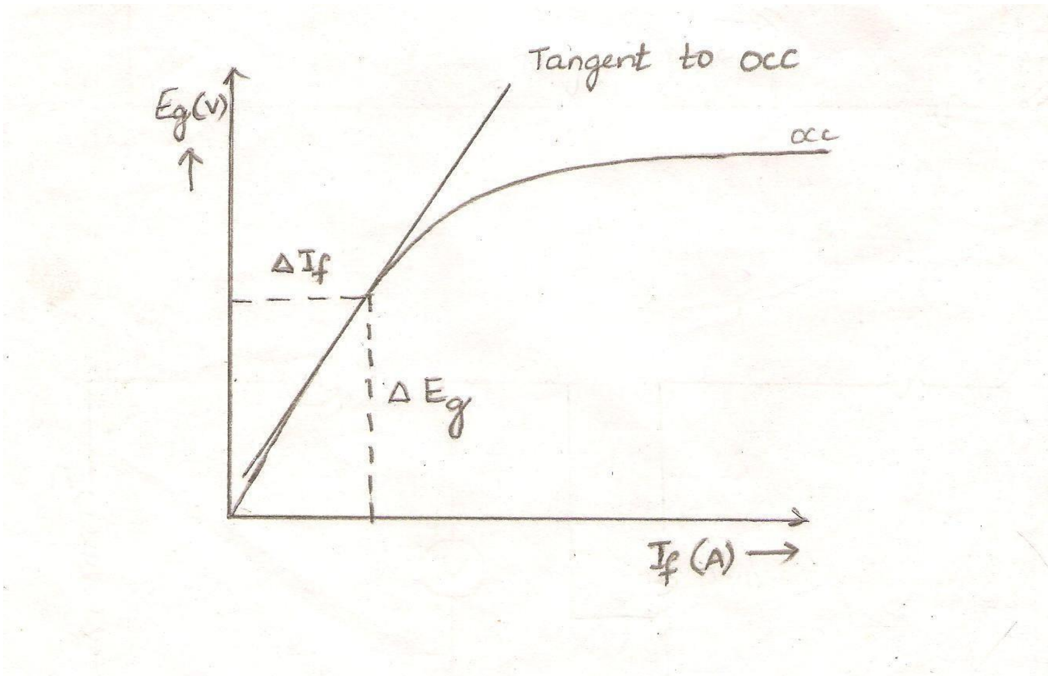
$$Kg = \frac{\Delta\ Eg}{\Delta\ I_f}$$

TABULAR COLUMN:

S.NO.	Field Current I_F (A)	Generated Voltage E_G (V)

Field Current I_F (A)	Voltage (V)	R_{FDC}

MODEL GRAPH:



CALCULATIONS:

1. Slope of the tangent Kg =
2. Average R_{FDC} = (Sum of Rfdc) / (No. of readings) =
3. $R_{FAC} = 1.6* R_{FDC}$
4. Average Z_F =420Ω5. $X_F = [Z_F^2 - R_{fac}^2]^{1/2}$
5. $L_F^{FAC} = X_F / 2\pi f$ =
6. Transfer function = $Kg/(SL_F+R_F)$ =

RESULT:

The transfer function of the D.C Generator is found

Viva-Voice Questions

1. Draw the Ckt of Transfer function of D.C Generator?
2. What are the applications of function of D.C Generator?
3. Define function of D.C Generator?
4. where it is used?
5. Explain Working Principle of function of D.C Generator?
6. How it is useful to do this experiment?
7. What are the types of function of D.C Generator?
8. Explain each one with neat sketch?
9. Draw the characteristics of function of D.C Generator?
10. What are the advantages of function of D.C Generator?

EXPERIMENT 7:

TEMPERATURE CONTROL USING PID

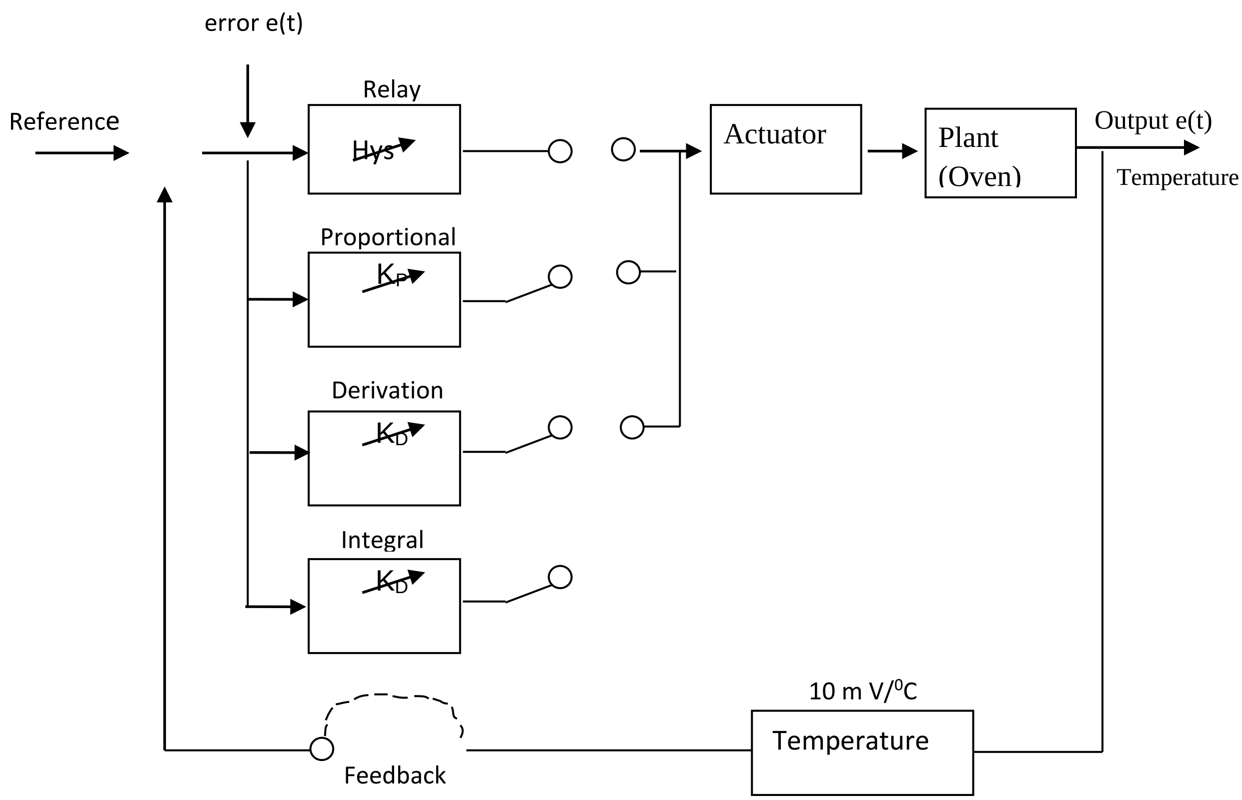
7.1 OBJECTIVE: To study the performance of PID controller used to control the temperature of an oven.

- By using PID Controller note down the set temperature and actual temperature and time.
- Draw the graph between actual temperature and time.

7.2 RESOURCES:

1. PID Controller
2. Patch chords

Theory:



Block Diagram of the Temperature Controller

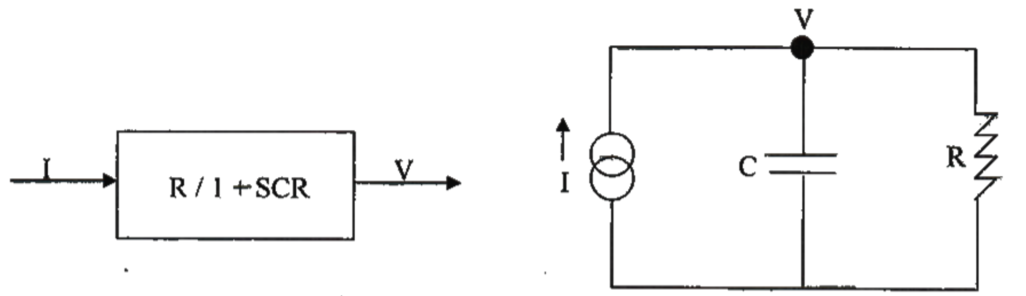


Fig. 2. Electrical Analog

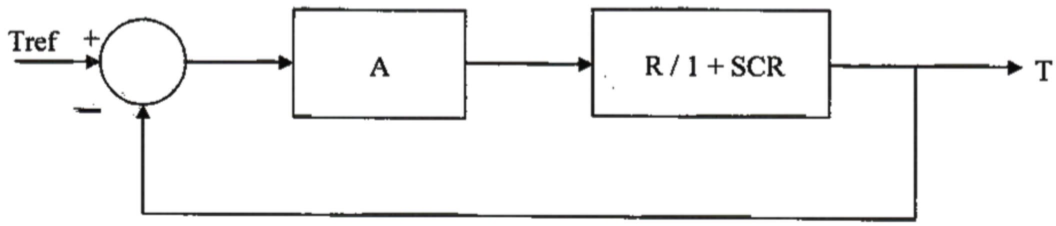


Fig. 3. Close Loop Temperature Control System

CONTROLLER

In temperature control systems, commonly used basic control actions are

- ON-OFF or relay.
- Proportional.
- Proportional -- Integral.
- Proportional -- Integral -- Derivative.

A BRIEF DESCRIPTION OF THESE ARE GIVEN BELOW:

(a) ON - OFF OR RELAY TYPE CONTROLLERS, it is two position controllers, consist of a simple and inexpensive switch/relay. Therefore, it is used very commonly in both industrial and domestic control systems. Some applications include air conditioner, refrigerator, oven, healers with thermostat. Solenoid operated two position values are commonly used in **hydraulic** and pneumatic systems. The basic input-output behaviors of this controller are shown in Fig. 4. The two positions of the controller are M_1 and M_2, and H is the Hysteresis or differential gap.

The Hysteresis enables the controller output to remain at its present value till the input or error has increased a little beyond zero. Hysteresis helps in avoiding too frequent switching of the control, although a large value results in greater errors. The response of a system with ON-OFF controller is shown in Fig. 5. Describing function technique is a standard method for the analysis of non-linear systems, for instance, one with an ON-OFF controller.

(b) PROPORTIONAL CONTROLLER is simply an amplifier of gain K_p which amplifies the error signal and passes it to the actuator. The noise, drift and bias currents of this amplifier set the lower limit of the input signal which may be handled reliably and therefore decide the minimum possible value of the error between the input signal and output. Also, the saturation characteristics of this amplifier sets the linear and non-linear regions of its operation.

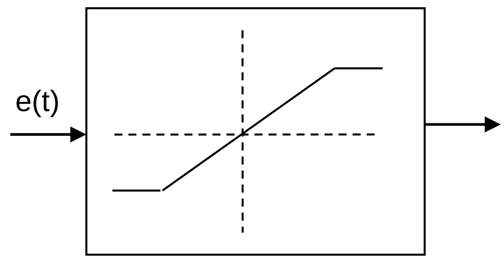


Fig. 6. Proportional Controller with saturation

A typical proportional controller may have an input-output characteristics as in Fig. 6. Such controller gives non-zero steady state error to step input for a type-0 system as indicated earlier. The proportional (P) block in system consists of a variable gain amplifier having maximum value. Kp_{max} of 20.

PROPORTIONAL-INTEGRAL(PI)CONTROLLER: Mathematical equation of such a controller is given by:

$$u(t) = K_P\, e(t) + K_I \int e(t)dt$$

Apply Laplace transform on both sides –

$$U(s) = (K_P + K_{I\,/}\, s)\; E(s)$$

$$U(s) / E(s) = (K_P + K_{I\,/}\, s)$$

and a block diagram representation is shown in Fig. 7. It may be easily seen that this controller

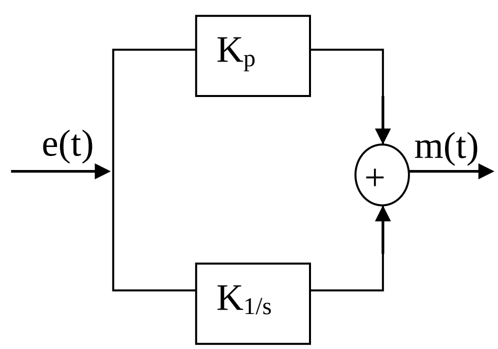


Fig. 7. P I Controller

introduces a -pole at the origin, i.e. increases the system type number by unity. The steady slate error of the system is therefore reduced or eliminated. Qualitatively, any small error signal e(t), present in the system, would get continuously integrated and generate actuator signal

mm forcing the plant output to exactly correspond to trie reference input so that the error is zero. In practical s> sterns, the error may not be exactly zero due to imperfections in an electronic integrator caused by bias current needed, noise and drift present and leakage of the integrator capacitor.

The integrator (I) block in the present system is realized with a circuit shown in Fig. 8 an has a transfer function.

$G_r(s) = l/(41s) = K, /s$ (2)

The integral gain is therefore adjustable in the range 0 to 0.024 (approx.). Due to the tolerance of large capacitance's, the value of K| is approximate.

PROPORTIONAL - DERIVATIVE (PD) CONTROLLER: Mathematical equation governing the this controller is given as:

$m(ct) = K_p e(t) + Kp\, de(t)/dt$

and a block diagram representation is shown in Fig. 7 (b)

$= K_p c(t) + T_d\, dc(t)/dt.$

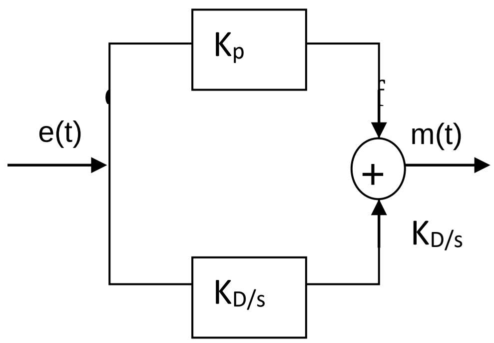


Fig. 7(b). P-D Controller.

The derivative (D) block in this system is realized with the circuit of Fig. (9)

This has a transfer function of

$C_d(s) = 19\text{-}97(s)$ approx. (3)

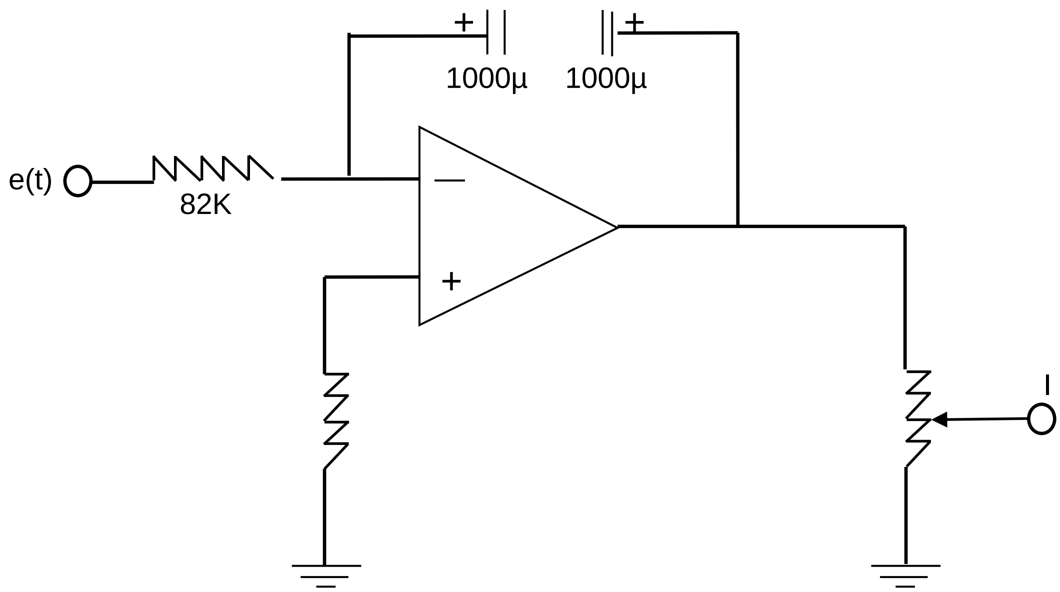


Fig. Circuit for Integrator

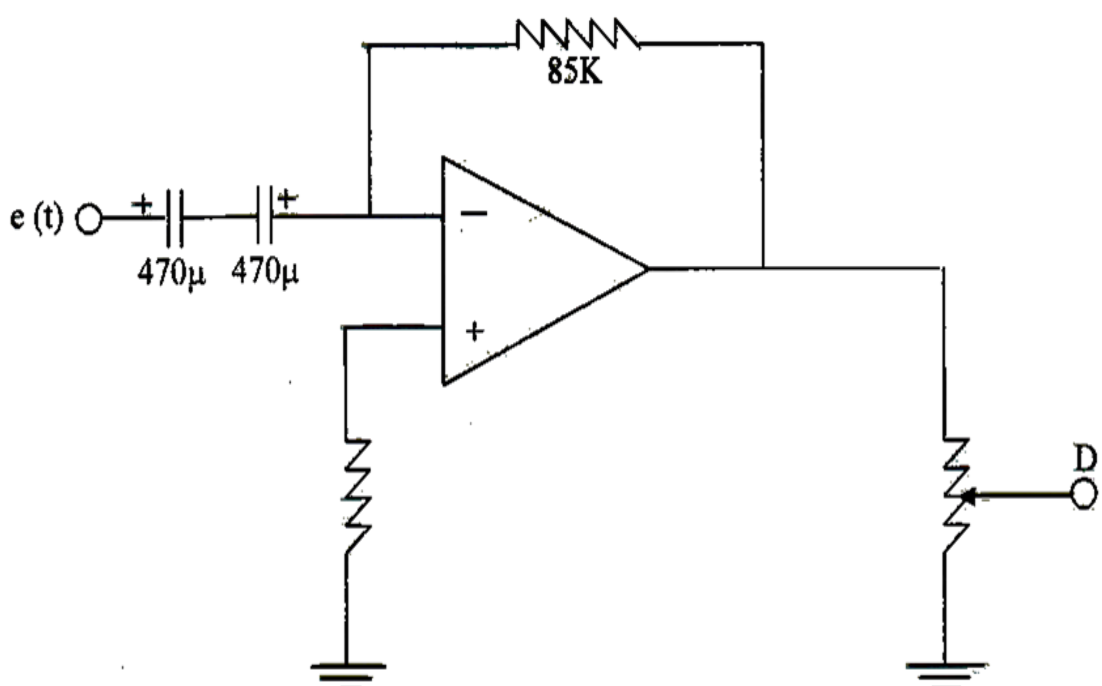


Fig. 9. Circuit for Differentiator

The derivative gain is there for adjustable in the rage 0 to 20 approximately. Again, the appreciation is due to the higher tolerance in the value of large capacitances.

Mathematical equations governing the operation of this controller is as

PROPORTIONAL-INTEGRAL- DERIVATIVE (P1D) CONTROLLER:

Mathematical equations governing the operation of this controller is as

$$m(t) = Kpe\ (t) + K_1 \int e(t)dt = K_D\ de(t) / dt$$

$$= Kpe(t) + 1/T_1 \int e(t)dt = T_D\ de(t) / dt$$

So that in the lap lace transform domain,

$M(s) / E(s) = (Kp + T_{DS} + 1T_1 s)$

A simple analysis would show that the derivative block essentially increases the damping ratio of the system and therefore improves the dynamic performance by reducing overshoot. The PID controller therefore, helps in redacting the steady state error with an improvement in the transient response.

The derivative (D) block in this system is realized with the circuit of Fig. 9. This has a transfer function.

Gd(s). = 19.97 s (approx.) (4)

THE derivative gain is therefore adjustable in the range 0 to 20 approximately. Again, the approximation is due to the higher tolerance in the values of large capacitances.

PID controller is one of the most widely used controller because of its simplicity. By adjusting is coefficients Kp. K_D (or TD) the controller can be used with a variety of system the process of setting the controller coefficients to suit a given plant is known as tuning are man) methods of 'tuning' a PID controller. In the present experiment, the METHOD of Ziegler-Nichol has been introduced which is suitable for the oven control system althOUGH better methods are available and may be attempted.

TEMPERATURE MEASUREMENT:

THE oven temperature can be sensed by a variety of transducer like thermostat, thermocouple, RTD and IC temperature sensors. In the present set-up, the maximum oven temperature is around 90 C which is well within the operating range of IC temperature sensor like LM35. further, these sensors are linear and have a good sensitivity, viz. 1µA/K. associated electronic circuits convert this output to 10m V/^{0}C which may be easily measured by a DVM. The time constant of the sensor has however BEEN neglected in the analysis since it is insignificant compared with the oven time constant.

EXPERIMENTAL WORK:

A variety OF experiments may be conducted with the help of this unit. The principal advantage of the MAT is that all power sources and metering are built in and one needs only a watch to be able to note DOWN THE temperature readings at precise time instants. After each run the oven has to be cooled to EARLY ME room temperature, which may take about 20-30 minutes.

7.3 PROCEDURE:

PLANT identification is the first step before an attempt can be obtained experimentally from its before MI attempt can be made to control it. In the present case the oven equations are obtained experimentally from its step response as out lined below:

(1) Keep Run/Wait switch to 'WAIT' S_2, to Set/Meas. Switch to "SET" and open 'FEEDBACK' terminals, (refer panel drawing).

(2) Connect P output to the actuator input and switch ON the unit.

(3) Set P potentiometer to 0.5 which gives Kp=10. Adjust reference potentiometer to read 5.0 on the DVM. This provides an input of 0.5 V to the driver.

(4) Put Set/Meas. Switch to the 'MEASURE' position and note down the room temperature.

(5) Put Run/Wai switch to 'RUN' position and note temperature reading every 15 sec, till be temperature becomes almost constant.

(6) Plot temperature-lime curve on a graph paper. Referring to Fig. 10, calculate T| and T2 and hence write the transfer function of the oven including its driver as

$$G(s): \; K\exp(0 - sT_2) / (1+sT_1), \text{ with } T \text{ in } °C.$$

ON – OFF CONTROLLER:

(7) Keep Run/Wait switch to 'WAIT position and allow the oven to cool the room **temperature.** Short "FEEDBACK' terminals.

(8) Keep Set/Meas. switch to the 'SET* position and adjust reference potentiometer to the desired output temperature, say 50⁽ C. by seeing on the digital display.

(9) Connect R output to the driver input. Outputs of P, D, and I must be disconnected from driver input. Select "HI" or "LO" value of Hysteresis. (First keep the Hysteresis switch to LO).

(10) Switch Set/Meas. switch to 'MEASURE' and Run/Wait switch to 'RUN' position. Read and record oven temperature every 15/30 sec., for about 20 minutes.

(11) Plot a graph between temperature and time and observe the oscillations (Fig. 12) in the steady state. Note down the magnitude of oscillations.

(12) Repeat above steps with the "J\HI" setting for Hysteresis and observe the rise time, steady-state error and percent overshoot.

TABULAR COLUMN:

Sl. No.	Set Temperature	Actual Temperature	Time

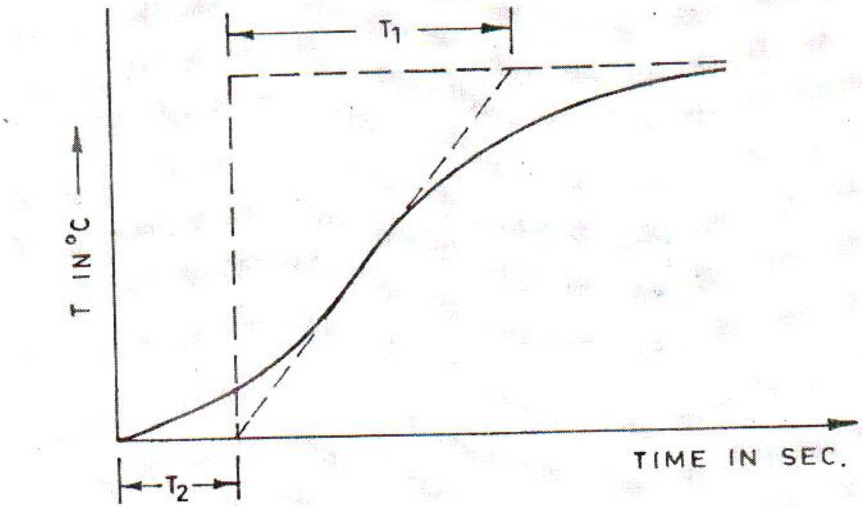


FIG. 10. OPEN LOOP RESPONSE OF THE OVEN

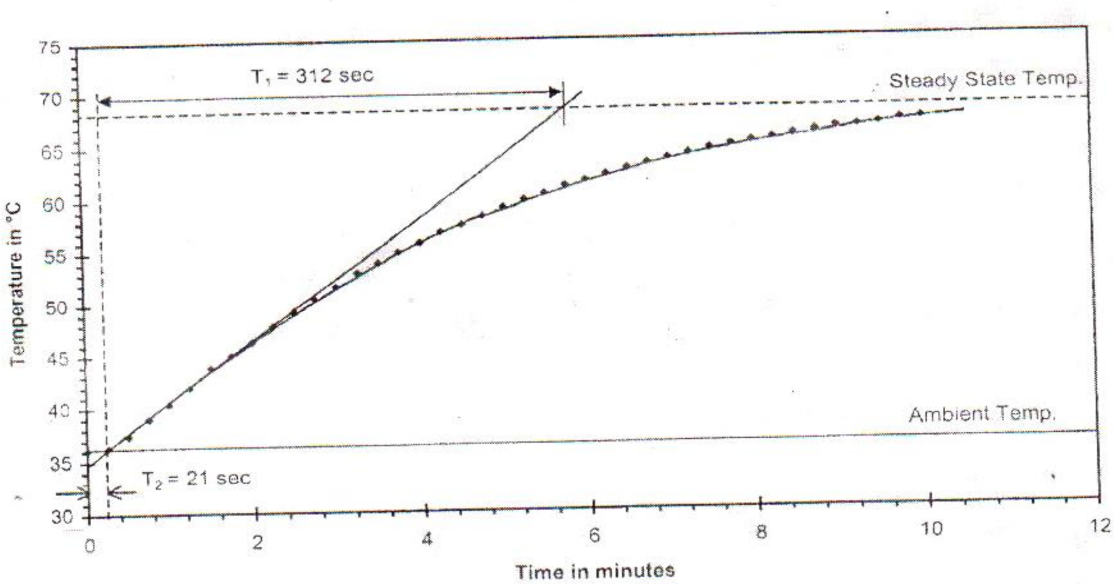


Fig. 11. OPEN-LOOP RESPONSE OF THE OVEN
(For P-Gain = 0.5)

PROPOTIONAL CONTROLLER:

Ziegler and Nichols suggest the value of K_p for this condition as:

$K_p = (1 / K) \times T_1 / T_2$

(13) Starting with a cool oven, keep switch Run/Wait switch to 'WAIT' position and connect P output to the driver input. Keep R. D and 1 outputs disconnection. Short 'FEEDBACK" terminals.

(14) Set P potentiometer to the above calculated value o K_P, keeping in mind that the maximum gain is 10.

(15) Select and set the desired temperature to say 50 C.

(16) Keep Run. /Wait switch to "Run" position and record temperature readings as before.

(17) Plot the observations on a linear graph paper and observe the rise time, steady-state error and percent overshoot (Fig. 13).

PROPORTIONAL-INTEGRAL CONTROLLER:

Ziegler **and** Nichols suggest the value of $\mathbf{K_P}$ and K_1 for these conditions as:

Kr = (0.9/K) x T_1/T_2; T_1 = 1/ $\mathbf{K_1}$ **=** 3.3 T_2, giving K_1 = 1 / 3.3 T_2.

(18) Starting with a cool oven, keep Run/Wait switch to 'WAIT' position, connect P and I outputs to the actuator input and disconnect R & D output. Short "FEEDBACK" terminals.

(19) Set P & I potentiometers to the above value of Kp and K_1 respectively, keeping in mind that the maximum value of K_p is 10 and that of K_1 is 0.024.

(20) Select and set the desired temperature to say 50°C.

(21) Keep Run/Wait switch to 'RUN* position and record temperature readings as before.

(22) Plot the response on a graph paper and observe the steady-slate error and percent overshoot. (Fig. 14).

PROPORTIONAL - DERIVATIVE CONTROLLER:

Ziegler and Nichols suggested the value of

K_p and K_d for this condition as

$K_P = (0.9 / k)\ T_1\ T_2$

$K_d = (T_0 = 0.5T_2)$

(23) Starting with a cool oven, beep run / wait switch to 'WAIT' position and connect P and output to actuator input keep R and I output disconnected. Short feedback terminals.

(24) Set P. and D potentiometer according to the above calculated values keeping in mind that the maximum values for their arc 20 and 20 respectively.

(25) Select and set the desired temperature to say 50 C.

(26) Keep Run / Wait switch to 'RUN* position and record temperature - time readings.

(27) Plot the response on a linear graph paper and observe the rise time steady state errors etc.

RESULT:

Hence, we have studied the performance of PID controller used to control the temperature of an oven.

CONCLUTIONS:

By The PID Controller noted the set temperature, actual temperature and time.

The graph plotted between actual temperature and time.

EXPERIMENT 8:

CHARACTERISTICS OF AC SERVOMOTOR

8:1 OBJECTIVE:

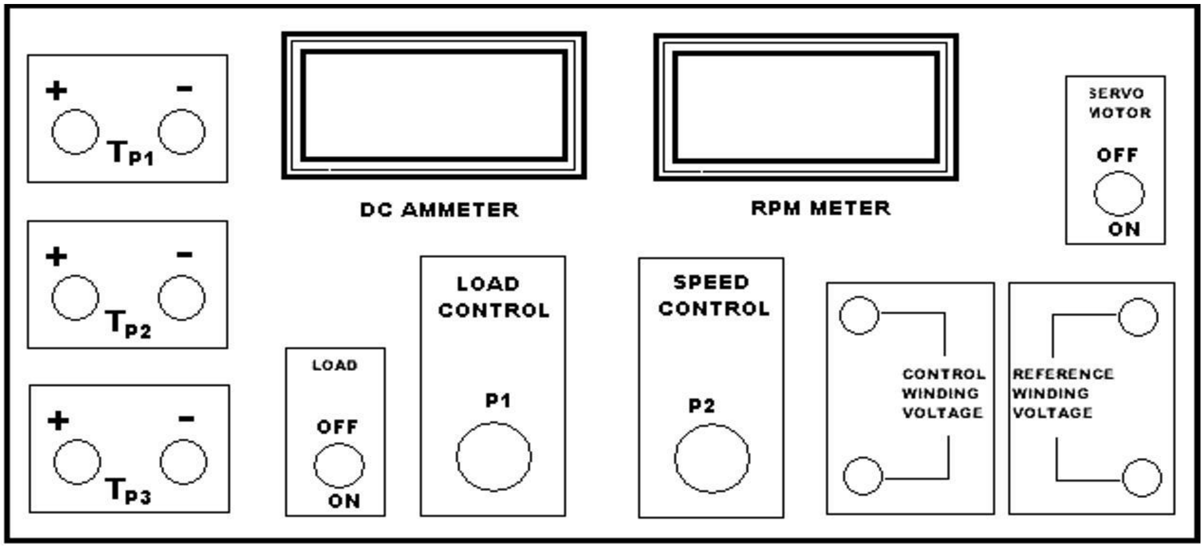
To study the Speed-Torque and Speed-Back e.m.f. characteristics of AC Servomotor.

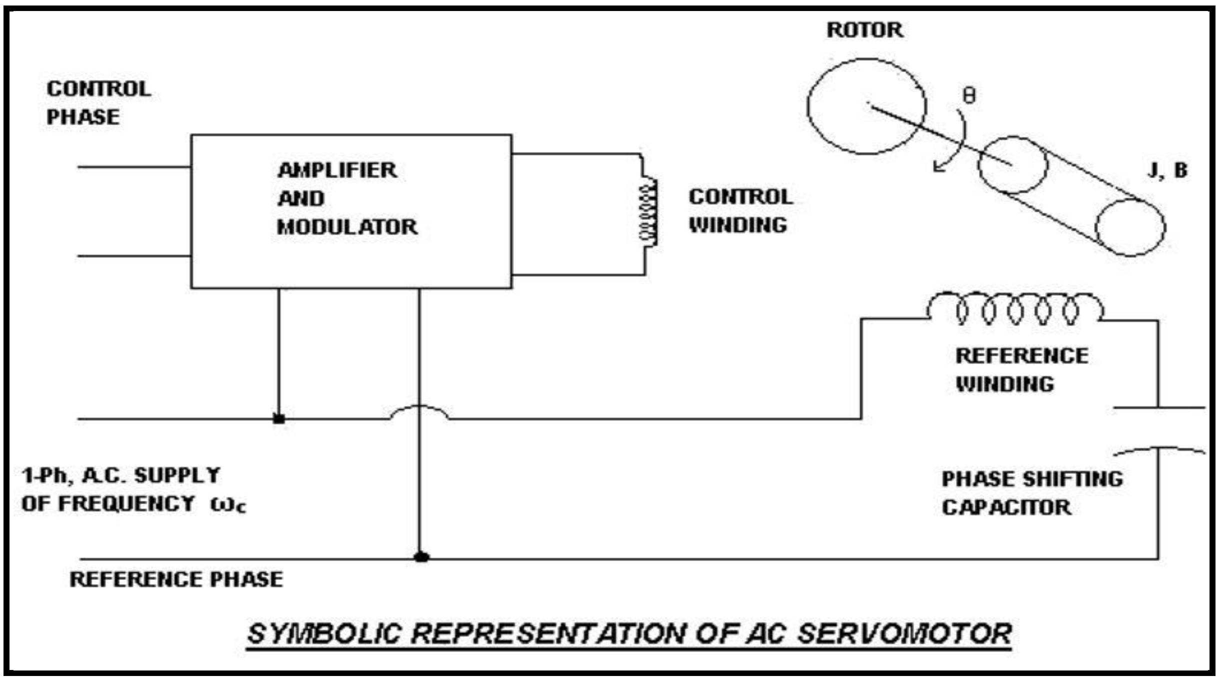
- Explain how the parameters changes when load changes
- To study of A.C. motor position control through continuous command.
- To study of error detector on A.C. motor position control through step command.
- To study of A.C. position control through dynamic response.

8:2 RESOURCES:

1. AC Servo Motor Kit
2. Patch Chords
3. Multimeter

8.3 BLOCK DIAGRAM:





THEORY:

An A.C servomotor is basically a two-phase induction motor except for certain special design features. A two-phase induction motor consisting of two stator windings oriented 90 degrees electrically apart in space and excited by a.c voltages which differ in time phase by 90 degrees. Generally, voltages of equal magnitude and 90 degrees phase difference are applied to the two stator phases thus making their respective fields 90 degrees apart in both time and space at synchronous speed. The stator windings are excited by voltages of equal r.m.s magnitude & 900 phase difference these currents give rise to a rotating magnetic field of constant magnitude the direction of rotation depends of on the phase relationship of the two currents (or voltages) the exciting currents produce a clock wise rotating magnetic field & phase shift of 1800 in i1 will produce an anti-clock wise rotating magnetic field.

8.4 PROCEDURE:

1. Speed, Back emf (E_b) Characteristics:

1. Study all the front panel controls and features carefully
2. Initially keep load switch and servomotor switch in OFF position.
3. Before switching ON the instrument, keep load control potentiometer P_1 and speed control potentiometer P_2 are in fully anti-clockwise (i.e. minimum) position.
4. Now switch **ON** the instrument and also switch **ON** the servomotor. You can observe that AC Servomotor will start rotating and the speed will be indicated by the rpm meter on front panel.
5. With load switch **OFF** position, vary the speed of the AC servomotor by rotating speed control potentiometer P_2 in clockwise direction and note down the back emf (**E_b**) generated by the DC machine at **T_p** terminals at different speed. Use digital millimeter to measure back emf voltage. Tabulate these readings.
6. Plot the graph Back emf Speed Vs voltage (**E_b**)

2. Speed, Torque Characteristics:

1. Initially keep load switch and servomotor switch in OFF position.
2. Before switching ON the instrument, keep load control potentiometer P_1 and speed control potentiometer P_2 are in fully anti-clockwise (i.e. minimum) position.
3. Now switch **ON** the instrument and also switch **ON** the servomotor. You can observe that AC Servomotor will start rotating and the speed will be indicated by the rpm meter on front panel.
4. By rotating P2, set control winding voltage (**V_c**) at 45V. Use digital millimeter to measure control winding voltage. Note down the speed of Ac

servomotor in table. Now keep P1 at minimum position and switch ON the load switch to apply the load. Note down the back emf voltage (**E_b**) from **T_p** Terminals. Note down the **E_b** and **I_a** values.

5. Repeat above step for different values (at least 3) of load control potentiometer. Note down the corresponding value of **I_a, E_b** and speed.
6. Repeat the above two steps for **V_c** = 55V and 60V.

8.5 TABULAR COLUMN:

1. Speed, Back emf (E_b) Characteristics:

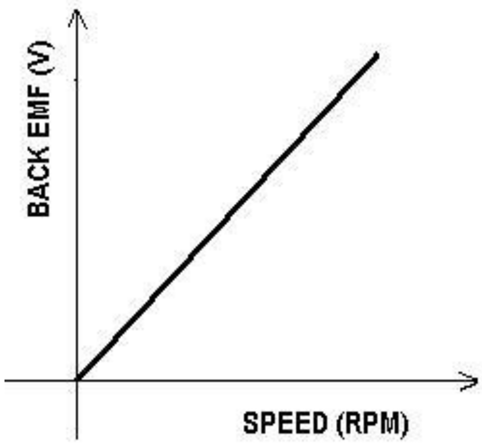
Sl. No.	Speed (N) in rpm	Back emf (E_b) in V

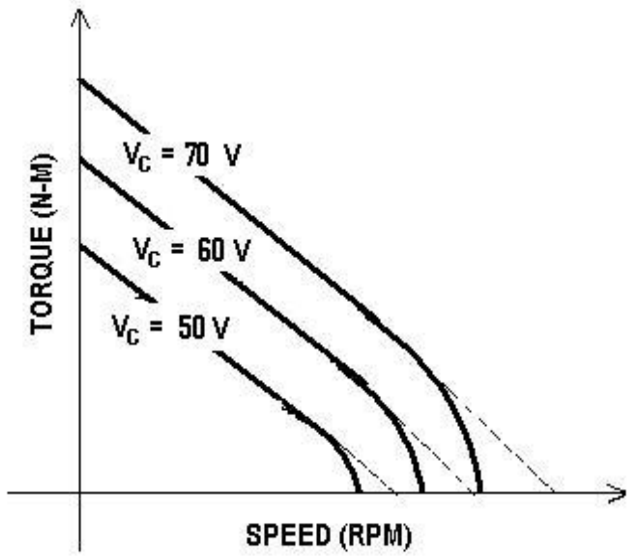
2. Speed, Torque (T) Characteristics:

V_c =

Sl. No.	Speed (N) (rpm)	Back emf (E_b) (Volts)	Current (I_a) (Amps)	Power (P) ($P=E_b \times I_a$) (Watts)	Torque (T) = $(P \times 1.019 \times 10^{-4} \times 60)/2N$ (N-m)

8.6 MODEL GRAPHS:





8.7 RESULT:

The study of the Speed-Torque and Speed-Back e.m.f. characteristics of AC Servomotor.

CONCLUTIONS:

The graph Plotted between speed and back emf, speed and torque of AC Servomotor.

The study of error detector on A.C. motor position control through step command is verified

8.8 PRE LAB-QUESTIONS:

1. What are the main parts of an ac servo motor?
2. What are the advantages and disadvantages of an AC servo motor over dc servo motor?
3. Give the applications of Ac servomotor?

4. Define servo mechanism?

8.9 POST LAB QUESTIONS:

1. What is the difference between regulator & servomechanism?
2. What are the components of AC position control?
3. How is position control achieved?
4. What are the applications of AC servomotors?
5. What is meant by the dynamic response of DC servomotor?
6. Why a revolver is used in Ac servo motor?

EXPERIMENT 9:

EFFECT OF P, PI, PID CONTROLLER ON A SECOND ORDER SYSTEM

9.1 OBJECTIVE:

To study the performance characteristics of an analog PID controller using simulated systems.

- The main objective in tuning PID controllers is to adjust the reactions of PID controllers to set point changes and unmeasured disturbances such that variability of control error is minimized
- BY Using P, PI, PID Controllers calculate Peak over shoot and steady state error
- By using PI Controller observe steady state error and by PD controller observe stability.

9.2 RESOURCES:

S. No.	Apparatus	Range	Quantity
1	PID Controller Kit	---	01
2	Cathode ray oscilloscope	---	01
3	Weights	---	01
4	Patch Cords	---	Some
5	BNC probes	---	Some

THEORY

Proportional Controller (P-Controller)

The proportional controller produces an output signal, which is proportional to the error signal. The transfer function of proportional controller is Kc. The term Kc is called the gain of the controller. Hence the proportional controller amplifies the error signal and increases the loop gain of the system.

The following aspects of system behavior are improved by increasing loop gain.

1. Stead state tracking accuracy
2. Disturbance signal rejection
3. Relative stability

In addition to increase in loop gain the decreases the sensitivity of the system to parameter variations. The drawback is proportional control action is that it produces a constant steady state error.

Proportional controllers (P):

The proportional controller produces an output, which is proportional to error signal.

$$u(t) \propto e(t)$$

$$\Rightarrow u(t) = e(t) K_p$$

Apply Laplace transform on both the sides -

$$U(s) = E(s) K_p$$

$$U(s)/ E(s) = K_P$$

Therefore, the transfer function of the proportional controller is.

here,

U(s) is the Laplace transform of the actuating signal u(t)

E(s) is the Laplace transform of the error signal e(t)

K_p is the proportionality constant

Derivative Controller (D):

The derivative controller produces an output, which is derivative of the error signal.

$$u(t) = K_D\, de(t) / dt$$

Apply Laplace transform on both sides.

$$U(s) = s\, E(s) K_D$$

$$U(s) / E(s) = s\, K_D$$

Therefore, the transfer function of the derivative controller is $s K_D$.

here,

K_D is the derivative constant.

Integral Controller (I):

The integral controller produces an output, which is integral of the error signal.

$$u(t) = \int e(t)dt\ K_I$$

Apply Laplace transform on both the sides –

$$U(s) = E(s)\ K_{I\,/\,s}$$

$$U(s) / E(s) = K_{I\,/\,s}$$

Therefore, the transfer function of the integral controller is K_I / s.
Where, K_I is the integral constant.

Proportional Derivative (PD) Controller:

The proportional derivative controller produces an output, which is the combination of the outputs of proportional and derivative controllers.

$$u(t) = K_P\ e(t) + K_D\ de(t) / dt$$

Apply Laplace transform on both sides –

$$U(s) = (K_P + K_D\ s)\ E(s)$$

$$U(s) / E(s) = (K_P + K_D\ s)$$

Therefore, the transfer function of the proportional derivative controller is (K_P +K_D s).

Proportional Integral (PI) Controller:

The proportional integral controller produces an output, which is the combination of outputs of the proportional and integral controllers.

$$u(t) = K_P\ e(t) + K_I \int e(t)dt$$

Apply Laplace transform on both sides –

$$U(s) = (K_P + K_{I\,/}\ s)\ E(s)$$

$$U(s) / E(s) = (K_P + K_{I\,/}\ s)$$

Therefore, the transfer function of proportional integral controller is K_P + $K_{I\,/}$ s.

Proportional Integral Derivative (PID) Controller:

The proportional integral derivative controller produces an output, which is the combination of the outputs of proportional, integral and derivative controllers.

$$u(t) = K_P\, e(t) + K_I \int e(t)dt + K_D\, de(t) / dt$$

Apply Laplace transform on both sides –

$$U(s) = (K_P + K_I / s + K_D\, s)\, E(s)$$

$$U(s) / E(s) = (K_P + K_I / s + K_D\, s)$$

Therefore, the transfer function of the proportional integral derivative controller is $(K_P + K_I / s + K_D\, s)$.

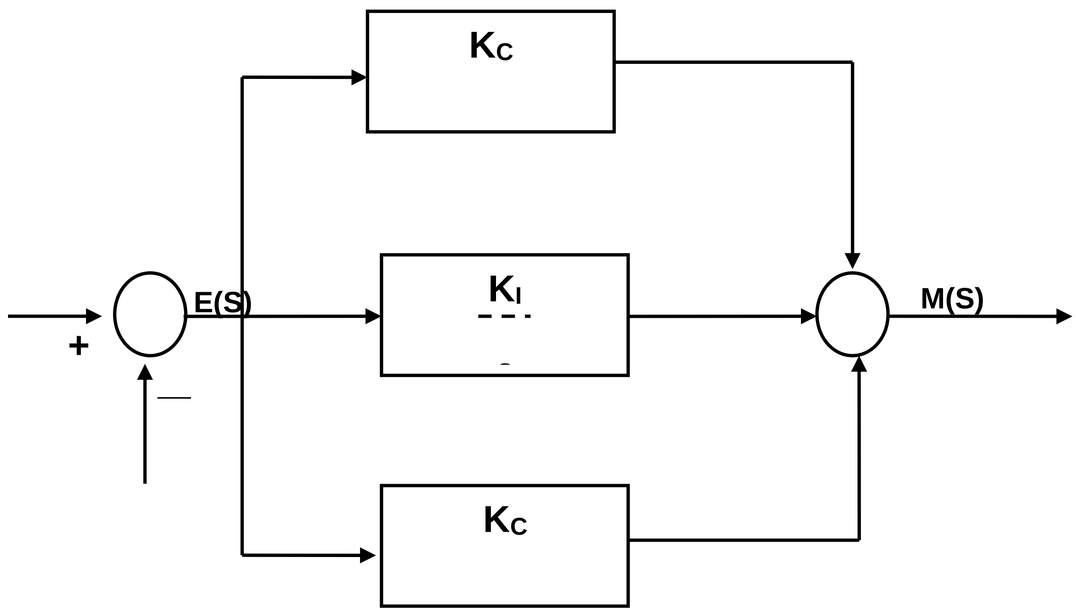
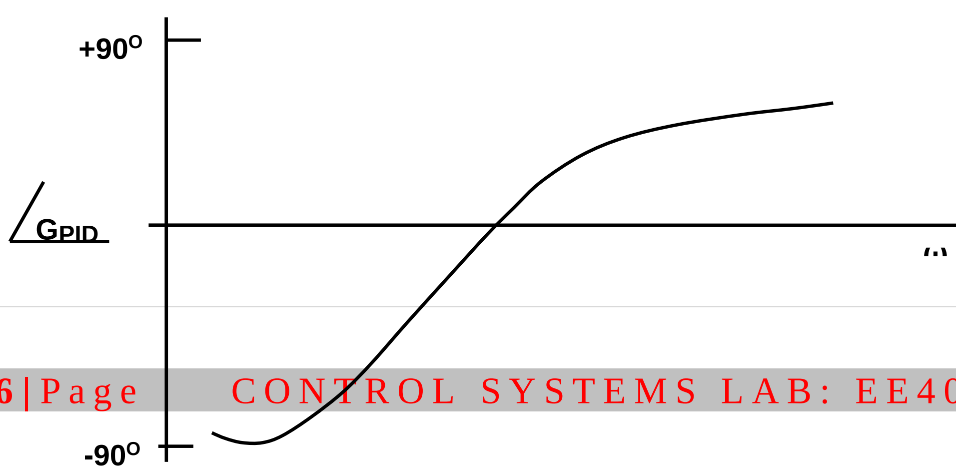


FIG. 3 PID CONTROLLER



here

$$T_j = \frac{K_c}{K_i} = \text{integral time constant}$$

$$T_d = \frac{K_d}{K_c} = \text{Derivative time constant}$$

It easy to develop the structure of PD, and PI controllers from above, by substituting K_j=0 and K_d =0 respectively.

A special terminology used in process control literature is given below to facilitate better understanding.

$$\text{Proportional Band} = \frac{1}{Kc} \times 100\%$$

$$\text{Reset rate} = \frac{K_i}{K_c} = \frac{1}{T_i} \text{ per minute}$$

Derivative Time = T_d

In the present unit, the three gains are adjustable in the following range with the help of calibrated 10-turn potentiometers.

K_c:0 to 20

K_I:0 to 1000

K_d :0 to 0.01

Characteristics

From Eq. (2), the transfer function of the PID controller may be written as

$M(s) = mK_d\, s^2 + K_c s + K_i$
$G_{PID}(s)$=--------------- = ---------------------
$E(s)$ s

K_d
= --------------------$(s+ \omega_1)(s+ \omega_2)$
s

where coiand o>**2** are the two zeros of the PID controller transfer function.

The above transfer function has a pole at the origin and two real zeros for $K_c > 4K_dK_i$. Notice that properly designed PID controller should not, in general, have a pair of complex conjugate zeros which may result in reduced damping. Bode diagram of the PID controller is shown in Fig.4.

It may see that the controller gain increase without limits as the frequency is decreased. This is due to the integral term, and it results in a reduction of steady state error. However, the negative phase angle introduced by the controller at low frequencies has a destabilizing effect as well. The corner frequency ω_1 should therefore be so located that large negative phase angle occurs at sufficiently low frequencies only, where the plant already had a good stability margin.

Again, the bode diagram of the controller Fig.4) shows an increased gain at high frequencies accompanied by a positive phase angle. The positive phase angle has a stabilizing effect while the large gain at high frequencies makes the system more respective to fast or sudden changes. The overall system then becomes relatively more stable, as it is capable of taking 'anticipatory' action in the presence of signals having fast variations.

9.3 PROCEDURE

P-Controller

1. Make the connections as shown in Fig. (a) with process made up of time delay and time constant blocks. Notice that the CRO operation in the X-Y mode ensures stable display even at low frequencies.
2. Set input amplitude (square wave) to 1V(p-p) for to the low value.
3. For various values of K_c =0.2, 0.4, --------- measure from the screen the values of

peak over shoot and steady state error and tabulate.

Pi-Controller

1. Make the connections for a I - order type -0 system with time delay (fig *J a)* with proportional and proportional and integral blocks connected)
2. Set input amplitude to 1V(p-p), frequency to *a low* value and Kj to zero.
3. For K_c =0.6 (say) observe and record the peak over shoot and steady state error.

With the K_c as above increase K_i in small steps and *record* peak over shoot and steady state error.

PID-Controller

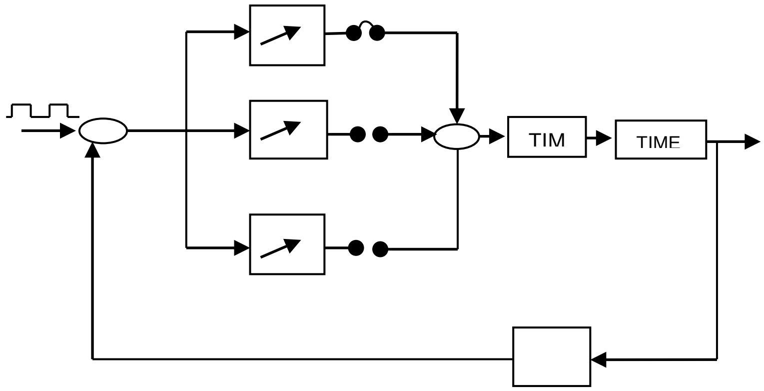
Make the connections as shown in Fig (a) with proportional integral and derivative blocks connected.

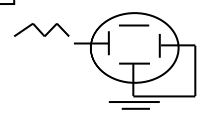
1. Set input amplitude to 1V(p-p) frequency to a low value K_c =0.6, $K_|$ =0.06, K_d =0
2. The system shows a fairly large over shoot record the peak over shoot and steady state error. Repeat the above steps for a non-zero value K_d.

$$K_c = \frac{\text{p-p square wave out put}}{\text{p-p square wave input}}$$

$$K_i\,(\max) = \frac{4\text{xfx(p-p) triangular wave output amplitude in volts}}{\text{p-p square wave amplitude in volts}}$$

$$K_d = \frac{\text{p-p square wave output}}{4\text{xfx(p-p) triangular wave input}}$$





$$\text{Steady state error} = \frac{\text{Step i/p} - X}{\text{Step i/p}}$$

9.4 OUTPUT WAVE FORM

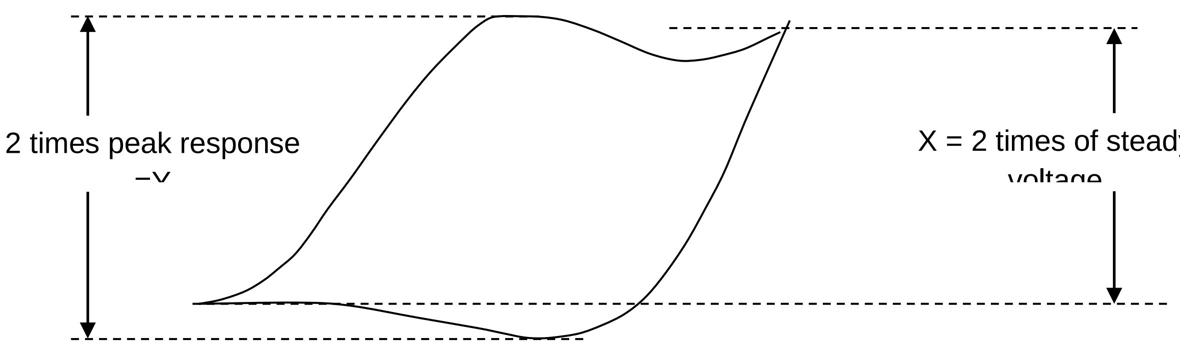


FIG. 6(a) CONNECTION DIAGRAM FOR P - CONTRON

9.5 TABULAR COLUMN

For P-Controller

S. NO.	K_P	X	Y	Steady state Error	% peak overshot

For PI-Controller P=0.6

S. NO.	K_i	X	Y	Steady state Error	% peak overshot

For PID-Controller P=0.6, I=0.06

S. NO.	K_d	X	Y	Steady state Error	% peak overshot

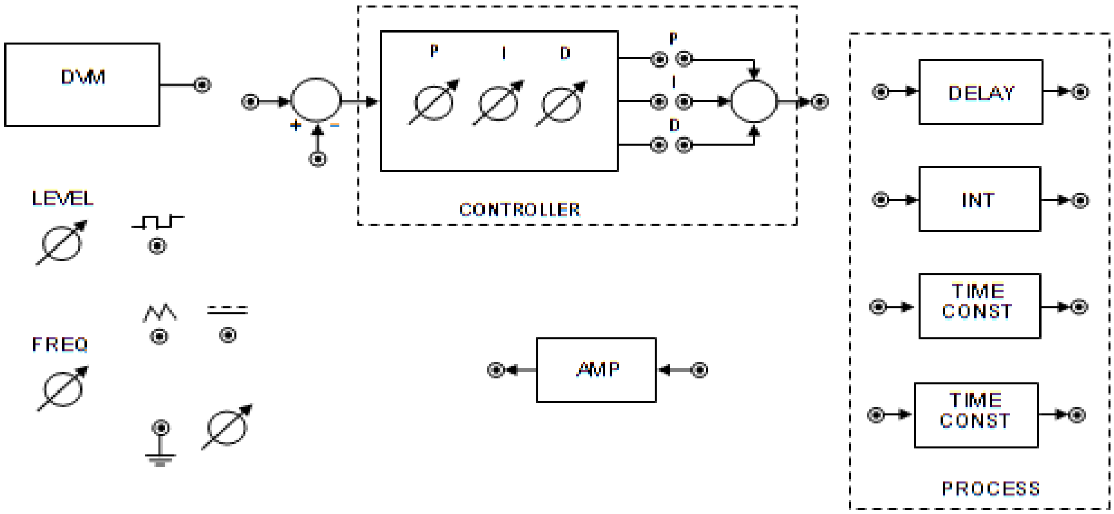


FIG. 1 SYSTEM SCHEMATIC

9.6 RESULT:

Hence the steady state performance of an analog P, PI & PID controller has been studied using simulated system.

CONCLUSIONS:

By Using P, PI, PID Controllers we calculated Peak over shoot and steady state error

By using PI Controller, we observed error zero and by PD controller is improved stability and using PID Controller we observed error reduced and stability improved

9.7 PRELAB QUESTIONS:

1. What is a controller?
2. What is the difference between a compensator and controller?

3. Write a brief note about Proportional Controller?
4. Write a brief note about Derivative Controller?
5. Write a brief note about Integral Controller?

9.8 LAB ASSIGMNETS:

1. To observe open loop performance of building block and calibration of PID Controls?
2. To study P, PI and PID controller with type 0 system with delay?
3. To study P, PI and PID controller with type 1 system?

9.9 POSTLAB QUESTIONS:

1. Write a brief note about PID Controller?
2. Compare the performance of PI and PD controller?
3. Which controller is used for improving the transient response of the system?
4. Which controller is used for improving the steady state response of the system?
5. What is the purpose of PID controller?

EXPERIMENT 10:

LAG AND LEAD COMPENSATION – MAGNITUDE AND PHASE PLOT

10.1 OBJECTIVE:

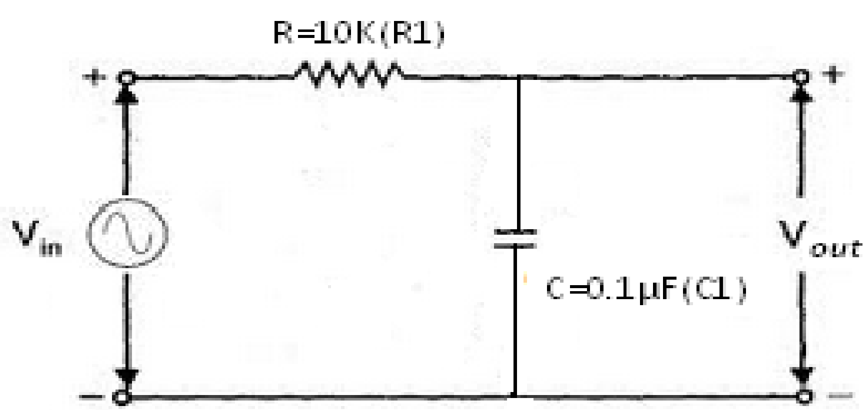
To study of Lead-Lag compensation networks.

- By using lag network varying frequency note down the phase angle and output voltage and calculate gain
- By using lead and lag-lead network varying frequency note down the phase angle and output voltage and calculate gain

10.2 RESOURCES:

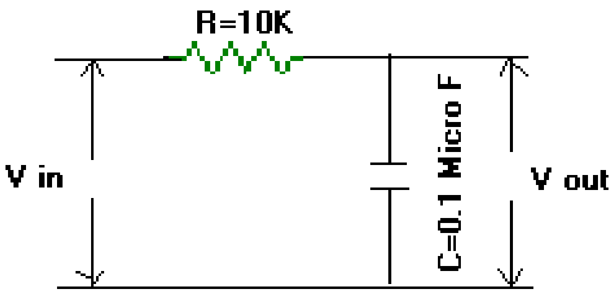
1. Lead lags Experimental kit, having sine wave source (50Hz to 1000Hz), and Frequencymeter and peak detector
2. Resistors-10KΩ
3. Capacitor – 0.1µF
4. Connecting Wires

10.3 CIRCUIT DIAGRAM:

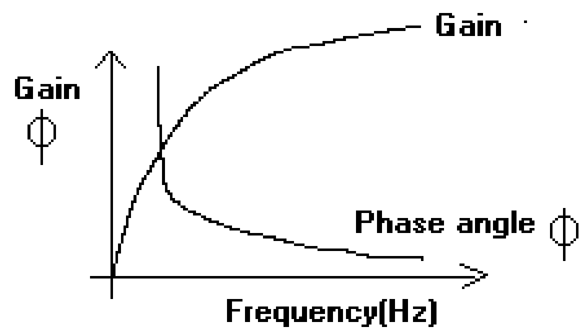


Lag Compensation Network:

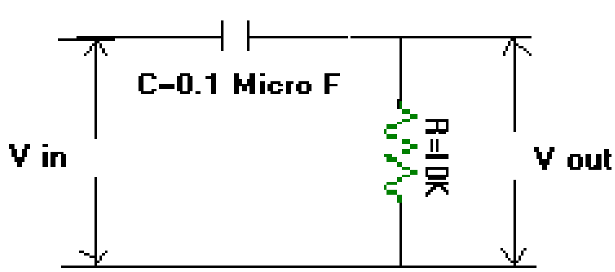
LEAD COMPENSATION



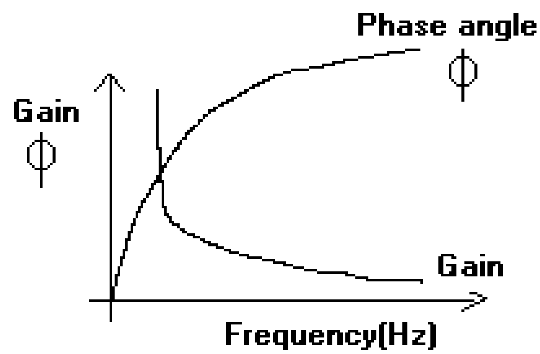
MODEL GRAPH

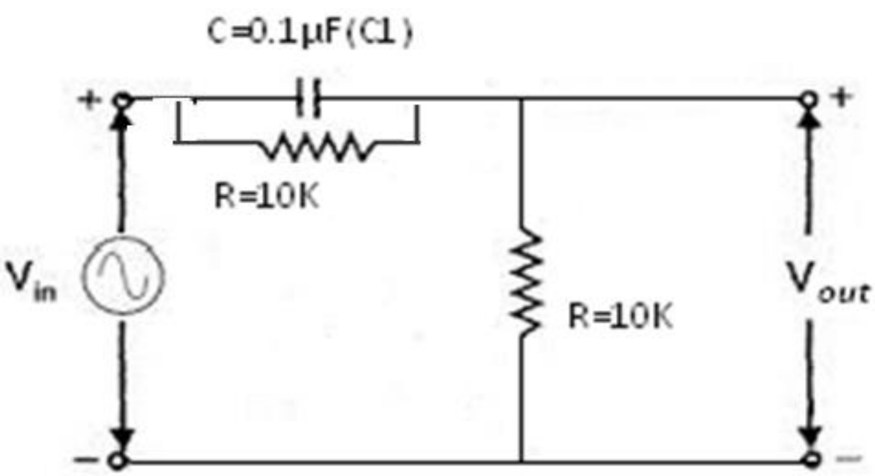


LAG COMPENSATION

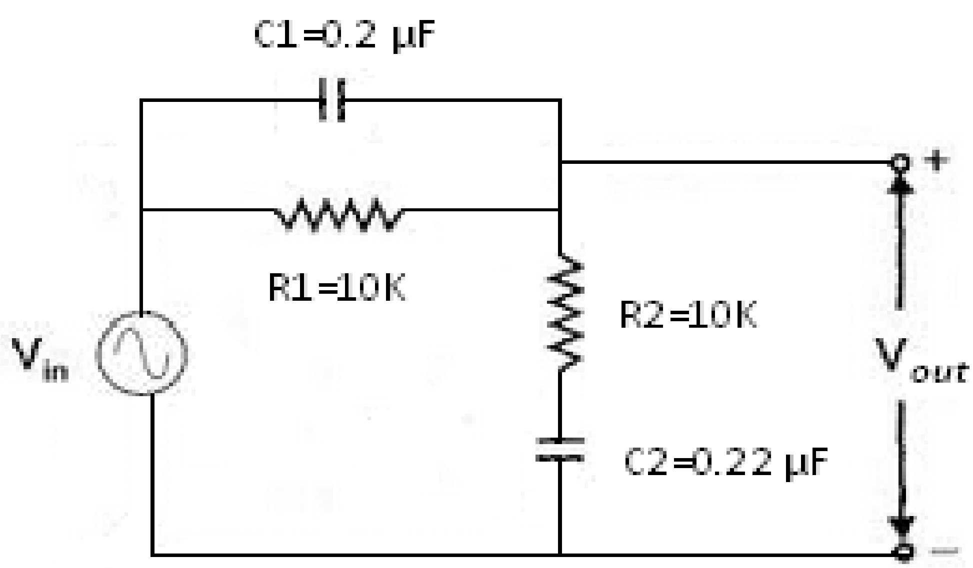


MODEL GRAPH

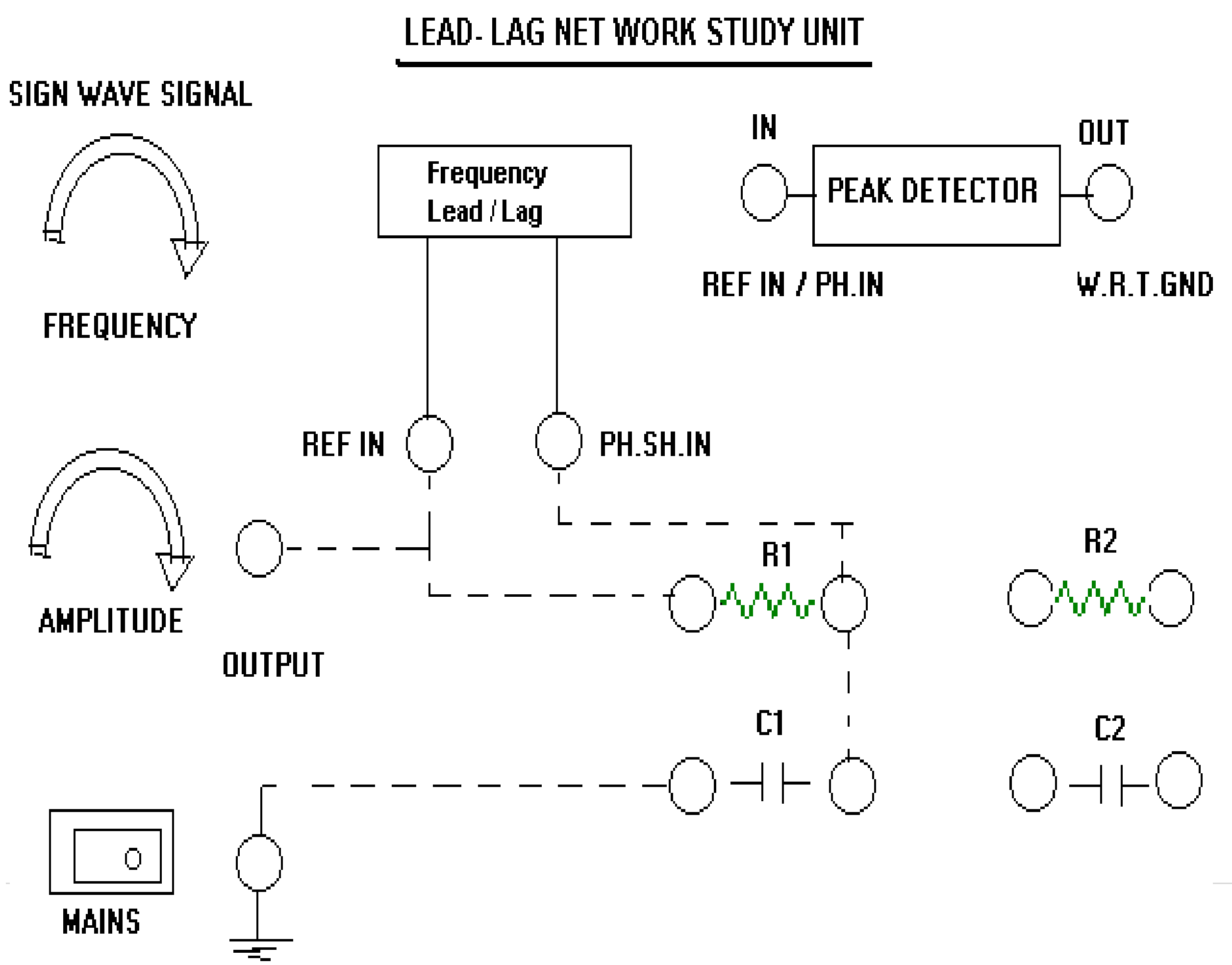




Lead Compensation Network:



Lag-Lead Compensator Network:



10.4 PROCEDURE:

1. Switch on the main supply to unit observe the sine wave signal by varying the frequency and amplitude potentiometer.
2. Now make the network connections for Lag, Lead and Lead-Lag networks connect the sine wave output to the networks input.
3. Note down the peak actuator input using digital voltmeter provided, now the meter will show peak voltage.
4. Set the amplitude of sine wave to some value ex: 3 Volts peak, 4Volts Peak etc.,
5. Now vary the frequency and note down frequency, phase angle difference and output voltage peak for different frequencies and tabulate all the readings.
6. Calculate the theoretical values of phase angle difference and gain compare these values with the practical values.
7. Plot the graph of phase angle versus frequency (phase plot) and gain versus frequency (magnitude plot).
8. Repeat the same for different values of R and C.
9. Repeat the same for different sine wave amplitude.
10. Repeat the same experiment for lead and lag-lead networks.

FORMULAE:

Lag Network :

Phase angle, $\Phi = \tan^{-1}\omega RC$

$$\text{Gain} = \frac{1/RC}{\sqrt{\omega^2 + \left(1/RC\right)^2}}$$

FORMULAE:

Lead Network:

Phase angle, $\Phi = \tan^{-1}\left(1/\omega RC\right)$

Gain $G_C = (j\omega) = \frac{V_{out}}{V_{in}} = \frac{j\omega RC}{1 + j\omega RC}$

$\frac{V_{out}}{V_{in}} = \frac{R}{Z} \quad Z = \sqrt{R^2 + \left(1/\omega C\right)^2}$

Vin = V

FORMULAE:

Lag-Lead Network:

$R_1C_1 = \tau_1,\ R_2C_2 = \tau_2$

$\beta = \frac{R_1 + R_2}{R_2} > 1$

$\beta = \frac{10k + 10k}{10k} = 2.0$

$\alpha = \frac{R_2}{R_1 + R_2}\ 0.5 < 1$

The transfer function of such a compensator is given by

$$G(s) = \frac{\left(s + 1/\tau_1\right)\left(s + 1/\tau_2\right)}{\left(s + 1/\beta\tau_1\right)\left(s + 1/\alpha\tau_2\right)}$$

(lag) (lead)

CALCULATIONS:

$R_1C_1 = \tau_1 = 0.002,\ R_2C_2 = \tau_2 = 0.002$

$\omega_0 = 1/\sqrt{\tau_1 \times \tau_2}$

The frequency at which phase angle zero is $\omega_0 = 1/\sqrt{\tau_1 \times \tau_2}$

$\omega_0 = 2\pi f = 500$

$f = 500/6.28 = 80\text{Hz}$

10.5 TABULAR COLUMN:

Lag Network :

Sl. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}

TABULAR COLUMN:

Lead Network :

Sl. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}

TABULAR COLUMN:

Lag-Lead Network:

Sl. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}

10.6 RESULT:

Hence, we have studied lag, lead, lag- lead compensation network

10.7 CONCLUTIONS:

By The lag network by varying frequency observed the phase angle and output voltage and calculated gain

By the lead and lag-lead network varying frequency observed the phase angle and output voltage and calculated gain

10.8 PRELAB QUESTIONS:

1. Write a brief note about Lag Compensator.
2. Write a brief note about Lead Compensator.
3. Write a brief note about Lag Lead Compensator.
4. Which compensation is adopted for improving transient response of a negative unity feedback system?

10.9 LAB ASSIGNMENTS:

1. To study the open loop response on compensator and Close loop transient response.
2. The max. phase shift provided for lead compensator with transfer function

3. G(s)=(1+6s)/(1+2s)

10.10 POSTLAB QUESTIONS:

1. Which compensation is adopted for improving steady response of a negative unity feedback system?
2. Which compensation is adopted for improving both steady state and transient response of a negative unity feedback system?
3. What happens to the gain crossover frequency when phase lag compensator is used?
4. What happens to the gain crossover frequency when phase lead compensator is used?
5. What is the effect of phase lag compensation on servo system performance?

EXPERIMENT 11:

SIMULATION OF P, PD, PI, PID CONTROLLER

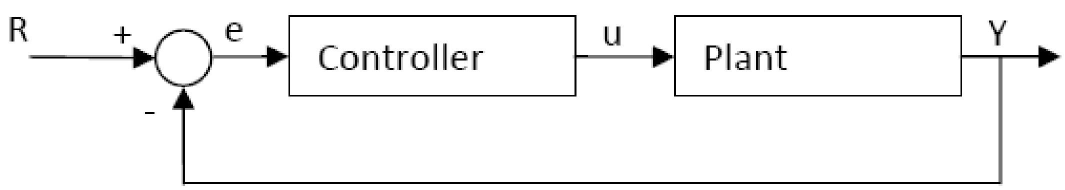
Aim: To simulate the P, PD, PI, PID controller for unit step input.

SOFTWARE REQUIRED:

1. **MATLAB**
2. **P**ersonal Computer with MATLAB.

Theory:

Consider the following unity feedback system:



Plant: A system to be controlled.

Controller: Provides excitation for the plant; Designed to control the overall system behavior.

The three-term controller: The transfer function of the PID controller looks like the following

$$K_P + \frac{K_I}{s} + K_D s = \frac{K_D s^2 + K_P s + K_I}{s}$$

KP =Proportional gain

KI = Integral gain

KD = Derivative gain

First, let's take a look at how the PID controller works in a closed-loop system using the

schematic shown above. The variable (e) represents the tracking error, the difference between the

desired input value (R) and the actual output (Y). This error signal (e) will be sent to the PID controller, and the controller computes both the derivative and the integral of this error signal. The signal (u) just past the controller is now equal to the proportional gain (KP) times the magnitude of the error plus the integral gain (KI) times the integral of the error plus the derivative gain (KD) times the derivative of the error.

$$u = K_P e(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt}$$

Plug these values into the above transfer function

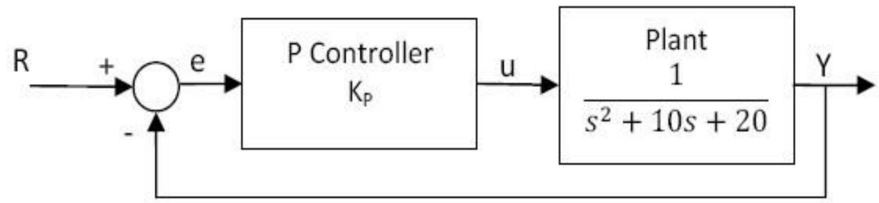
$$\frac{X(s)}{F(s)} = \frac{1}{s^2 + 10s + 20}$$

The goal of this problem is to show you how each of K_p, K_i and K_d contributes to obtain

- Fast rise time
- Minimum overshoot
- No steady-state error

Proportional control:

The closed-loop transfer function of the above system with a proportional controller is:

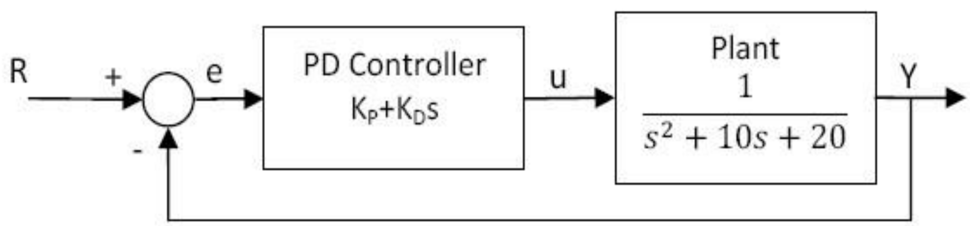


$$\frac{X(s)}{F(s)} = \frac{K_P}{s^2 + 10s + (20 + K_P)}$$

Let the proportional gain (K_P) equal 300:

Proportional-Derivative control:

The closed-loop transfer function of the given system with a PD controller is:

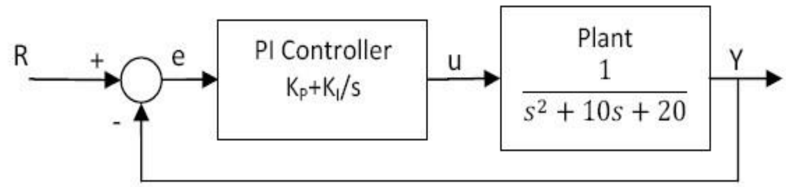


$$\frac{X(s)}{F(s)} = \frac{K_D s + K_P}{s^2 + (10 + K_D)s + (20 + K_P)}$$

Let K_P equal 300 as before and let K_D equal 10.

Proportional-Integral control:

Before going into a PID control, let's take a look at a PI control. For the given system, the closed-loop transfer function with a PI control is:

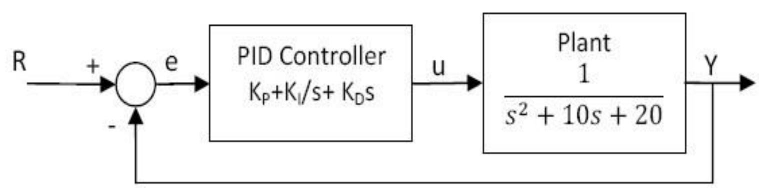


$$\frac{X(s)}{F(s)} = \frac{K_P s + K_I}{s^3 + 10s^2 + (20 + K_P)s + K_I}$$

Let's reduce the K_P to 30, and let K_I equal 70.

Proportional-Integral-Derivative control:

Now, let's take a look at a PID controller. The closed-loop transfer function of the given system with a PID controller is:



$$\frac{X(s)}{F(s)} = \frac{K_D s^2 + K_P s + K_I}{s^3 + (10 + K_D)s^2 + (20 + K_P)s + K_I}$$

After several trial and error runs, the gains Kp=350, Ki=300, and Kd=50 provided the desired response. To confirm, enter the following commands to an m-file and run it in the command window. You should get the following step response.

The characteristics of P, I, and D controllers:

The proportional controller (K_P) will have the effect of reducing the rise time and will reduce, but never eliminate, the steady state error. An integral controller (K_I) will have the effect of eliminating the steady state error, but it may make the transient response worse. A derivative control (K_D) will have the effect of increasing the stability of the system, reducing the overshoot and improving the transient response.

Effect of each controller K_P, K_I and K_D on the closed-loop system are summarized below

CL Response	Rise Time	Overshoot	Settling Time	S-S Error
K_P	Decrease	Increase	Small Change	Decrease
K_I	Decrease	Increase	Increases	Eliminate
K_D	Small Change	Decreases	Decreases	Small Change

Program:

Open-loop step response:

```
num=1;
den=[1 10 20];
plant=tf(num,den);
step(plant)
```

Proportional control:

```
Kp=300;
contr=Kp;
sys_cl=feedback(contr*plant,1);
t=0:0.01:2;
step(sys_cl,t)
```

Proportional-Derivative control:

```
Kp=300;
Kd=10;
contr=tf([Kd Kp],1);
sys_cl=feedback(contr*plant,1);
t=0:0.01:2;
step(sys_cl,t)
```

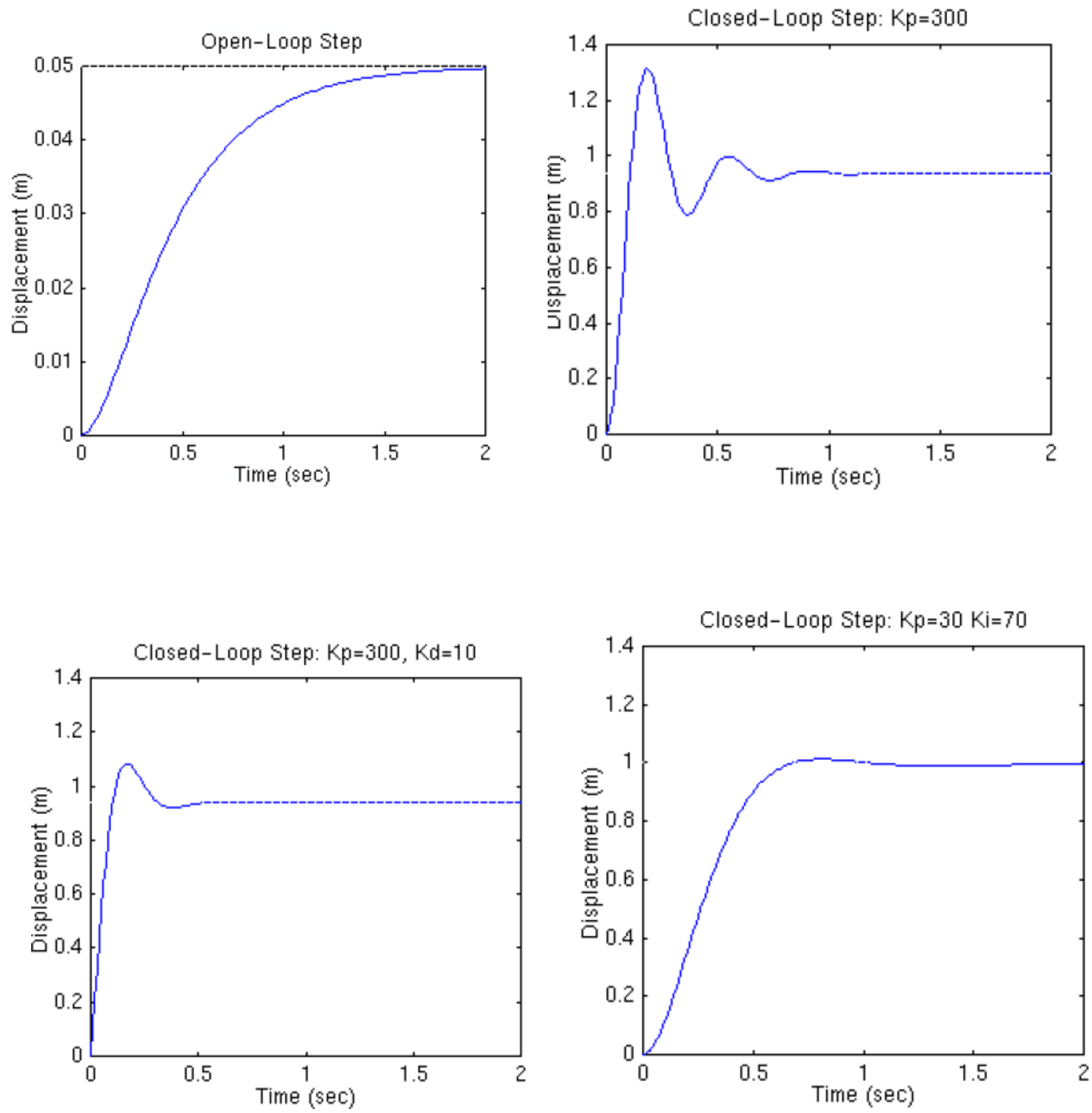
Proportional-Integral control:

```
Kp=30;
Ki=70;
contr=tf([Kp Ki],[1 0]);
sys_cl=feedback(contr*plant,1);
t=0:0.01:2;
step(sys_cl,t)
```

Proportional-Integral-Derivative control:

```
Kp=350;
Ki=300;
Kd=50;
contr=tf([Kd Kp Ki],[1 0]);
sys_cl=feedback(contr*plant,1);
t=0:0.01:2;
step(sys_cl,t)
```

Model graph;


Open-Loop Step
Displacement (m)
Time (sec)
Closed-Loop Step: Kp=300
Displacement (m)
Time (sec)
Closed-Loop Step: Kp=300, Kd=10
Displacement (m)
Time (sec)
Closed-Loop Step: Kp=30 Ki=70
Displacement (m)
Time (sec)

Observation:

Effect of each controller K_P, K_I and K_D on the closed-loop system are summarized below

CL Response	Rise Time	Overshoot	Settling Time	S-S Error
K_P	Decrease	Increase	Small Change	Decrease
K_I	Decrease	Increase	Increases	Eliminate
K_D	Small Change	Decreases	Decreases	Small Change

Result:

EXPERIMENT NO – 12

LINEAR SYSTEM ANALYSIS (TIME DOMAIN ANALYSIS, ERROR ANALYSIS) USING SUITABLE SOFTWARE

12.1 OBJECTIVE: To write a program and simulate dynamical system of I/O model

- To Observe the characteristics of time response of a second order system in MATLAB
- To Calculate damping factor, delay time, rise time, peak time, peak over shoot, setting time and damped natural frequency.

12.2 RESOURCES:

1) MATLAB Software
2) Personal Computer

12.3 PROGRAM:

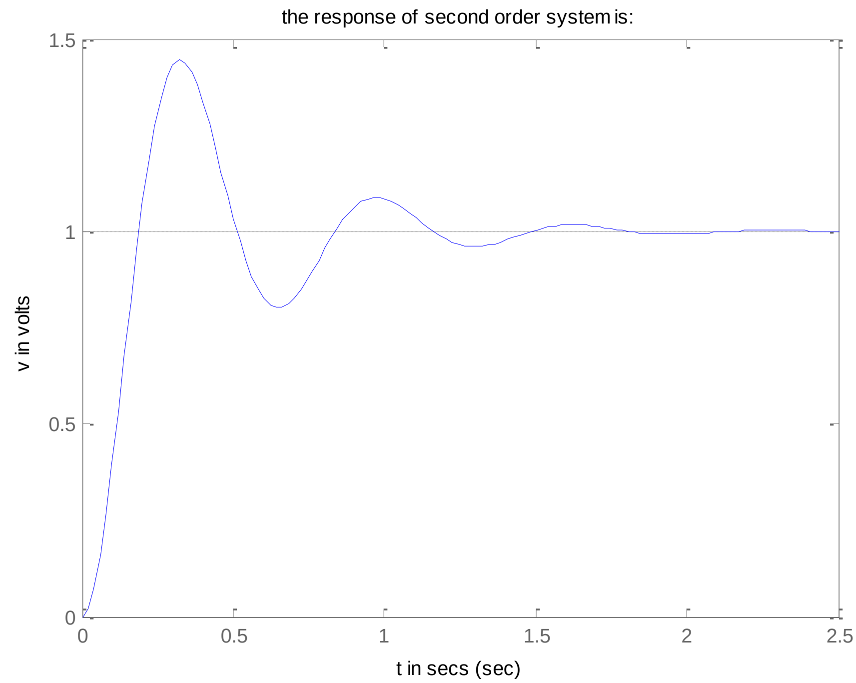
```
num=input ('enter the numerator of transfer function:')

den=input ('enter the denominator of transfer function:')

s=tf (Num, den)

step(s)

title ('the response of second order system is:')

Xlabel ('t in secs')

Ylabel ('v in volts')

[nt, dt] = tfdata(s,'v')

Wn = sqrt (dt (3))
```

```
Z = dt (2)/(2*wn)

Disp ('the rise time is:')

tr=pi-(atan^-1(sqrt(1-z^2)/z)/(wn*sqrt(1-z^2)))

disp('the peak time is:')

tp=pi/(wn*sqrt(1-z^2))

disp('the settling time is:')

ts=4/(z*wn)

disp('the peak over shoot is:')

pos=exp((-z*pi)/sqrt(1-z^2))*100

end
```

OUTPUT:

```
enter the numerator of transfer function:100

num =

   100

enter the denominator of transfer function: [1 5 100]

den =

     1     5   100

Transfer function:

      100

---------------
```

```
s^2 + 5 s + 100

nt =

     0     0   100

dt =

     1     5   100

wn =

    10

z =

    0.2500

the rise time is:

tr =

    2.8238

the peak time is:

tp =

    0.3245

the settling time is:

ts =

    1.6000

the peak over shoot is:

pos =

   44.4344
```



RESULT:

Hence, we have executed a program and simulated dynamical system of I/O model

CONCLUSIONS:

The values of damping factor, delay time, rise time, peak time, peak over shoot, setting time and damped natural frequency are calculated observed time response. The practical values are verified with theoretical calculated values.

PRE –LAB QUESTIONS:

1. Define Type and Order of a System
2. Define Delay Time
3. Define Rise Time

LAB - ASSIGNMENTS QUESTIONS:

1. Define Peak Over Shoot
2. Define Settling Time
3. Define Steady State Error

EXPERIMENT 13:

STABILITY ANALYSIS (BODE, ROOT LOCUS, NYQUIST) OF LINEAR TIME INVARIANT SYSTEM USING SUITABLE SOFTWARE

13.1 OBJECTIVE:

- To analyze frequency response of a system by plotting Root locus, bode plot and Nyquist plot using MATLAB software.
- To Observe root locus, Bode plot in the MATLAB and stability of closed loop Transfer function.
- To Calculate Phase cross over frequency, gain cross over frequency, Phase margin and gain margin.

13.2 RESOURECES:

1. MATLAB Software
2. Personal Computer

13.3 PROCEDURE:

1. Click on MATLAB icon.
2. From FILE menu click on NEW button and select SCRIPT to open Untitled window
3. Enter the following program in untitled window.

13.4 PROGRAM:

For Root Locus Plot:

```
 %Root Locus Plot
clear all;
clc;
```

```
disp (‘Transfer Function of given system is: \n’);

num = input (‘Enter Numerator of the Transfer Function: \ n’);

den = input (‘Enter Denominator of the Transfer Function:\ n’);

G = tf(Num, den);

figure (1);

rlocus(G);
```

For Bode Plot:

```
%Bode Plot

clear all;

clc;

disp(‘Transfer Function of given system is : \n’);

num = input (‘Enter Numerator of the Transfer Function: \ n’);

den = input (‘Enter Denominator of the Transfer Function: \ n’);

G = tf(num,den);

figure(2);

bode(G);

%margin(G); It can be used to get Gain Margin, Phase Margin etc

[Gm,Pm,Wpc,Wgc] = margin(G);
```

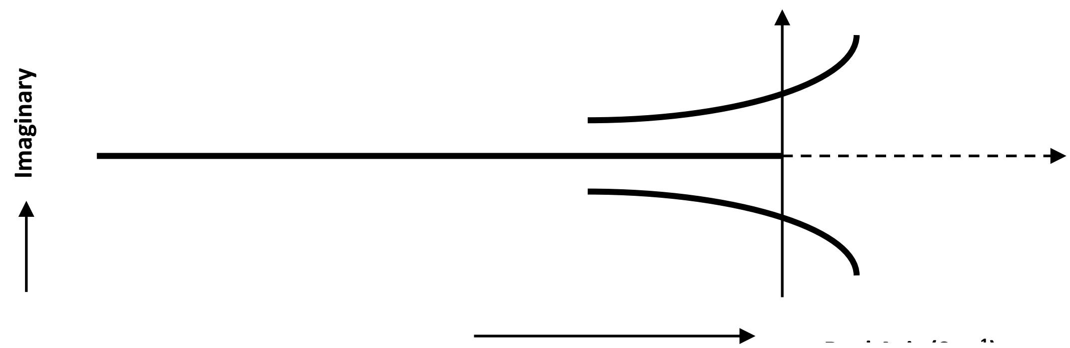
```
disp('Phase Cross Over frequency is : \n');
Wpc
    disp('Gain Cross Over frequency is : \n');
Wgc
disp('Phase Margin in degrees is : \n');
Pm
disp('Gain Margin in db is : \n');
Gm = 20*log(Gm)
Gm
if (Wgc<Wpc)
        disp('Closed loop system is stable')
else
if (Wgc>Wpc)
        disp('Closed loop system is unstable')
else
        disp('Closed loop system is Marginally stable')
end
```

1. Save the above program by clicking on SAVE button from FILE menu (or) Ctrl+S

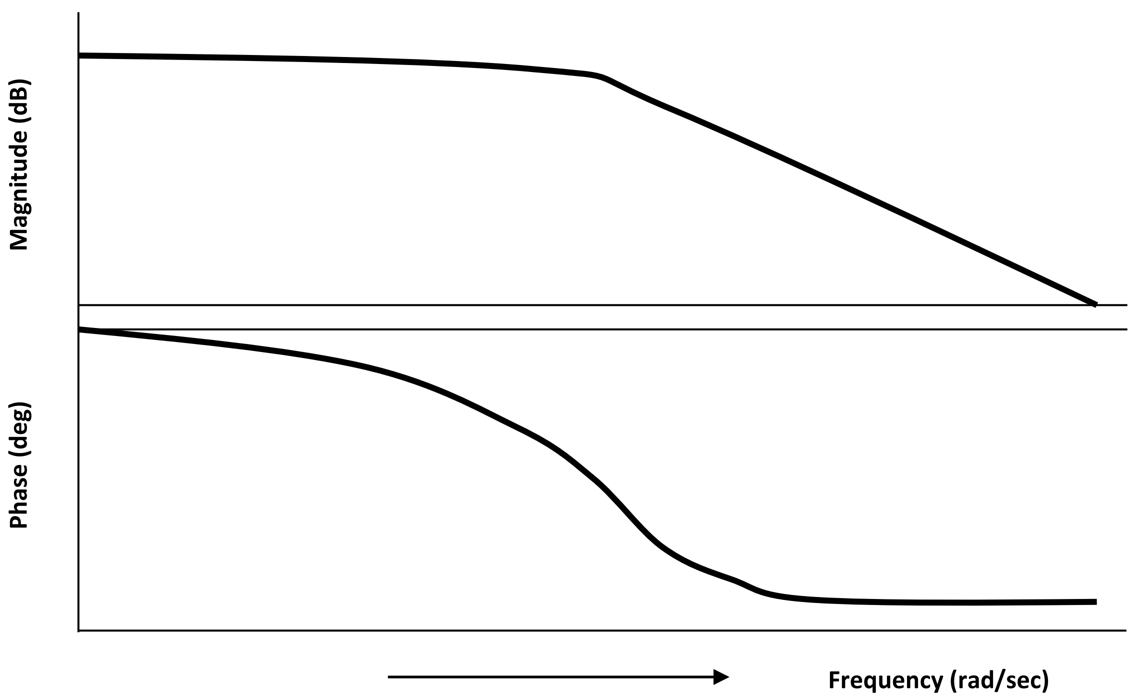
2. Run the program by clicking RUN button (or) F5 and clear the errors (if any).
3. Observe the output on the MATLAB Command Window and plots from figure window.

13.5 MODEL GRAPHS:

Root Locus plot:



Bode Plot:



OUTPUT:

Phase Cross Over frequency is:

Wpc =

Gain Cross Over frequency is:

Wgc =

Phase Margin in degrees is:

Pm =

Gain Margin in db is:

GM =

13.6 THEORETICAL CALCULATION:

1. Phase Margin:

1. For a given Transfer Function G(s), get G(jω) by placing **s= jω**.
2. Separate Magnitude and Phase terms from G(jω).
3. Equate magnitude of G(jω) to **ONE** and get ω value, this ω is called Gain Cross Over Frequency (ω_{gc})
4. Substitute ω_{gc} in place of G(jω), get the phase angle (φ).
5. Now Phase margin (PM) = 180 + φ

2. Gain Margin:

1. For a given Transfer Function G(s), get G(jω) by placing **s= jω**
2. Separate Magnitude and Phase terms from G(jω).
3. Equate imaginary part to **ZERO** and get ω value, this ω is called Phase Cross Over Frequency (ω_{pc})
4. Substitute ω_{pc} in real pat, get the corresponding gain (K).

5. Now Gain Margin (GM) = 20 $\log_{10}$ (1/K)

3. Maximum Allowable Gain:

1. For a given Transfer Function G(s), place K in the numerator and get the characteristic equation Q(s) = 1 + G(s).
2. Get Q(jω) by placing s = jω.
3. Separate imaginary and real terms from Q(jω).
4. Equate imaginary part to **ZERO** and get ω values, these values called Imaginary Cross Over points.
5. Substitute ω_{pc} in real pat and equate real part of G(jω) to **ZERO** and get the corresponding gain (K).
6. This gain is called maximum Allowable Gain (K_{max}) or Limiting value of the Gain for stability.

13.7 TABULAR COLUMN:

Specification	Gain Margin (GM) and Gain Cross Over Frequency (W_{gc})	Phase Margin (PM) and Phase Cross Over Frequency (W_{pc})	Maximum allowable gain (K_{max})
From MATLAB			
Theoretical			

13.8 RESULT:

Hence Root Locus Plot, Bode Plot and Nyquist plot of given transfer function has been plotted and verified with theoretical calculations.

CONCLUSIONS:

By The plotted root locus, Bode plot in the MATLAB the stability of closed loop Transfer function is verified

The Values of Phase cross over frequency, gain cross over frequency, Phase margin and gain margin. The practical values are verified with theoretical calculated values.

13.9 PRE LAB-QUESTIONS:

1. What is gain margin and phase margin?
2. What is gain cross over frequency and phase crossover frequency?
3. What are the different types of stability conditions?
4. What are the advantages and disadvantages of root locus, bode & Nyquist plot?
5. What are the advantages of frequency response analysis?

13.10 LAB ASSIGNMENTS:

1. For the above function, if a pole is added, how the stability will be effected for all the plots?
2. For the above function, if a pole is removed, how the stability will be affected for all the plots?
3. For the above function, if a zero is added, how the stability will be effected for all the plots?
4. For the above function, if a zero is removed, how the stability will be affected for all the plots

13.11 POST LAB QUESTIONS:

1. What are complementary Root Loci?

2. What are contours?
3. How can you analyze the stability of system with bode, nyquist?

EXPERIMENT 14:

STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING SUITABLE SOFTWARE -VERIFICATION

14.1 OBJECTIVE:

To Transform a given Transfer Function to State Space Model and from State Space Model to Transfer Function using MATLAB.

14.2 RESOURCES:

1. MATLAB Software
2. Personal Computer.

14.3 PROCEDURE:

1. Click on MATLAB icon.
2. From FILE menu click on NEW button and select SCRIPT to open Untitled window.
3. Enter the following program in untitled window.

14.4 PROGRAM:

For Transfer Function to State Space Model:

```
%Transfer Function to State Space Model

Clear all;

clc;

disp('Transfer Function of given system is : \n');

Num = [2 3 2];
```

```
Den = [2 1 1 2 0];

sys = tf (num, den);

Disp (‘Corresponding State Space Model A, B, C, D are: \n’);

[A, B, C, D] = tf2ss (num, den)
A

B
C

D
```

14.5 PROGRAM:

For State Space Model to Transfer Function:

```
%State Space Model to Transfer Function

Clear all;

clc;

disp (‘A, B, C, D Matrices of given State Space Model are:: \n’);

A = [1 2;3 4]

B = [1;1]

C = [1 0]

D = [0]

[num, den] = ss2tf (A, B, C, D);

Disp ((‘And corresponding Transfer Function is: \n ‘);
```

Sys = tf (num, den);

Sys

4. Save the above program by clicking on SAVE button from FILE menu (or) Ctrl+S
5. Run the program by clicking RUN button (or) F5 and clear the errors (if any).
6. Observe the output from on the MATLAB Command Window.

14.6 OUTPUT:

Transfer Function to State Space Model:

Transfer Function of given system is

Transfer Function:

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

Corresponding State Space Model A, B, C, D are:

```
A =   -0.5000   -0.5000   -1.0000   0
       1.0000         0         0   0
            0    1.0000         0   0
            0         0    1.0000   0

B =   1
      0
      0
```

0

C = 0 1.0000 1.5000 1.000

D = 0

OUTPUT:

State Space Model to Transfer Function:

A, B, C, D Matrices of given State Space Model are:

A = 1 2

3 4

B = 1

1

C = 1 0

D = 0

and corresponding Transfer Function is:

s–2

----

s^2 – 5s -2

14.7 RESULT:

Hence, the given transfer function to state space model and state space model to transfer function is transformed by using MATLAB.

14.8 PRELAB QUESTIONS:

1. What are the advantages & disadvantages of state space analysis?
2. What are the disadvantages of transfer function?
3. What are the different functions in MATLAB?
4. **What is workspace and command window?**

14.9 LAB ASSIGNMENTS:

1.
```
        8s + 1
------------------------------ formulate state space model?
   9s^3 + s^2 + s + 2
```

2.
```
   s^4 +s^3+s^2+s+ 1
----------------------------     formulate state space model?
    9s^3 + s^2 + s + 2
```

3.
```
              s
------------------------------ formulate state space model?
   9s^3 + s^2 + s +
```

14.10 POSTLAB QUESTIONS:

1. How to call MATLAB in batches?
2. Explain Handle graphics in MATLAB?
3. Explain the following commands:

   Acker, Bode, Ctrb, Dstep, Feedback, Impulse, Margin, Place, Rlocus, stairs

EXPERIMENT 15:

Design of Lead-Lag compensator for the given system and with specification using suitable software

AIM: To design lag, lead compensator, lag-lead compensator

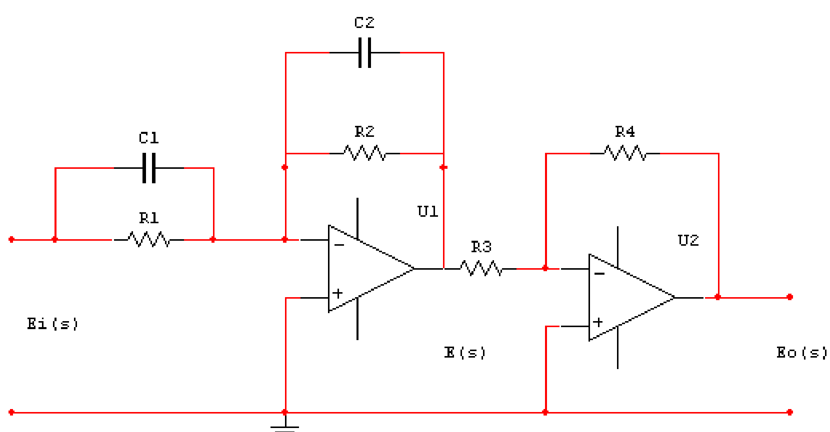
THEORY:

The primary objective of this experiment is to design the compensation of single –input-single-outputlinear time invariant control system.

Compensation is the modification of the system dynamics to satisfy the given specification. The compensation is done by adding some suitable device in which is called as compensator. Compensator is realized by such a way as to meet the performance specifications.

If sinusoidal input is applied to a network and if the steady state output has a phase lead, then the network is called a lead network, and if the output has a phase lag, then the network is called as a phase lag network.

Compensators are realized in our experiments using op-amps, electrical RC network as shown in figure.



$$\frac{Eo(s)}{Ei(s)} = \frac{R_2}{R_1}\frac{R_4}{R_3}\frac{R_1C_1s+1}{R_2C_2s+1} = \frac{R_4C_1s+\frac{1}{R_1C_1}}{R_2C_2s+\frac{1}{R_2C_2}} = K_c\alpha\frac{Ts+1}{\alpha Ts+1}$$

Where

$$T = R_1 C_1$$

$$\alpha T = R_2 C_2$$

$$K_c = \frac{R_4 C_1}{R_3 C_2}$$

$$\alpha = \frac{R_2 C_2}{R_1 C_1}$$

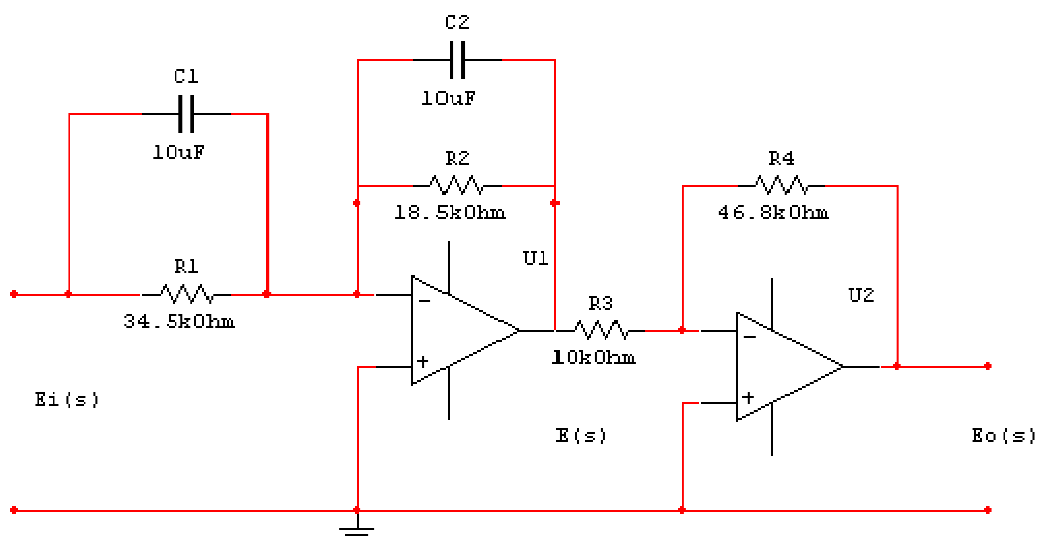
This network is a lead network if $R_1 C_1 > R_2 C_2$ or $\alpha < 1$.

Or this is a lag network if $\alpha > 1$ or $R_1 C_1 < R_2 C_2$

PROCEDURE

1) Consider any uncompensated system
2) Design the lead and lag compensator from the given circuit using the above equations.
3) Connect this design compensator to uncompensated system in series compensation.
4) Then find the closed loop transfer function equation for this compensated system
5) Plot the response for both uncompensated and compensated system

For Lead Compensator



The closed loop transfer function equation for the compensated system becomes

$$\frac{C(s)}{R(S)} = \frac{18.7(S+2.9)}{s(s+2)(s+5.4)+18.7(s+2.9)}$$

$$= \frac{18.7S+54.23}{s^3+7.4s^2+29.5s+54.23}$$

Hence

Numc = [0 0 18.7 54.23]

Denc = [1 7.4 29.5 54.23]

for the uncompensated system the closed loop transfer function is

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

Hence

Numc = [0 0 4]

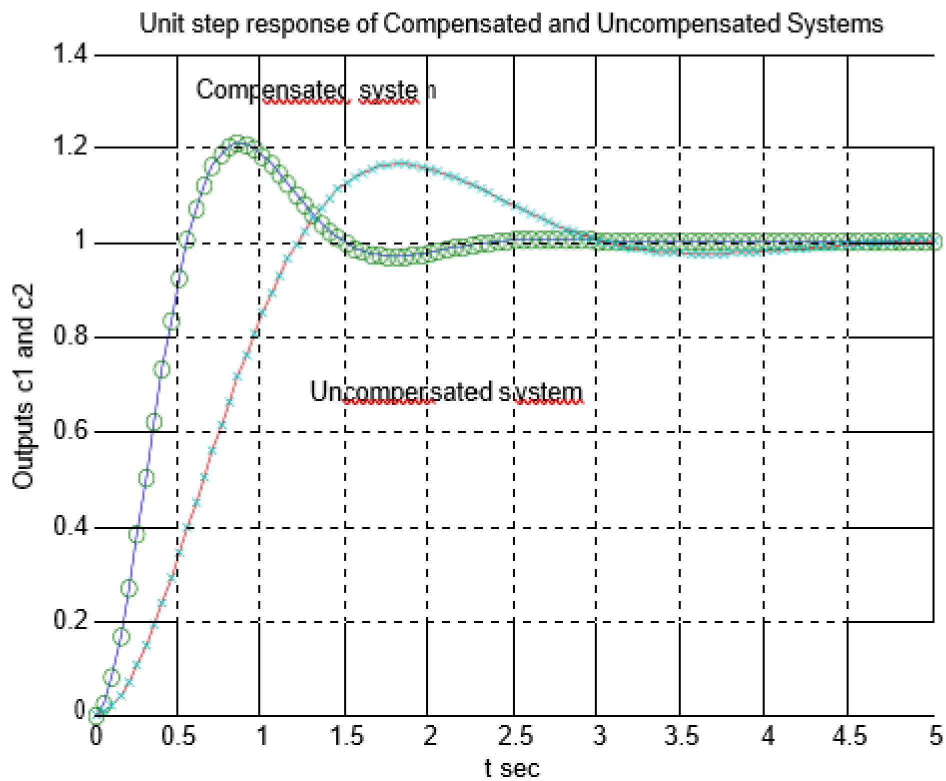
Denc = [1 2 4]

PROGRAM:

```
% Unit Step Response of Compensated and Uncompensated systems

Numc = [0 0 18.7 54.23];
Denc = [1 7.4 29.5 54.23];

Num = [0 0 4];
Den = [1 2 4];
t=0:0.05:5;
[c1, x1, t] = step (numc, denc, t);
[c2, x2, t] = step (num, den, t);
plot (t, c1, t, c1,'o', t, c2, t, c2,'x');
grid;
Title ('Unit step response of Compensated and Uncompensated Systems');
```

```
Xlabel ('t sec')
Ylabel ('Outputs c1 and c2');
text (0.6,1.32,'Compensated system');
text (1.3,0.68,'Uncompensated system');
```

Unit step response of Compensated and Uncompensated Systems



For Lag Compensator

The closed loop transfer function equation for the compensated system becomes

$$\frac{C(s)}{R(S)} = \frac{1.0235(s+0.05)}{s(s+0.005)(s+1)(s+2)+1.0235(s+0.05)}$$

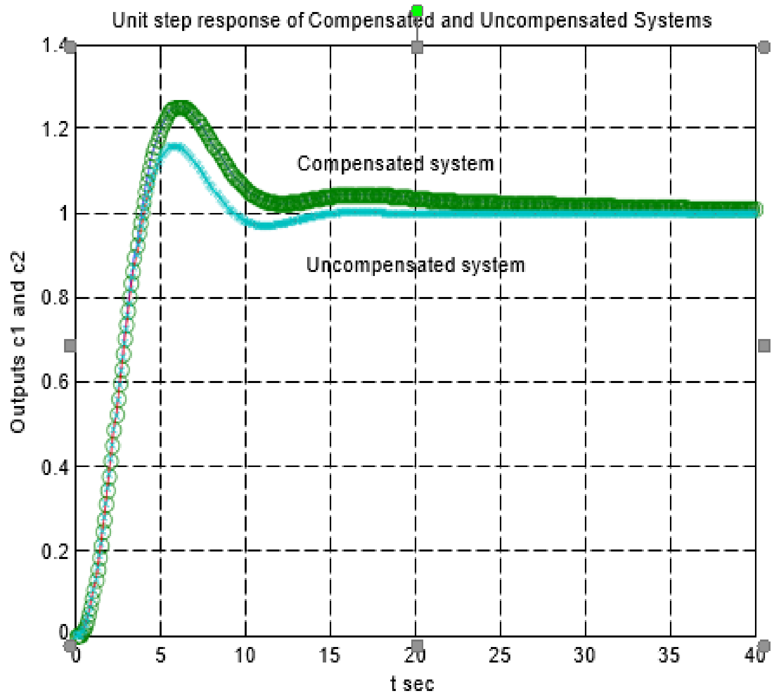
$$= \frac{1.0235s+0.0512}{s^4+3.005s^3+2.015s^2+1.0335s+0.0512}$$

for the uncompensated system the closed loop transfer function is

$$\frac{C(s)}{R(S)} = \frac{1.06}{s(s+1)(s+2)+1.06}$$

PROGRAM:

```
% Unit Step Response of Compensated and Uncompensated systems
Numc = [0 0 0 1.0235 0.0512];
Denc = [1 3.005 2.015 1.0335 0.0512];
num = [0 0 0 1.06];
den = [1 3 2 1.06];
t=0:0.1:40;
[c1, x1, t] = step (numc, denc, t);
[c2, x2, t] = step (num, den, t);
Plot (t, c1, t, c1,'o', t, c2, t, c2,'x');
grid;
text (13,1.12,’Compensated system’);
text (13.6,0.88,'Uncompensated system');
title ('Unit step response of Compensated and Uncompensated Systems');
xlabel ('t sec');
ylabel ('Outputs c1 and c2');
```



RESULTS & DISCUSSIONS: Compensators are added to existing systems to improve theirperformance.

- Such compensators based on the change required in performance of the system have been designed and improvement in performance analyzed using MATLAB.
- Change in the performance of the system with compensator is observed.

Experiment - 16

CHARACTERISTICS OF MAGNETIC AMPLIFIERS

Aim: To study the performance characteristics of magnetic amplifier.

Apparatus:

S. No.	Apparatus	Range	Quantity
1	Magnetic amplifier kit	(0-100) kΩ	02
2	Ammeter	(0-1)A MC	02
		(0-2)A MI	02
3	Patch cords	---	Some
4	lamp	100W	01

Procedure:

Series connected magnetic amplifier:

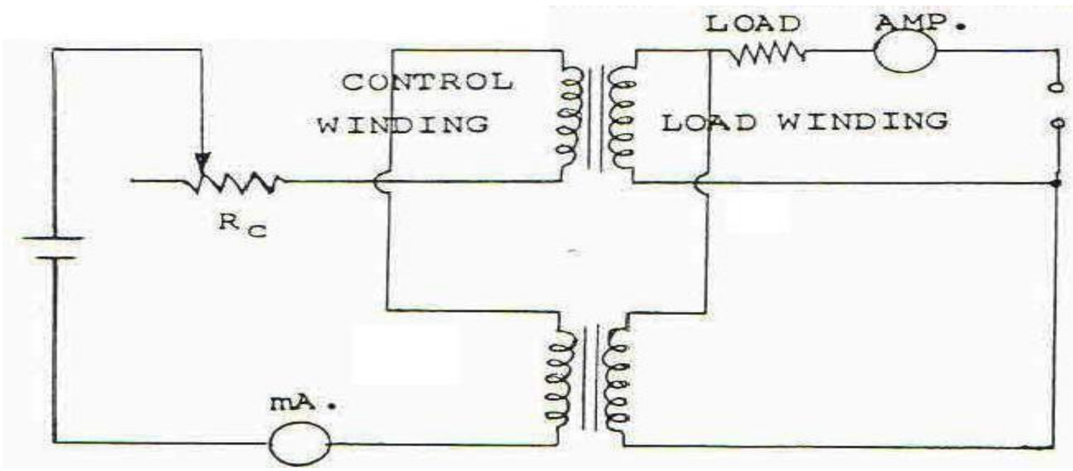
Complete circuit diagram for conducting this experiment is built in the unit itself. Following procedure has to be followed for conducting this experiment

1. Keep the slide switch in position D which will be indicated after unit is switched ON.
2. Keep control current setting knob at its extreme left position which ensures zero control at starting.
3. With the help of plug-in links connect the following terminals on the front panel.
    a) Connect AC to A1
    b) Connect B1 to A2
    c) Connect B2 to L
4. Connect 100W lamp in the holder provided for this purpose and switch on the unit.
5. Now gradually increase the control current by rotating control current setting knob clockwise in steps and note down control and

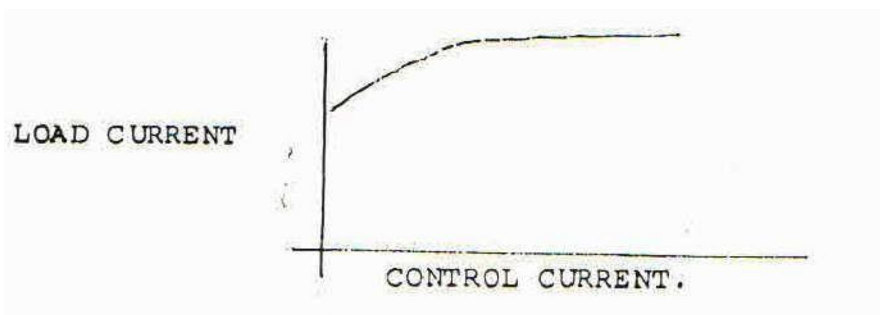
corresponding load current.

6. Plot the graph of load current versus control current.

Parallel connected magnetic amplifier:



Model Graph:



Tabular column:

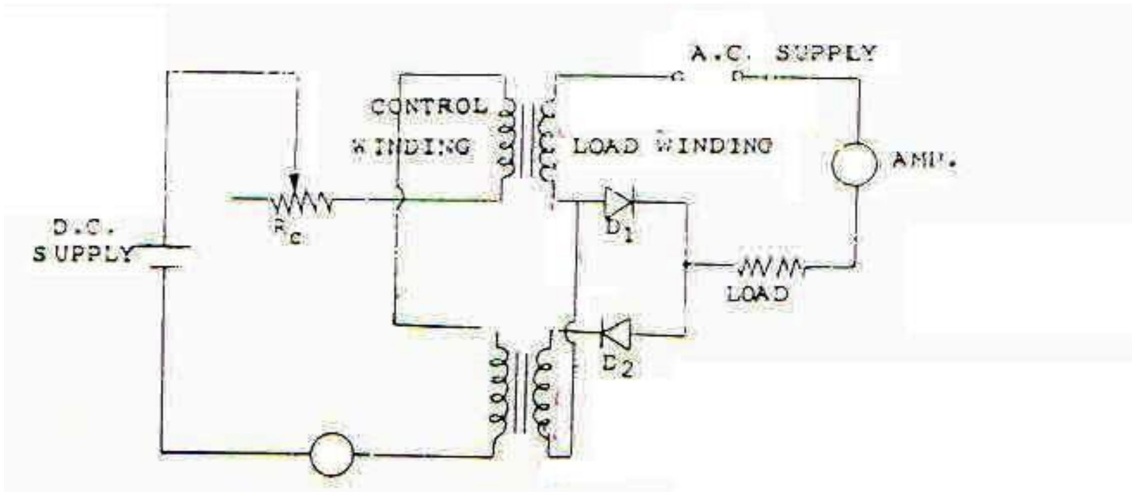
S.NO	Control Current	Load Current

Parallel connected magnetic amplifier:

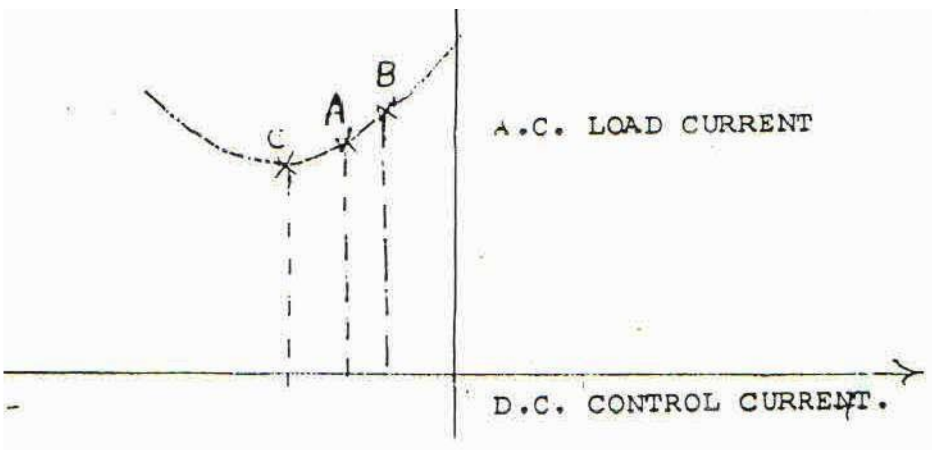
Complete circuit diagram for conducting this experiment is built in the unit itself. Following procedure has to be followed for conducting this experiment

1. Keep the slide switch in position D which will be indicated after unit is switched ON.
2. Keep control current setting knob at its extreme left position which ensures zero control current at starting.
3. With the help of plug-in links connect the following terminals on the front panel.
   a) Connect AC to A1
   b) Connect A1 to A2
   c) Connect B2 to L
   d) Connect B1 to B2
4. Connect 100W lamp in the holder provided for this purpose and switch on the unit.
5. Now gradually increase the control current by rotating control current setting knob clockwise in steps and note down control and corresponding load current.
6. Plot the graph of load current versus control current.

Self-Saturated Magnetic amplifier:



Model Graph



Tabular column:

S.NO	Control Current	Load Current

Self-Saturated Magnetic amplifier:

Complete circuit diagram for conducting this experiment is built in the unit itself. Following procedure has to be followed for conducting this experiment

1.Keep the slide switch in position ‘E ‘which will be indicated after unit is switched ON.

2.Keep control current setting knob at its extreme left position which ensures zero control current at starting.

3.With the help of plug-in links connect the following terminals on the front panel.

a) Connect AC to C1

b) Connect A3 to B3

c) Connect B3 to L

4.Connect 100W lamp in the holder provided for this purpose and switch on the unit.

5.Now gradually increase the control current by rotating control current setting knob clockwise in steps and note down control and corresponding load current.

6.Plot the graph of load current versus control current.

Result:

Viva Questions:

1. Describe the basic operation of magnetic amplifier.
2. State the common usage of magnetic amplifier.
3. Describe the purpose of various components of magnetic amplifier.
4. Describe various methods of changing inductance.
5. Describe saturable core reactor.
6. Describe in detail the circuitry of magnetic amplifier.
7. Give the purpose of saturable reactor in magnetic amplifier.
8. Explain working of magnetic amplifier in saturable reactor mode.
9. Explain working of magnetic amplifier in self-saturable reactor mode.
10. Compare the input and output characteristics in both the modes.

Experiment - 17

DETERMINATION OF STEADYSTATE ERROR USING MATLAB

Aim: To obtain the steady state error for the given input.

Apparatus:

S. No.	Apparatus	Range	Quantity
1	Personal Computer with MATLAB software	---	01

Procedure:

1. Obtain the steady state error for the given input.
2. Verify the result with MATLAB.

Program:

```
Clear ();

numg = [1 0]

deng = [1 2]

numg = conv (conv [1 0], [1 2])

G = tf (numg, deng)

Kp = dcgain (G);

ess=5\1+kp

numsg =conv ([1 0], numg)

densg = deng

sg = tf (numsg, densg)

kv = dcgain (sg)
```

```
ess=5\kv
nums2g= conv ([1 0], numsg)

dens2g = densg

s2g = tf (nums2g, dens2g)

kp = dcgain (s2g)
ess=3\ka
```

Theoretical calculations:

Result:

Viva Questions:

1. What is order of a system?
2. What is steady state error?
3. For reducing steady state error which type of controller is used?
4. Which type of controller anticipates error?
5. What is reset rate?
6. What are the standard test signals?
7. What are the various types of error constants?
8. For a step input and type 1 system the steady state error is?
9. For a ramp input and type 0 system the steady state error is?
10. For a step input and type 0 system the steady state error is?