CONTROL SYSTEMS AND SIMULATION LAB

LAB MANUAL

Subject Code	:	A60290
Regulations	:	R15– JNTUH
Class	:	III Year II Semester (EEE)

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad – 500 043

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Department of Electrical and Electronics Engineering

	Program Outcomes
PO1	**Engineering Knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	**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.
PO3	**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.
PO4	**Conduct Investigations of Complex Problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	**Modern Tool Usage**: Create, select, and apply appropriate techniques, APPRATUS, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	**The Engineer and Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	**Environment and Sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	**Individual and Team Work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	**Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	**Project Management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	**Life - Long Learning**: Recognize the need for, and have the preparation and ability to engage in independent and life - long learning in the broadest context of technological change.
	Program Specific Outcomes
PSO1	**Professional Skills:** Able to utilize the knowledge of high voltage engineering in collaboration with power systems in innovative, dynamic and challenging environment, for the research based team work.
PSO2	**Problem - Solving Skills:** Can explore the scientific theories, ideas, methodologies and the new cutting edge technologies in renewable energy engineering, and use this erudition in their professional development and gain sufficient competence to solve the current and future energy problems universally.
PSO3	**Successful Career and Entrepreneurship:** The understanding of technologies like PLC, PMC, process controllers, transducers and HMI one can analyze, design electrical and electronics principles to install, test , maintain power system and applications.

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ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp. No.	Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	Time response of Second Order systems	PO2, PO4	PSO1, PSO2
2	Characteristics of Synchros	PO1, PO2, PO3	PSO2
3	Programmable Logic Controller - Study and verification of truth tables of logic gates, simple Boolean expressions and application of speed control of motor	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2
4	Effect of feedback on DC servo motor	PO3, PO6, PO9	PSO1, PSO2
5	Transfer function of DC motor	PO2, PO4	PSO2
6	Effect of P, PD, PI, PID Controller on second order systems.	PO1, PO3, PO4	PSO1, PSO2
7	Lag and Lead compensation - Magnitude and phase plot	PO1, PO2, PO3, PO4	PSO1, PSO2
8	Transfer function of DC generator	PO1, PO3	PSO1
9	Temperature controller using PID	PO1, PO3, PO4	PSO1, PSO3
10	Characteristics of magnetic amplifiers	PO1, PO3, PO4	PSO1
11	Characteristics of AC Servo motor.	PO1, PO3	PSO1, PSO2
12	PSICE simulation of Op - Amp based Integrator and Differentiator circuits	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2
13	Stability analysis (Bode, Root Locus, Nyquist) of Linear Time Invariant system using MATLAB.	PO1, PO3, PO4	PSO1, PSO3
14	State space model for classical transfer function using MATLAB	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2

CONTROL SYSTEMS AND SIMULATION LABORATORY

OBJECTIVE

The objective of the lab is to design a system and calculate the transfer function, analyzing the stability of the system (both open and closed loop, with positive and negative feedback) with time domain approach and frequency response analysis, using MATLAB and also developing the system which is dynamic in nature with state space analysis approach.

OUTCOMES:

Upon the completion of Control Systems practical course, the student will be able to attain the following:

1. Recognize the symbols for the different parts of a block diagram: functional blocks, summing blocks and branch points. Simplify a block diagram using block diagram algebra to obtain a transfer function between any two points in the diagram.
2. Model a mechanical (masses, dampers and springs) and electrical system (inductors, resistors, capacitors) in the form of a transfer function.
3. Determine the impulse, step, and ramp response of a system, given a transfer function model.
4. Perform Routh's stability criterion and root locus of a system to determine stability. For systems with unknown values, determine the range of values for which the system will be stable and explain how adding a pole or a zero affects the stability.
5. Analyze feedback control systems in the time and frequency domain to use state space concepts to describe systems.
6. Recognize the "type" of a system (based on the number of free integrators) and discuss the expected error characteristics as related to step, ramp, and acceleration inputs.
7. Interpret design criteria as related to the closed loop pole location on the complex plane.
8. Draw the Frequency response plots like Bode, Nyquist and Polar plots (magnitude and phase) for a given transfer function.
9. Design feedback compensators to achieve a set of desired closed loop system characteristics and design a compensator in the frequency domain to meet specific design requirements using a lead compensator, lag compensator, or lead-lag compensator.
10. Develop a PLC program for an automatic control system of a medium degree of complexity and select the right hardware for a given application.
11. Consider such aspects of the automation system as network communication, human machine interface, safety and protection against interference.

EXPERIMENT - 1

TIME RESPONSE OF SECOND ORDER SYSTEM

1.1   AIM:

To study the time response of a second order series RLC System .

1.2   APPRATUS:

S. No.	Equipments
1	Second order system study unit.
2	Cathode Ray Oscilloscope
3	Multimeter
4	Connecting Leads

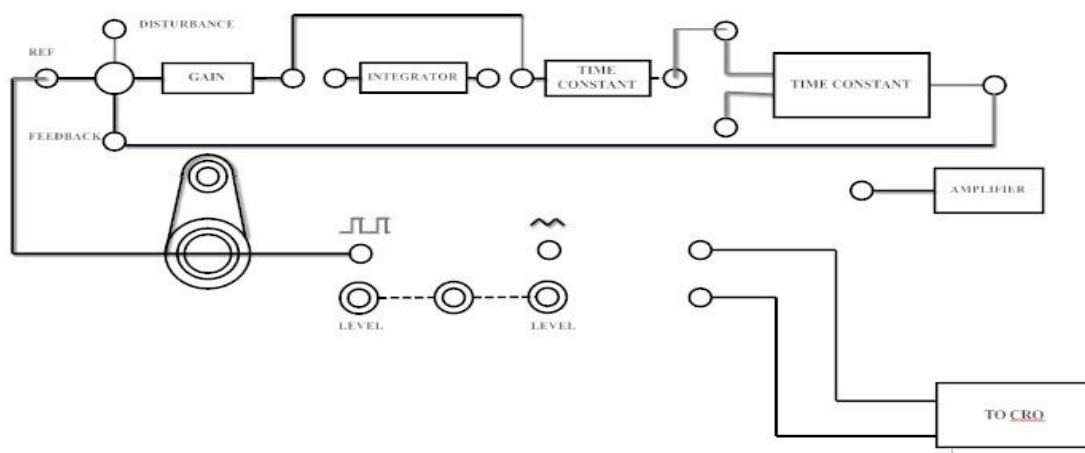**1.3   BLOCK DIAGRAM:**

Fig – 1.1 Time Response of Second order System
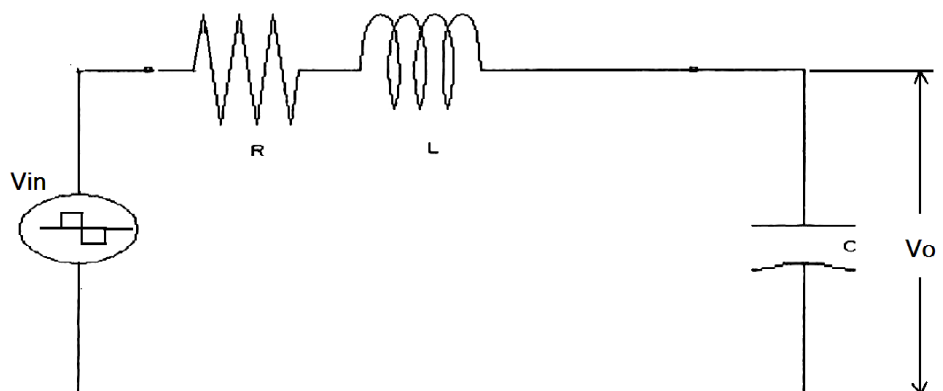
1.4   CIRCUIT DIAGRAM:

Fig – 1.2 Series RLC second order Equilent

1.5   PROCEDURE:

1. Connections are given as per the block diagram.
2. Adjust the input square wave such that the magnitude of the wave is 1V (p-p).
   (Check the square wave in CRO by placing CRO in Channel 1 mode).
3. Observe the time response on the CRO (Channel 2) by varying the resistance by changing the knob provided on the front panel.
4. Take the corresponding values of Peak Time (T_P), Peak Over Shoot (μ_P) (i.e. Max Peak Value -1) using trace papers.
5. Calculate Damping Ratio (δ), Undamped Natural Frequency (ω_n) from the following formulae

   $$\delta = \ln(\mu_P) / \sqrt{(\prod{}^2 + \ln(\mu_P)^2)}$$
   $$\omega_n = \prod / T_P \sqrt{(1- \delta^2)}$$

6. Calculate the parameters L & C of RLC system using the following formulae

   $$\delta = (R/2) \sqrt{(C/L)}$$
   $$\omega_n = 1 / \sqrt{(LC)}$$

7. Now calculate Settling Time (T_S), and Damped Frequency (ω_d) using the following formulae

   $$T_S = 4 / (\delta \omega_n) \qquad \text{------ (2\% Settling Time)}$$
   $$\omega_d = \omega_n \sqrt{(1- \delta^2)}$$

1.6   TABULAR COLUMN:

S. No.	R	L	C	Maximum Peak (μ_P)	Peak Time (T_P)	Damping Ratio (δ)	Undamped natural frequency (ω_n)	Damped Frequency (ω_d)	Settling Time (T_S)
1									
2									
3									
4									
5									

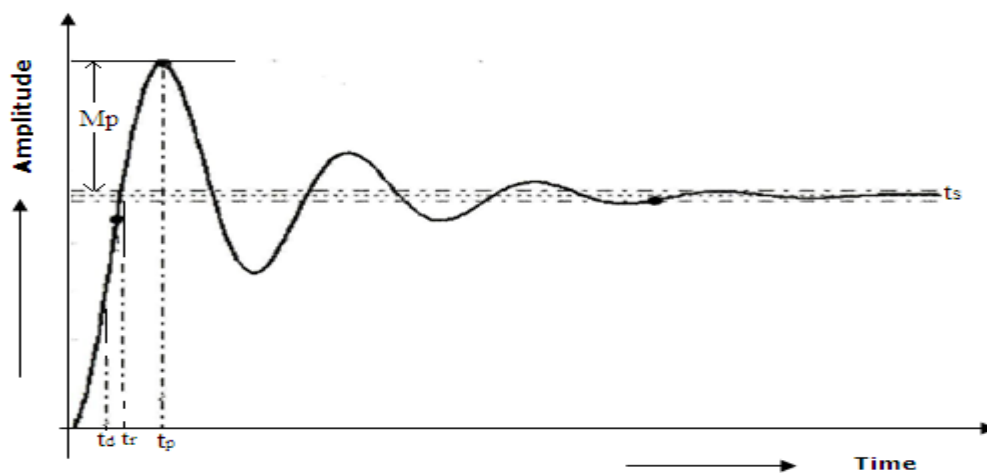| S. No.	R	L	C	Maximum Peak (μ_P)	Peak Time (T_P)	Damping Ratio (δ)	Undamped natural frequency (ω_n)	Damped Frequency (ω_d)	Settling Time (T_S)
1									
2									
3									
4									
5									

1.7   MODEL GRAPH:

Fig - 1.3 Time Specifications of Second order System

1.8   RESULT:

1.9   PRE LAB VIVA QUESTIONS:

1. What are the Open loop and closed loop control systems?
2. Give the advantages of closed loop control systems.
3. What do you mean by feedback and what are the types of feedback?
4. What is a system?

5. Define rise time, peak time, settling time, peak overshoot, damping ratio, steady state error.

1.10   LAB ASSIGNMENTS:

1. To study the time response of a second order series RLC System to determine the parameters of L & C from ramp input
2. To study the time response of a second order series RLC System to determine the parameters of L & C from sinusoidal input

1.11   POST LAB VIVA QUESTIONS:

1. In this experiment what type of feedback is used? Why?
2. Give a practical example for a first order system.
3. Give a practical example for a second order system.

EXPERIMENT 2
CHARACTERISTICS OF SYNCHROS

2.1   AIM

To study
 i) Synchro Transmitter characteristics.
ii) Synchro Transmitter – Receiver Characteristics.

2.2   APPARATUS:

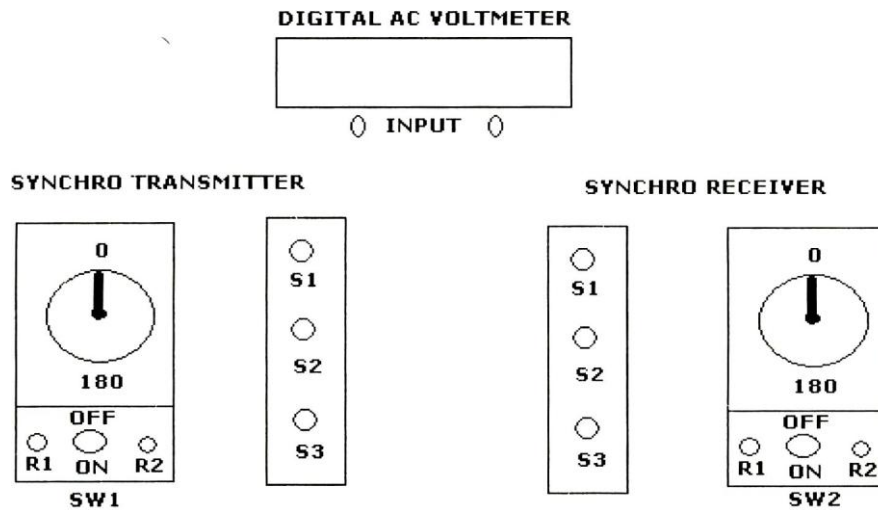| S. No.	Equipments
1	Synchro Transmitter – Receiver Kit
2	Patch chords

2.3   BLOCK DIAGRAM:

Fig – 2.1 Synchro-Transmitter Pair
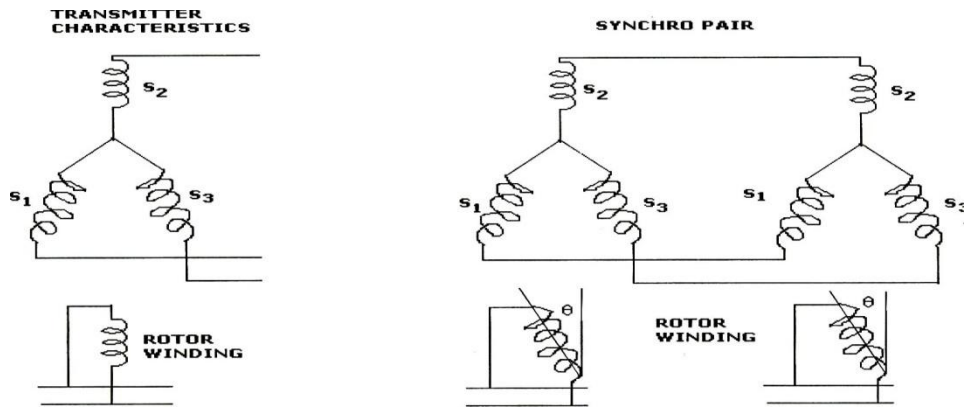
2.4 CIRCUIT DIAGRAM:

Fig – 2.2 Circuit Diagram of Synchro-Transmitter Receiver

2.5 PROCEDURE:

2.5.1 Transmitter Characteristics

1. Connect the mains supply to the system with the help of a cable provided. Do not connect any patch cords to terminals marked S_1, S_2 and S_3, R_1 and R_2.

2. Switch ON mains of the unit.

3. Initially switch ON Sw1, starting from1 ZERO position, note down the voltage between stator winding terminals (i.e. V_{S1S2}, V_{S2S3} and V_{S3S1}) in a sequential manner.

4. Measure these voltages by using AC voltmeter provided in the trainer and note down the readings.

5. Plot a graph of angular position of rotor voltages for all three phases.

2.5.2 Transmitter - Receiver Characteristics

1. Connect the mains supply cable.

2. Connect S_1, S_2 and S_3 terminals of synchro transmitter to S_1, S_2 and S_3 of synchro receiver by patch cords provided respectively.

3. Switch ON mains supply and also S_1 and S_2 on the kit.

4. Move the pointer i.e. rotor position of synchro transmitter T_x in steps of 30˚and observe the new rotor position in synchro receiver.

5. Observe that whenever T_x rotor is rotated, the T_r rotor follows if for both the directions of rotations and their positions are in good agreement.

6. Note down the input angular position and output angular position and plot the graph.

2.6 TABULAR COLUMN:

2.6.1 Transmitter Characteristics

S. No.	Rotor Position	V_{S1S2}	V_{S2S3}	V_{S3S1}
1				
2				
3				

2.6.2 Transmitter - Receiver Characteristics

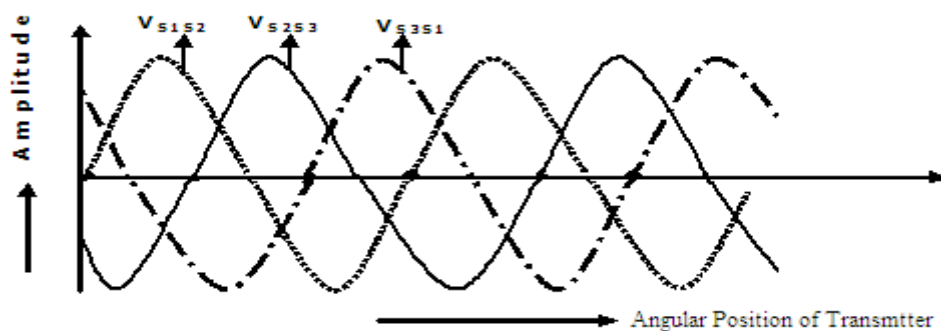| S. No.	Angular Position of Transmitter	Angular Position of Receiver
1		
2		
3		

2.7 MODEL GRAPH:

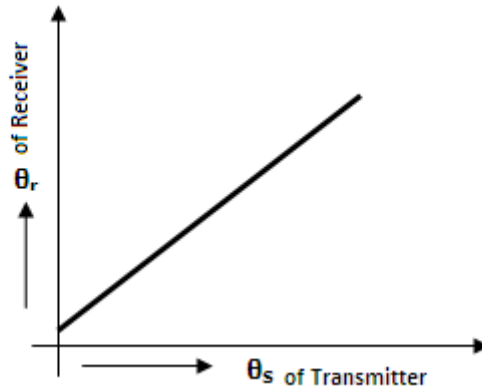**Fig – 2.3 Synchro Transmitter Characteristics**

Fig – 2.4 Synchro Transmitters - Receiver Characteristics

2.8 RESULT:

2.9 PRE LAB VIVA QUESTIONS:

1. Define the term "synchro".
2. Name the two general classifications of Synchros.
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. Mention the application of Synchros.

2.10 LAB ASSIGNMENTS:

1. To draw the characteristics of receiver.
2. How it will works 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.

2.11 POST LAB VIVA 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 Synchros.
4. State the purposes and functions of multispeed synchro systems.
5. List the basic components that compose a torque synchro system.

EXPERIMENT - 3

STUDY OF PROGRAMMABLE LOGIC CONTROLLER

3.1   AIM:

Study and develop the ladder program using PLC for the following modules
      (i) Logic gate simulation
      (ii) Boolean algebra

3.2   APPARATUS:

S. No	Name of the equipment	Quantity
1	PLC Trainer Kit	1
2	Logic gate simulation module	1

3	Boolean algebra panel	1
4	DC motor Control using relays	1
5	Personnel Computer	1
6	Connecting wires	1

3.3 CIRCUIT DIAGRAM:
   BLOCK DIAGRAM OF PLC TRAINER
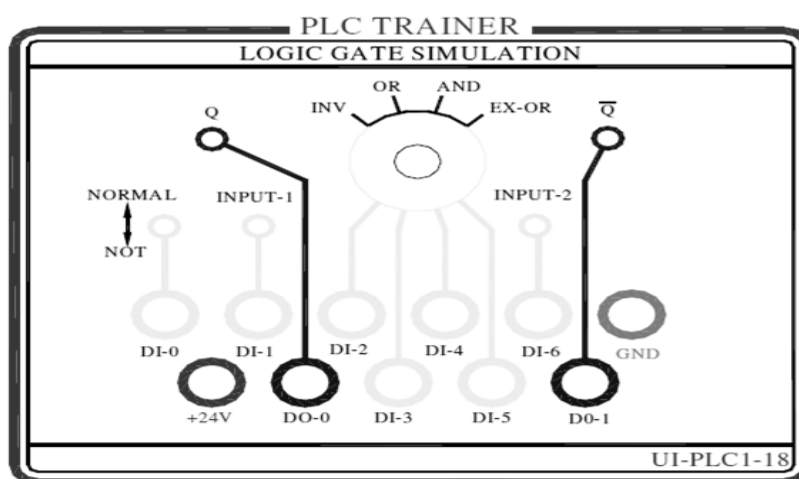
Fig – 3.1 Logic Gate Modules

Truth table INV gate

Q	$\bar{Q}$
0	1
1	0

Truth table for AND gate:

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

Truth table for OR gate:

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

Truth table for EX-NOR gate:

X	Y	$X \circledR Y = \bar{X}\,\bar{Y} + XY$
0	0	1
0	1	0
1	0	0
1	1	1

```
0    X0
     ─┤├──────────────────────────────────────────────────(M0  )

2    X0
     ─┤/├─────────────────────────────────────────────────(M1  )

4    M0    X2
     ─┤├───┤├─────────────────────────────────────────────(M2  )

7    M0    X3
     ─┤├───┤├─────────────────────────────────────────────(M3  )

10   M0    X4
     ─┤├───┤├─────────────────────────────────────────────(M4  )

13   M0    X5
     ─┤├───┤├─────────────────────────────────────────────(M5  )

16   M1    X2
     ─┤├───┤├─────────────────────────────────────────────(M6  )

19   M1    X3
     ─┤├───┤├─────────────────────────────────────────────(M7  )

22   M1    X4
     ─┤├───┤├─────────────────────────────────────────────(M8  )

25   M1    X5
     ─┤├───┤├─────────────────────────────────────────────(M9  )
```

28 M2 X1   (Y0   )

    M3 X1
        X6

    M4 X1 X6

    M5 X1 X6
        X1 X6

    M6 X1

    M8 X1
        X6

    M7 X1 X6

    M9 X1 X6
        X1 X6

68 Y0   (Y1   )

70   END

3791

Fig – 3.2 Logic Gate Simulation

PLC TRAINER

BOOLEAN ALGEBRA (DEMORGAN'S THEOREM)

1st LAW   2nd LAW

$\overline{A+\overline{B}+C}$ $\overline{A}.B.\overline{C}$ $\overline{A}.\overline{B}.C$ $\overline{\overline{A}+B+C}$

A   B   C   A   B   C

DI-0   DI-1   DI-2   DI-3   DI-4   DI-5

+24V   DO-0   DO-1   DO-2   D0-3   GND

UI-PLC1-24
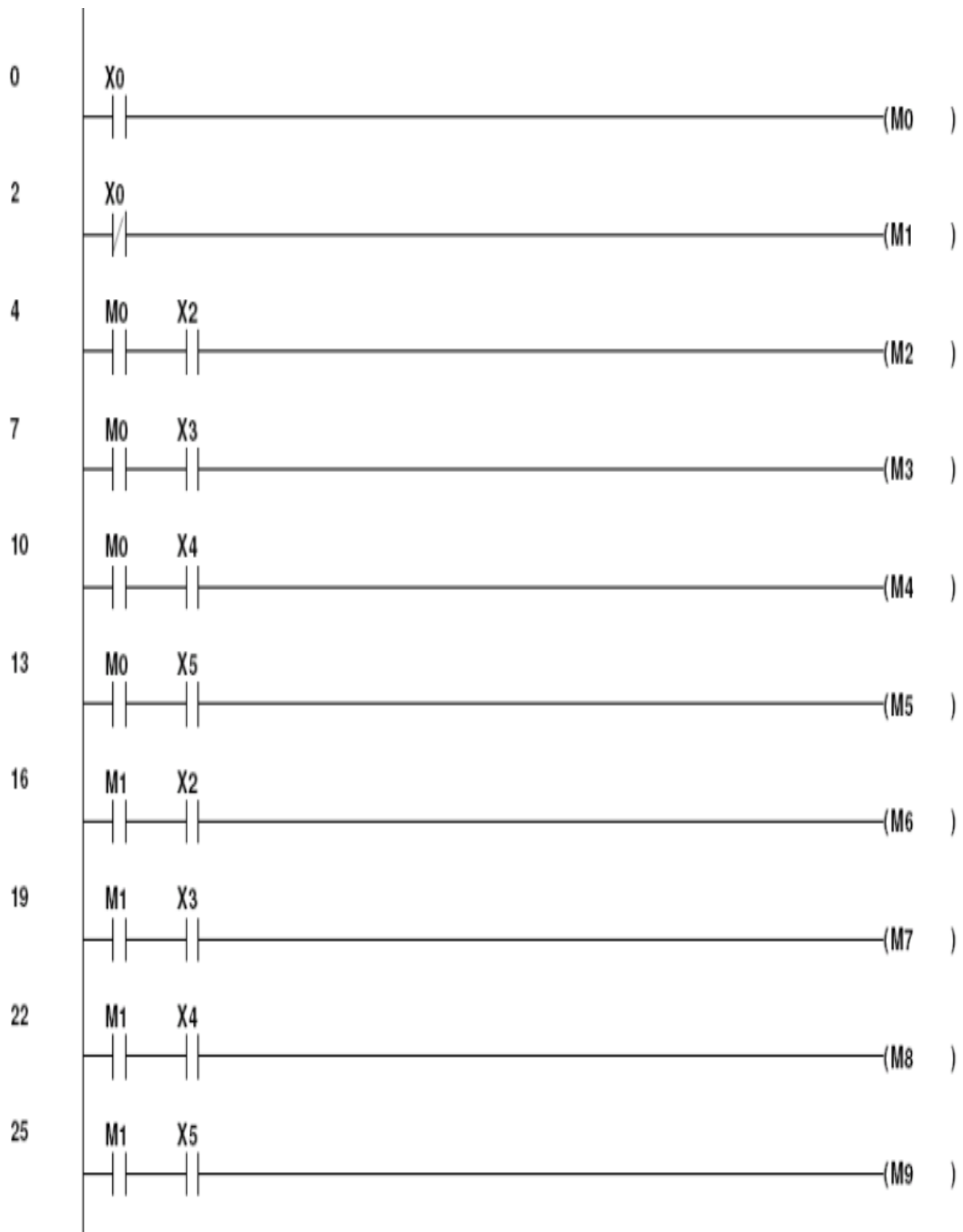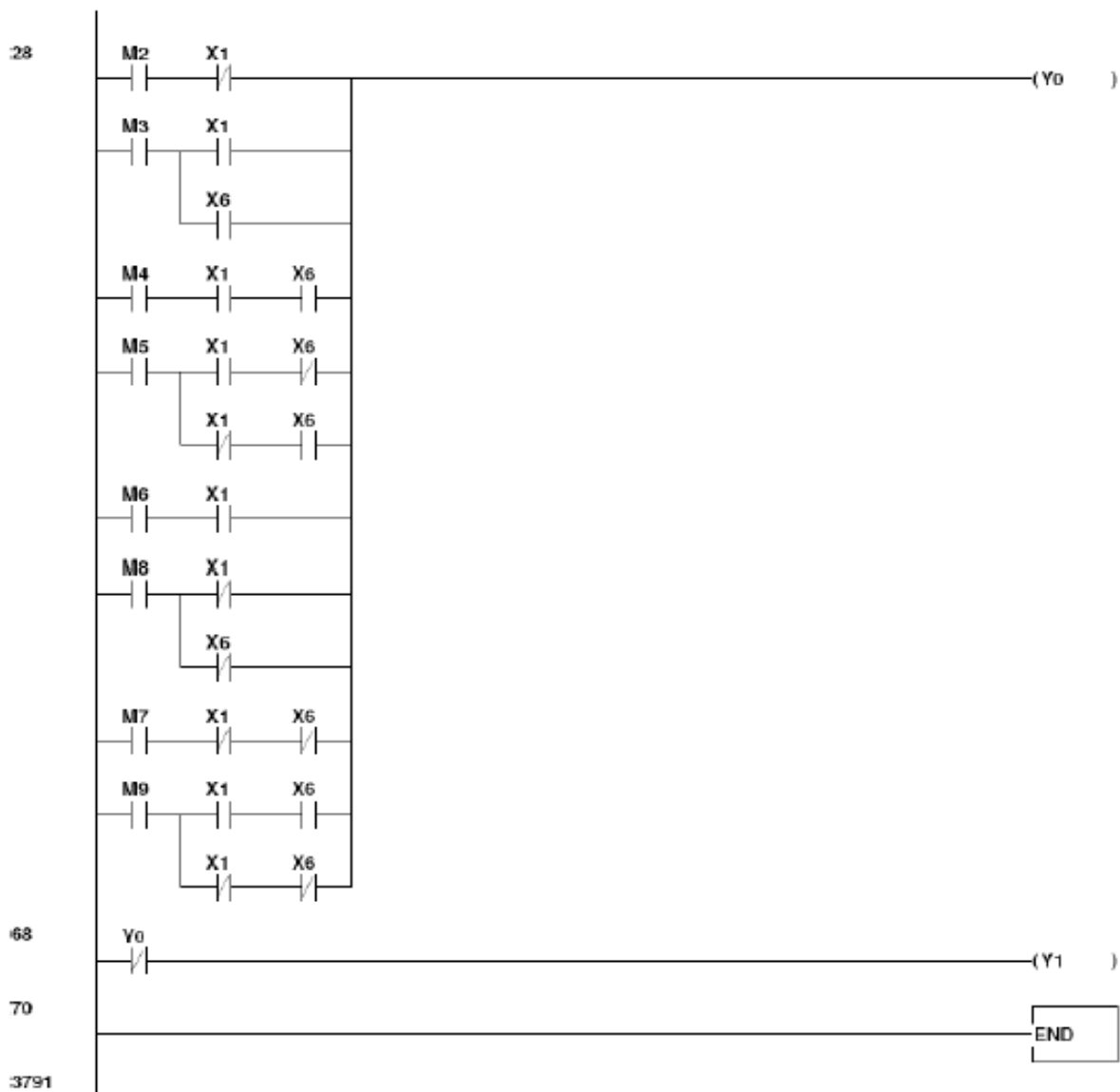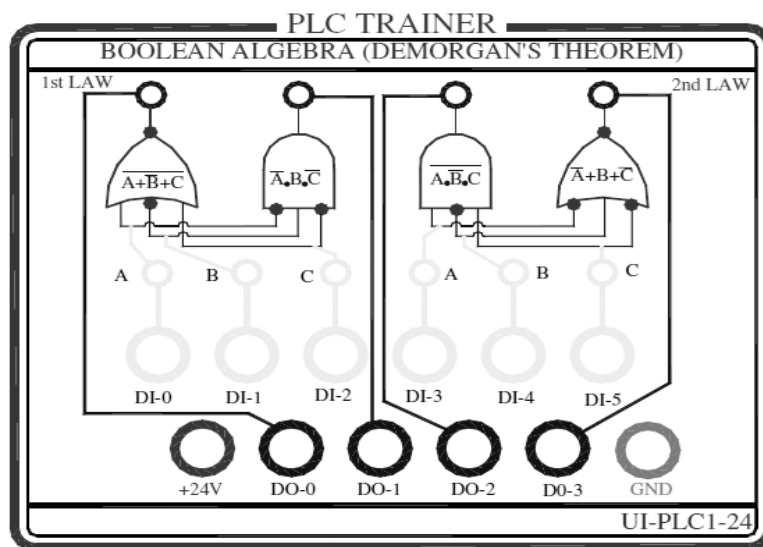
Fig – 3.3 Boolean Algebra Module

16 | P a g e

Demorgan's Ist Law

A	B	C	$\overline{(\bar{A} + B + \bar{C})}$	$A.\bar{B}.C$
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

Dorgan's IInd Law

A	B	C	$\overline{(\bar{A}.B.\bar{C})}$	$A+\bar{B}+C$
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
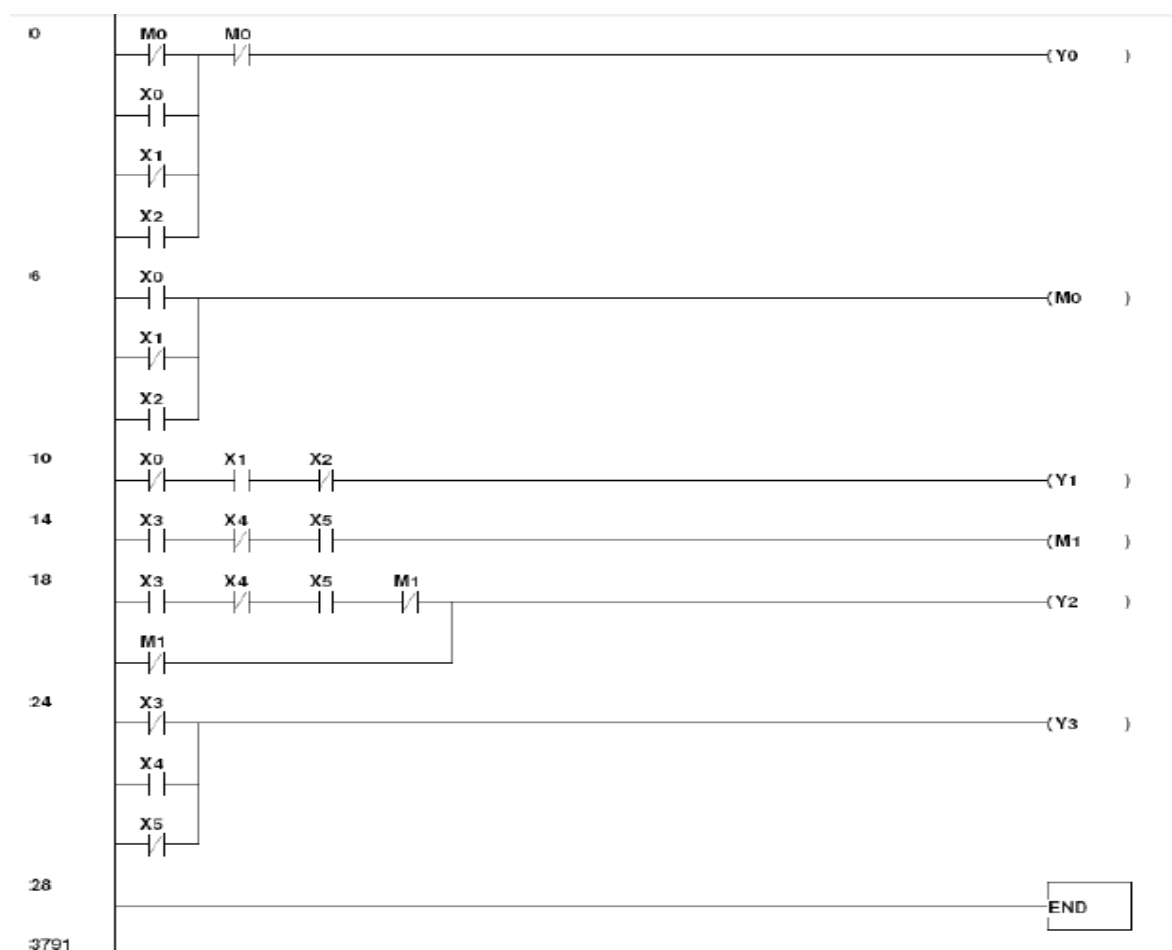
Fig – 3.4 Boolean algebra simulation

3.4 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 mode window, 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 the command mode and the SFC diagram through compiling)

10 The command mode (after the command is edited, convert it to the ladder and the SFC diagram through 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), View (V).

3.5 RESULT:

3.6 PRE LAB VIVA QUESTIONS

1. What is PLC?

2. Write down two advantages of PLC.

3. Differentiate between normally ON and normally OFF switch.

4. Distinguish between Timers and counters.

5. What is Latches?

3.7   POST LAB VIVA QUESTIONS:

1. What is the function of MCR (Master Control Relay)?
2. Where in the PLC memory is is each timer storing its data?
3. How does the operation of an OFF -delay timer differ from that of an on-delay timer?
4. How does each type of timer get reset back to zero?
5. How long of a time period can a timer time? What is the maximum "count" value for a timer?

EFFECT OF FEEDBACK ON DC SERVO MOTOR

4.1   AIM:

To study the effect of feedback on DC servo motor.

4.2   APPARATUS:

DC servo motor kit and DVM.

4.3   CIRCUIT DIAGRAM:
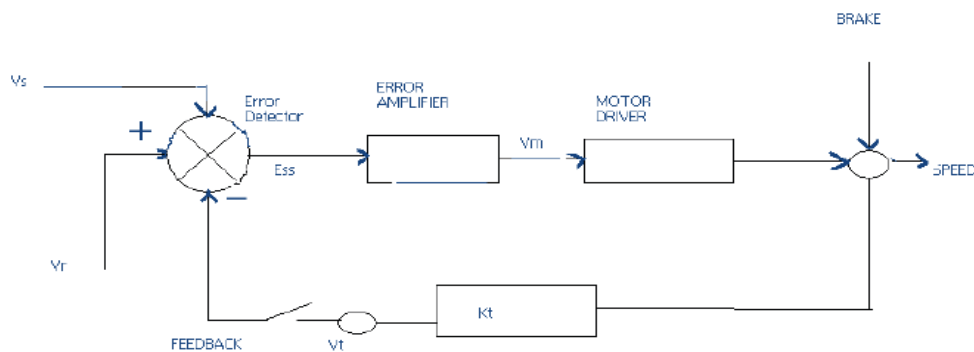
Fig – 4.1 Block diagram of Effect of Feedback on DC servo motor

4.4   PROCEDURE:

OPEN LOOP PERFORMANCE:

1. Connect the main unit to the supply. Keep the gain Switch off. Set Vr = 0.7 or 0.8. Connect DVM with feedback signal socket Vt.

2. Note the Speed N rpm from display and tacho output Vt in volts from DVM. Record N rpm and Vt

3. volts for successive gain 4-10 in observation table.

4. Calculate Vm = Vr * Ka. Where Ka is the gain set from control 3 – 10.

5. Vr = 0.7 V.

6. Vm at gain 3 = 0.7 * 3= 2.1 V.

7. Plot N vs Vt and N Vs Vm graph.

CLOSED LOOP PERFORMANCE:-

1. In this case the gain switch is kept in on position thus feedback voltage gets subtracted from reference voltage.

2. This is observed by decreased motor speed. Record the result between gain factor Ka and speed N. draw the graph between techo voltage Vt and speed N.

4.5   PRECAUTIONS:

1. Apply the voltage slowly to start the motor
2. Take the reading properly.
3. Do not apply breaks for long time as the coil may get heated up.
4. Switch OFF the main power when not in use.

4.6   OBSERVATION TABLE:

S.NO	GAIN (Ka)	Vt (volts)	N(rpm)	Vm=Vr×Ka

4.7   MODAL GRAPHS:
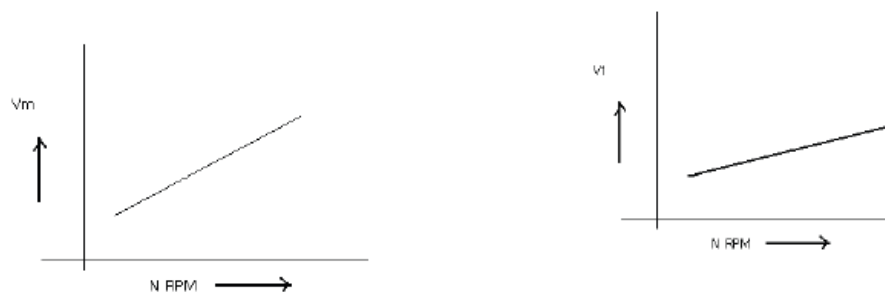
Fig – 4.2 Model Graphs for Open Loop
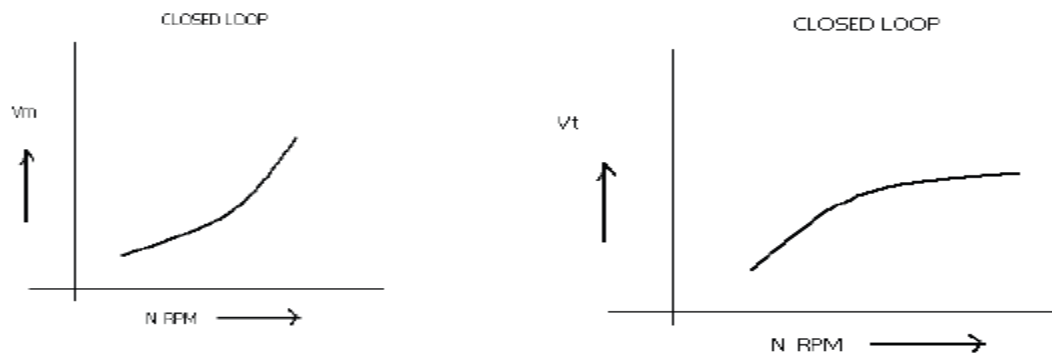
Fig – 4.3 Model Graphs for Closed Loop

4.8   RESULT:

4.9   PRE LAB VIVA QUESTIONS:

1. What are the uses of DC servo motor?
2. What are the types of DC servo motors?
3. How the speed of DC servo motor is controlled?
4. What is the relation between torque and speed of DC servo motor?
5. Why the speed torque characteristics of DC servo motor has large Negative Slope?

4.10   POST LAB VIVA QUESTIONS:

1. What is the effect of negative slope?
2. In which wattage the DC servo motors are available?
3. What are the special features of DC SERVO MOTORS?
4. How the direction of rotation of DC servo motor can be changed?
5. What is transfer function of DC SERVO MOTOR?

<h1 style="text-align:center">EXPERIMENT - 5</h1>

<h2 style="text-align:center">TRANSFER FUNCTION OF DC MOTOR</h2>

5.1   AIM:

To determine the transfer function of armature controlled dc motor by performing load test on dc motor and speed control by armature voltage control to plot characteristics between back e.m.f. and angular velocity and armature current Vs torque.

5.2   APPARATUS:

1.   Armature controlled DC motor
2.   Patch cards
3.   Tachometer

5.3   FRONT PANEL DETAILS:

AC, IN :   Terminals to connect 230V AC mains supply.

MCB :   2 pole 16A MCB to turn ON / OFF AC supply to the controller.

Armature VA : Potentiometer to vary the armature voltage from 0 – 200V.

ON / OFF : ON / OFF switch for arm voltage with self start.

0 – 200V DC : 0 – 200V variable DC supply for armature

0 – 230V AC " 0 – 230V variable AC supply to final inductance eof   field coil with NC lamp
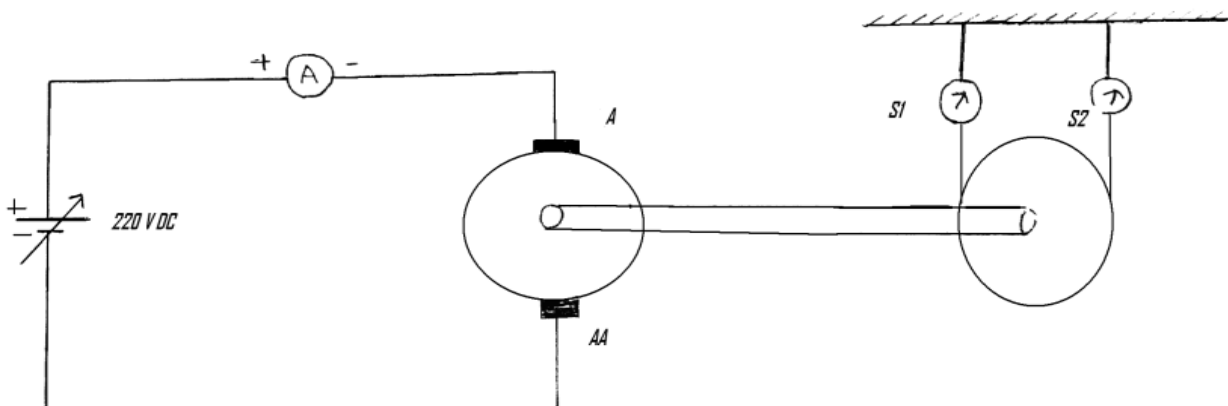
(AC Voltage Controller)

5.4   CIRCUIT DIAGRAM:

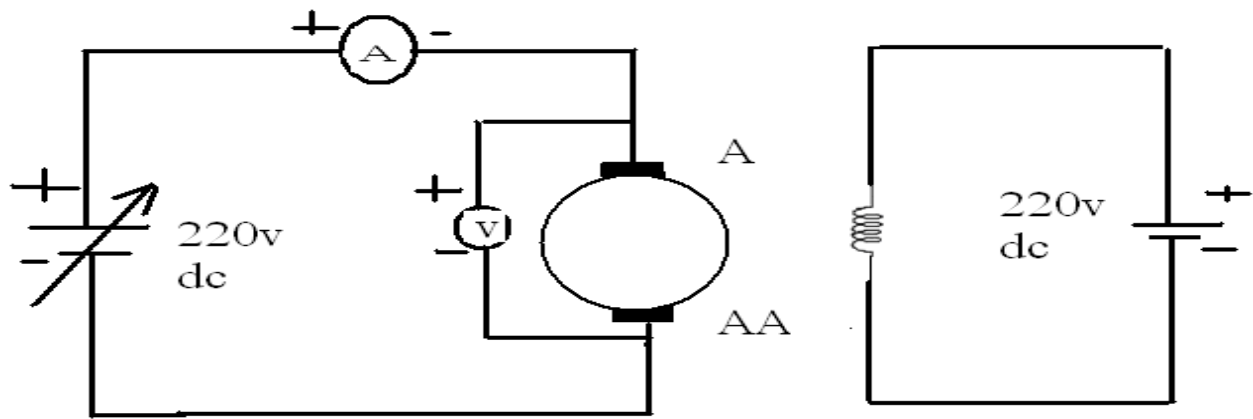
Fig – 5.1 Load Test on DC Motor

Fig – 5.2 Armature voltage control

5.5   THEORY:

The speed of DC motor is directly proportional to armature voltage and inversely proportional to flux in field winding. In armature controlled DC motor the desired speed is obtained by varying the armature voltage.

Let Ra = Armature resistance, Ohms

La = Armature Inductance , Henris

Ia = Armature current, Amps

Va = Armature voltage, Volts

Eb = Back emf,

Kt = Torque constant, N-m/A

T = Toque developed by motor, N=m

q = Angular displacmenet of shaft, rad

J = Moment of inertia of motor and load, Kg-m2/rad.

B = Frictional coefficient of motor and load, N-m/rad-sec.

Kb = Back emf constnat, V/(rad-sec)

By applying KVL to the equivallent circuit of armature, we can write,

IaRa + La (dIa/dt) + Eb = Va

Torque of DC motor proportional to the product of flux & current. Since flux is constant.

T α Ia

T = Kt Ia

The differential equation governing the mechanical system of motor is given by

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

The back emf of DC machine is proportional to speed of shaft.

Eb α dθ/dt; Back emf, Eb = Kb(dθ/dt)

The Laplace transform of various time domain signals involved in this system are

L[Va] = Va(s); L[Eb]=Eb(s); L(T) = T(s); L[Ia] = Ia(s); L[θ]=[s]

on taking Laplace transform of the system differential

$$I_a(s) + L_a.s.I_a(s) + E_b(s) = V_a(s) \quad - \quad (1)$$

$$T(s) = K_t I_a(s) \quad - \quad (2)$$

$$Js^2\theta(s) + Bs\theta(s) = T(s) \quad - \quad (3)$$

$$E_b(s) = K_b s\theta(s) \quad - \quad (4)$$

on equating equations (2) & (3)

$$K_t I_a(s) = (Js^2 + Bs)\theta(s)$$

$$I_a(s) = \frac{(Js^2 + Bs)}{K_t}\theta(s)$$

equation (1) can be written as

$$(Ra + SLa)\ Ia(s) + Eb(s) = Va(s)$$

substitute Eb(s) & Ia(s) in above equation, we get

$$(R_a + SL_a)\frac{(JS^2 + BS)}{K_t}\theta(S) + K_b S\theta(S) = V_a(S)$$

$$\left[\frac{(R_a + SL_a)(JS^2 + BS) + K_b K_t S}{K_t}\right] = V_a(S)$$

the required transfer functions is q(s) / Va(s)

$$\frac{\theta(s)}{V_a(s)} = \frac{K_t}{(R_a + sL_a)(Js^2 + Bs) + K_b K_t s}$$

$$= \frac{K_t}{(R_a(\frac{sL_a}{Ra} + 1)Bs\left[1 + \frac{Js^2}{Bs}\right] + K_b K_t s}$$

$$\frac{\theta(s)}{V_a(s)} = \frac{\frac{Kt}{R_a B}}{s[(1 + sTa)(1 + sTm) + K_b K_t / R_a B]}$$

where , La/Ra = Ta = Electrical Time constant

and J/B = Tm = mechanical time constant

The parameters which determine the transfer function are Kt, Kb, Ri, La, B, J and these parameters are found by conducting the following tests

Brake Test

This test is conducted to find torque constant Kt and Back emf constant KbIt is a direct method and consists of applying a brake to water cooled pulley mounted on the motorshaft. A belt is wound round the pulley and its two ends are attached to two spring balances S1 and S2. The tension of the belt can be adjusted with the help of the wheels. Obviously, the force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances.

> S1 and S2 spring balances in Kg.
>
> R is the radius of the brake drum in meters.
>
> N is the speed of the motor in rpm.
>
> Torque T = (S1 – S2) R x 9.81 N-m.
>
> The slope of plot between Eb Vs w gives Kb.
>
> The slope of plot between Torque Vs Ia gives Kt.

SPEED CONTROL BY ARMATURE VOLTAGE CONTROL:

This test is conducted for determines B. The motor is run on no load with a suitable excitation by connectivity it to a d.c. source. The only torque under no load condition at any constant speed is the friction. Torque By only. The plot between torque and speed gives the B.

5.6   PROCEDURE:

I)   LOAD TEST ON DC MOTOR

1. Circuit connections are made as per the circuit diagram.
2. Connect 220V fixed DC supply to the field of DC motor and brake drum belt should be lessened.
3. Start the motor by applying 0 - 220V variable DC supply from the controller till the motor rotates at rated speed.
4. Note down meter readings which indicates no load reading.
5. Apply load in steps up to rated current of the motor and note down corresponding I, N, F1 & F2 readings.
6. Switch off the armature DC supply using armature supply ON / OFF swich and then switch OFF the MCB.

II)   SPEED CONTROL BY ARMATURE VOLTAGE CONTROL:

1. Circuit connections are made as per the circuit diagram. „
2. Connect 220V fixed DC supply to the motor field. Keep the armature control pot at its Maximum 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.

5.7   PRECAUTIONS:

1. Connect the polarities correctly and vary the knobs slowly. Avoid loose connections.
2. Take the readings without parallax errors.

5.8   OBSERVATION TABLE:

1.   LOAD TEST:

S.No	Speed (r.p.m)	IA(A)	F1 (Kg)	F2 (Kg)	T = (F1 – F2)x6.5x9.81 N.M.
1					
2					
3					
4					
5					
6					

2. ARMATURE VOLTAGE CONTROL:

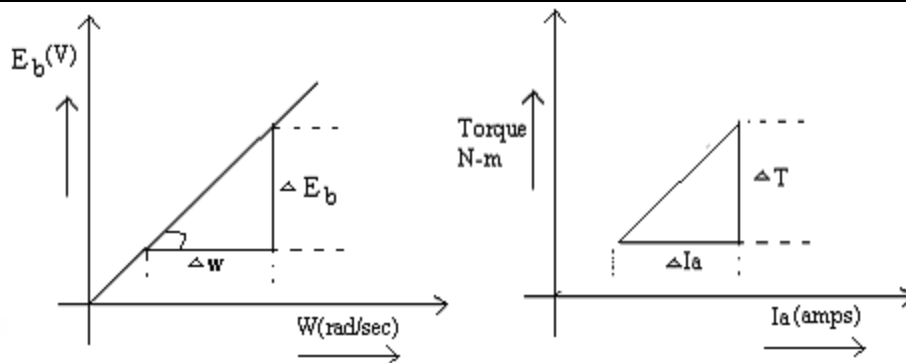| S.No	Speed (r.p.m)	Ia(A)	V (volts)	Eb = V-IaRa	W = 2 Π N/60
1					
2					
3					
4					
5					
6					

Fig – 5.3 Model Graphs

5.9 MODEL CALCULATIONS:

a). Motor Paramaters

DC motor – 0.5 HP / 220V / 1500 rpm

Arm resistance Ra = 1.8Ω

Arm Inductance La = 135mH

Field Resistance Rf = 650Ω

Field inductance Lf = 21 H

Moment of intertia J = 0.024 Kg/m2

Friction fo-efficient B = 0.8

TRANSFER FUNCTIONS:

1) $\dfrac{\omega(s)}{V_a(s)} = \dfrac{K_{m1}}{S\tau + 1}$

$K_{m1} = \dfrac{K_b}{R_a B + K_b K_t}$, $\tau = \dfrac{JR_a}{K_b K_t}$

2) $\dfrac{\omega(s)}{T_L(s)} = \dfrac{Km_2}{S\tau + 1}$; $km_2 = \dfrac{R_a}{R_a B + K_b K_t}$

3) $\dfrac{I_a(s)}{V_a(s)} = \dfrac{K_{m3}(s\tau_m + 1)}{s\tau + 1}$

$Km_3 = \dfrac{B}{R_a B + K_b K_t}$ $\tau_m = \dfrac{J}{B}$

5.10   RESULT:

5.11   PRE LAB VIVA QUESTIONS:

1. Why does the speed fall slightly when the D.C. shunt motor is loaded?
2. What will happen if the field current of the D.C. shunt motor gets interrupted?
3. What are the possible errors in the experiment?
4. How will you avoid the breaking arrangements getting heated?
5. Up to what capacity of motor can this type of test be done?
6. Why the motors are not operated to develop maximum power.
7. By applying which law, the direction of rotation of d.c. motor can be determined.

5.12   POST LAB VIVA QUESTIONS:

1. The transfer function dc motor with armature control is _____ system.
2. The transfer function dc motor with field control is _____ system.
3. What is order the of the transfer function of DC motor?
4. The motor time constant is given by; _____
5. In armature control _____ is maintained constant.
6. Armature control is suitable for speeds _____

EXPERIMENT - 6

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

6.1   AIM:

To study the steady state performance of an analog P, PI & PID controller using simulated system.

6.2   APPRATUS:

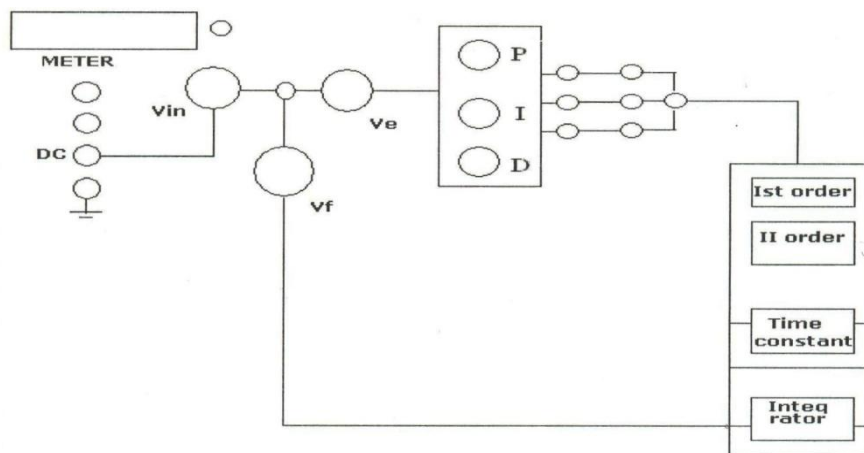| S. No.	Equipment
1	PID Controller
2	Patch Chords

6.3   BLOCK DIAGRAM:

Fig – 6.1 Block diagram Effect of P, PI, PID Controller on a second order system

6.4   PROCEDURE:

1. Make the connections as per the block diagram.
2. Set input DC amplitude to 1V.
3. Adjust I, D to Zero.
4. For various values of P, measure V_f, V_i and V_e using meter provided on the kit and note down the readings.

6.5   TABULAR COLUMN:

P Controller   (Variable Proportionate gain)

S. No.	P	V_i	V_f	V_e
1				
2				
3				
4				

PI Controller (Constant Proportionate gain and Variable Integral gain)

P =

S. No.	I	V_i	V_f	V_e
1				
2				
3				
4				

PID Controller (Constant Proportionate gain & Integral gain and Variable Differential gain)

P =   **I =**

S. No.	D	V_i	V_f	V_e
1				
2				
3				
4				

6.6   RESULT:

6.7   PRE LAB VIVA 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.

6.8   LAB ASSIGNMENTS:

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.

6.9   POST LAB VIVA 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. Whch controller is used for improving the steady state response of the system?
5. What is the purpose of PID controller?

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EXPERIMENT - 7

STUDY OF LEAD – LAG COMPENSATION NETWORKS

</div>

7.1   AIM:

To study of Lead - Lag compensation networks.

7.2   APPARATUS:

S.No.	Equipment
1	Lead-Lag network study unit
2	C.R.O

7.3   CIRCUIT DIAGRAM:

<div align="center">
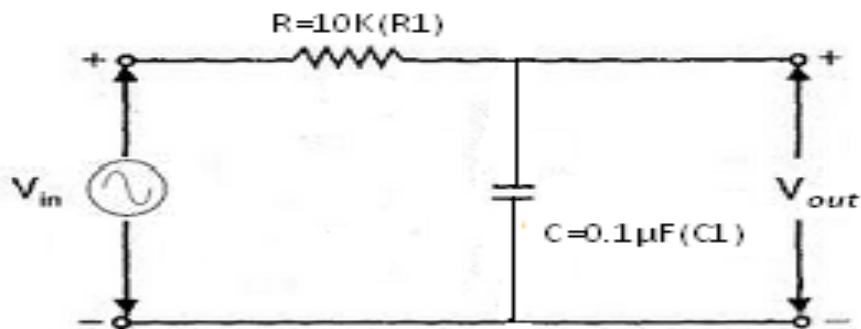
Fig – 7.1 Lag Compensation Network

</div>

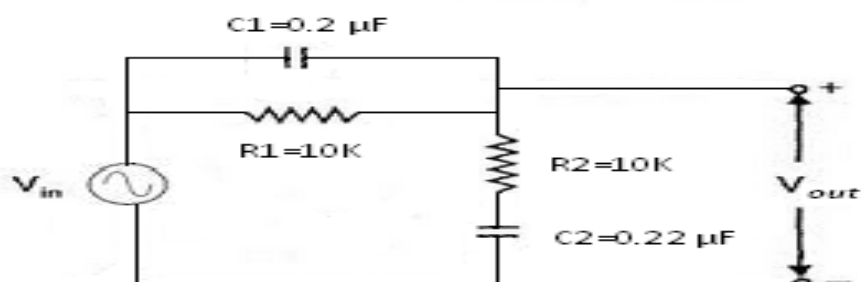<div align="center">
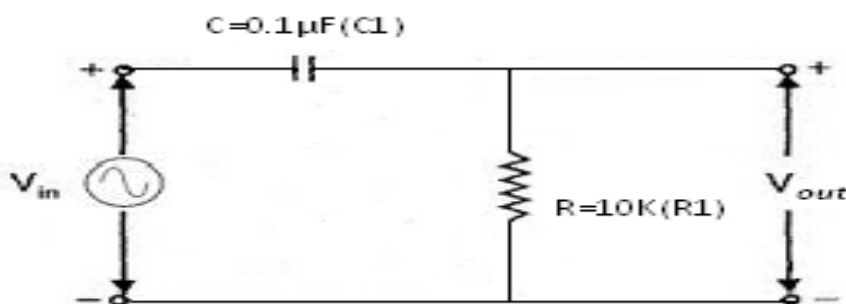
Fig – 7.2 Lead Compensation Network

</div>

<div align="center">

Fig – 7.3 Lag-Lead Compensator Network

</div>

7.4   PROCEDURE:

1. Switch on the main supply to unit observes 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 shows 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, $\Phi = \tan^{-1}\omega RC$

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

FORMULAE
Lead Network

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

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

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

$V_{in} = V$

FORMULAE
Lag-Lead Network

$$R_1 C_1 = \tau_1, \quad R_2 C_2 = \tau_2$$

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

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

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

The transfer function of such a compensator is given by

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

(lag)　　(lead)

CALCULATIONS:

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

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

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

$\omega_0 = 2\pi f = 500$
$f = 500/6.28 = 80\text{Hz}$

7.5　TABULAR COLUMN:
Lag Network

S.No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}
1				
2				
3				

TABULAR COLUMN:
Lead Network

S. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}
1				
2				
3				

TABULAR COLUMN :
Lag-Lead Network

S. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}
1				
2				
3				

7.6   RESULT:

7.7   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?

7.8   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 G(s)=(1+6s)/(1+2s)

7.9   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?

TRANSFER FUNCTION OF DC GENERATOR

8.1   AIM:

To determine the transfer function of separately excited DC generator using thyristor controller.

8.2   APPRATUS:

S. No.	Equipment
1	Thyristor controller
2	MGSET (Motor Generator)
3	DC Ammeter
4	DC Voltmeter
5	AC Ammeter
6	AC Voltmeter

8.3   BLOCK DIAGRAM:

| V_f | → | $1/R_f+sL_f$ | → | K_g | → | E_g |

| V_f | → | K_g/R_f+sL_f | → | E_g |

| $V_f(s)$ | → | $(K_g/L_f) /$ $(s+Rf/Lf)$ | → | E_g |
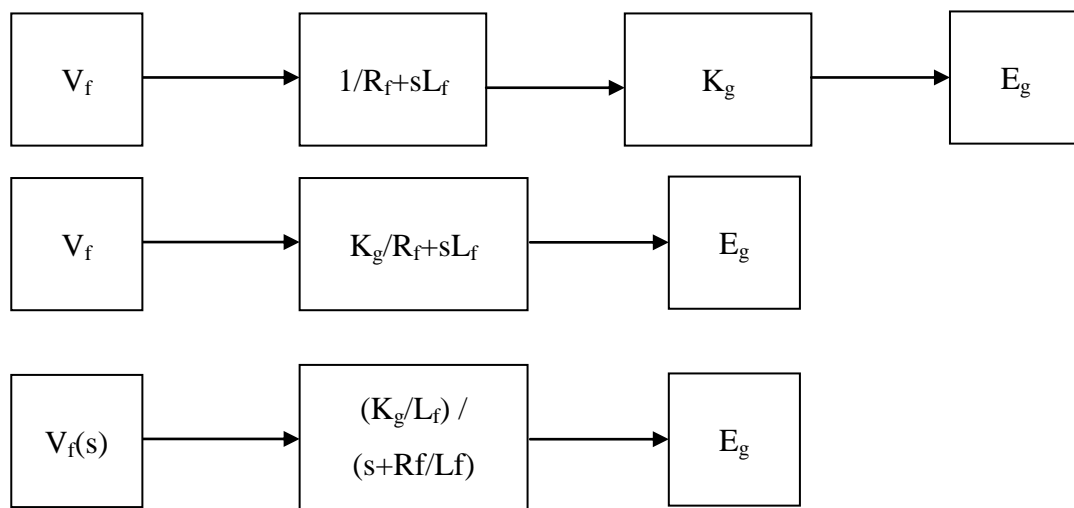
Fig – 8.1 Block Diagram

INTERNAL CIRCUIT DIAGRAMS
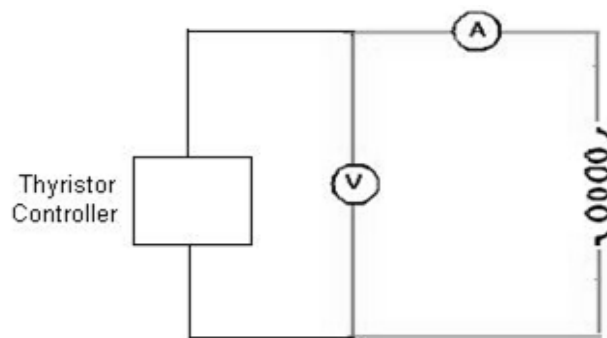
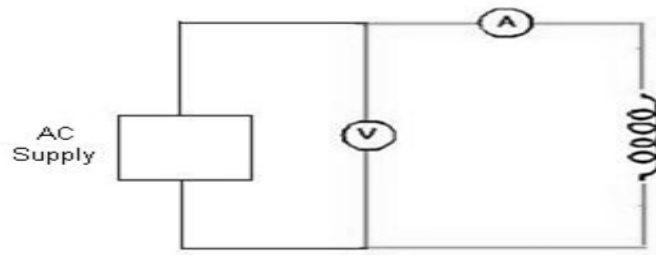**Fig – 8.2 Measurement of Field Resistance**
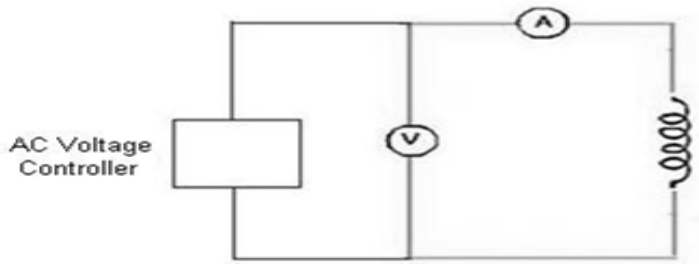
Fig – 8.3 Measurement of Field Inductance

Fig – 8.4 AC Voltage Controller

8.4 PROCEDURE:

1. Make the connection as given in the circuit diagram.

2. Connect motor field supply to field adjust the motor field voltage to its rated voltage 220V.

3. Connect generator field supply to field of generator and keep the generator field potentiometer to its minimum position.

4. Now switch **ON** the armature thyristor controller till the motor runs at its rated speed - 1500 r.p.m.

5. Now note down I_f and E_g and enter in the tabular column.

6. Now vary generator field controller and note down E_g for different I_f 's and enter in the tabular column.

7. Draw the graph of E_g volts V_S I_f amps.

   $K_g = \Delta E_g / \Delta I_f$

Measurement of Field Resistance

1. Make the connection as given in the circuit diagram.

2. Armature winding should be kept open.

3. Apply suitable DC voltage form GENERATOR FIELD CONTROLLER and note down V and I readings.

4. V/I ratio which given field resistance.

5. Repeat the step for various input DC voltage and find out field resistance.

6. Take the average value as the field resistance.

Measurement of Field Inductance

1. Make the connection as given in the circuit diagram.

2. Armature winding should be kept open.

3. Connection thyristor controller as AC voltage controller as shown.

4. Vary the AC voltage applied and note down V_f and I_f and enter the readings in the tabular column and find out Z_f, X_f and L_f.

5. Note down V_f and I_f for different AC voltage controller calculate L_f.

6. Take the average value as the field inductance.

8.5 TABULAR COLUMN:

1. Measurement of Field Resistance

S.No.	V_f (volts)	I_f (Amps)	$R_f = V_f/I_f$ (Ω)
1			
2			
3			
4			

2. Measurement of Field Inductance

S. No.	V_f (volts)	I_f (Amps)	$Z_f = V_f/I_f$ (Ω)	$X_f = \sqrt{Z_{f2} - R_f}$	$L_f = X_f/2\prod f$
1					
2					
3					
4					

3. AC Voltage Controller

S. No.	E_f (volts)	I_f (Amps)	K_g (Ω)
1			
2			
3			

8.6 CALCULATIONS:

Field Resistance $R_f =$

Field Inductance $L_f =$

$K_g = \Delta E_g / \Delta I_f$

Transfer function of separately excited generator $T(s) = E_g(s)/ V_f(s)$
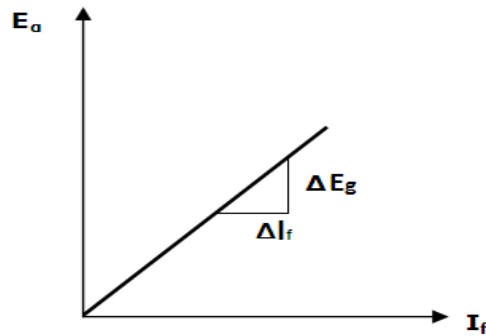
8.7   MODEL GRAPHS

Fig – 8.5 Model Graphs

8.8   RESULT:

.

8.9   PRE LAB VIVA QUESTIONS:

1. What are the different types of generator?
2. Explain the characteristics of shunt generator.
3. Explain the characteristics of series generator.
4. Explain the characteristics of compound generator.

8.10   LAB ASSIGNMENTS:

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

8.11   POST LAB VIVA QUESTIONS:

1. By varying the field resistance in the transfer function, check the stability and speed control of generator.
2. By varying the armature resistance in the transfer function, check the stability and speed control of generato**r.**

EXPERIMENT - 9

CHARACTERISTICS OF MAGNETIC AMPLIFIER

9.1 AIM:

To study the control characteristics of Magnetic Amplifier

    i) Series connection   ii) Parallel Connection

9.2 APPRATUS:

S. No.	Equipments
1	Magnetic Amplifier Demonstration kit
2	A Rheostat of 50Ω and 5A
3	Patch chords

9.3 CIRCUIT DIAGRAM:
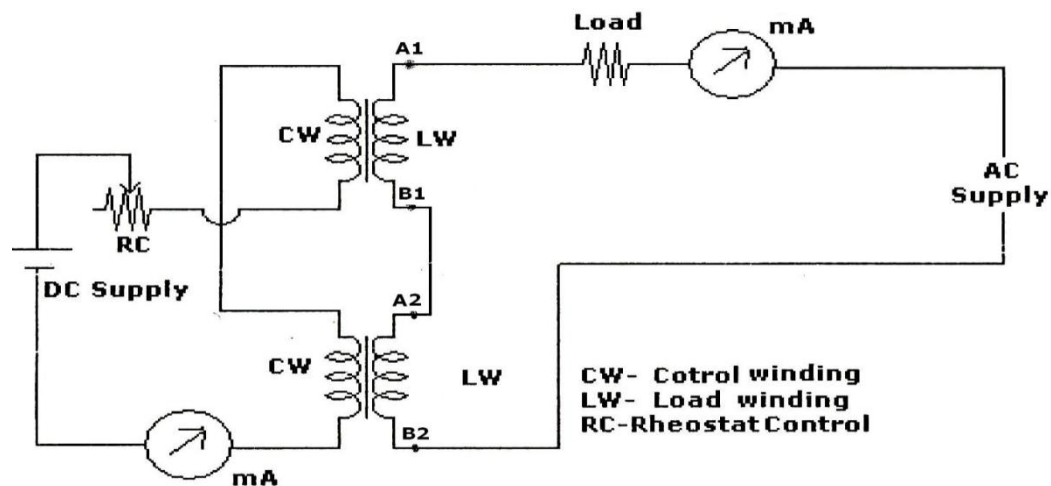
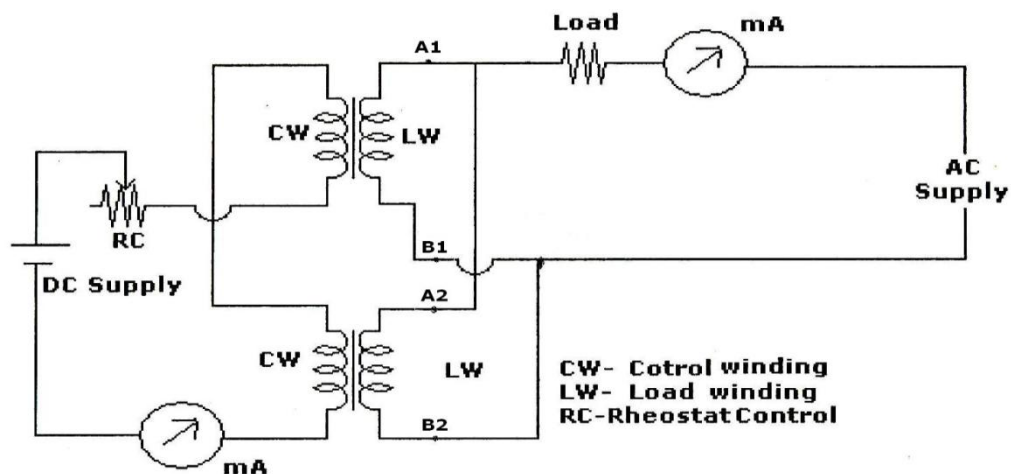**Fig -9.1 Series connected Magnetic Amplifier**

Fig -9.2 Parallel connected Magnetic Amplifier

9.4   PROCEDURE:
Series Connected Magnetic Amplifier

1. Keep toggle switch in position D on front panel.
2. Keep control current setting knob at its extreme left position

    (i.e., Rotate in anti clockwise direction) which ensures Zero control current at starting.
3. With the help of patch cords connect following terminals on the front panel
a. Connect **AC** to A_1
b. Connect B_1 to A_2
c. Connect B_2 to **L**
4. Now connect variable rheostat (or bulb) on front panel.
5. Switch ON the unit.
6. Now increase control current by rotating the corresponding knob in steps and note down the Control Current and corresponding Load Current.
7. Plot the graphs of Load Current Vs Control Current.

Parallel Connected Magnetic Amplifier

1. Keep toggle switch in position D on front panel.
2. Keep control current setting knob at its extreme left position (i.e. Rotate in anti clockwise direction) which ensures Zero control current at starting.
3. With the help of patch cords connect following terminals on the front panel
    a. Connect **AC** to A_1
    b. Connect A_1 to A_2
    c. Connect B_1 to B_2
    d. Connect B_2 to **L**
4. Now connect variable rheostat (or bulb) on front panel.
5. Switch ON the unit.
6. Now increase control current by rotating the corresponding knob in steps and note down the readings of Control Current and corresponding Load Current.
7. Plot the graphs of Load Current Vs Control Current.

9.5   ABULAR COLUMN:
Series Connected Magnetic Amplifier

S. No.	Control Current (I_C)	Load Current (I_L)
1		
2		
3		

Parallel Connected Magnetic Amplifiers:

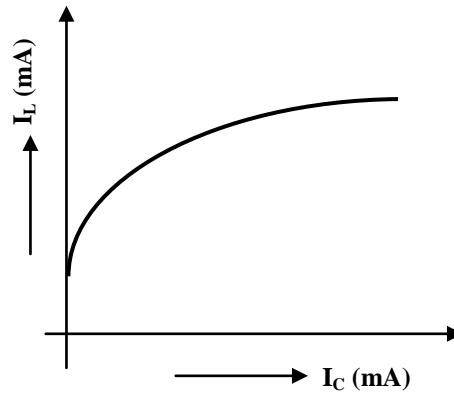| S. No.	Control Current (I_C)	Load Current (I_L)
1		
2		
3		

9.6 MODEL GRAPH:

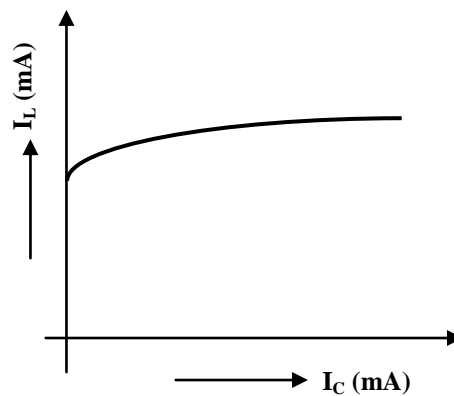**Fig – 9.3 Series connected Magnetic Amplifier**

Fig – 9.4 Parallel connected Magnetic Amplifier

9.7 RESULT:

9.8   PRE LAB VIVA QUESTIONS:

1. What is a magnetic amplifier?

2. What are the applications of magnetic amplifier?

3. What are the advantages and disadvantages of magnetic amplifier?

4. Describe various methods of changing inductance?

9.9   LAB ASSIGNMENTS:

1. In series connection how the characteristics will change when inductive load is connected?

2. In parallel connection how the characteristics will change when inductive load is connected?

3. Compare the input and output characteristics in both the modes.

9.10   POST LAB VIVA QUESTIONS:

1. Describe saturable core reactor?

2. Give the purpose of saturable reactor in magnetic amplifier.

3. Describe in detail the circuitry of magnetic amplifier?

EXPERIMENT - 10

TEMPERATURE CONTROL SYSTEMS

10.1   AIM:

To study the performance of P, PI, PID controller's used to control the temperature of an oven.

10.2   APPRATUS:

Temperature control kit.
Oven
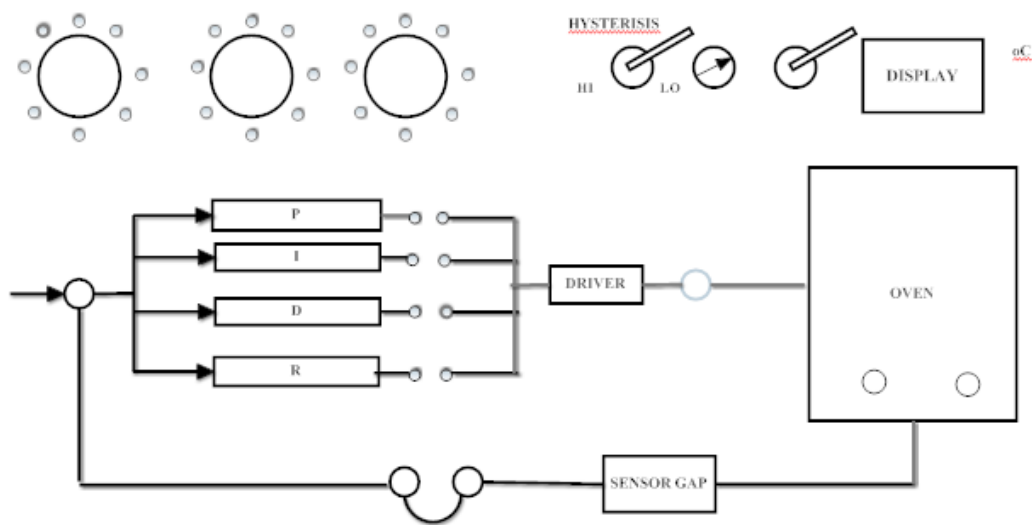Patch cards
Stop watch

10.3   CIRCUIT DIAGRAM:

Fig – 10.1 Block Diagram of Temperature Control Systems

10.4   PROCEDURE:
Proportional controller:

1. Keep S1 switch to wait position and allow oven to cool to room temperature. Short the feedback terminals.

2. Keep S2 to set position and adjust the reference potentiometer to desired output temperature say 60° by seeing on the digital display.

3. Connect the 'P' output to the driver, input of P,I,R must be disconnected from drive input and set 'p' potentiometer value to '1'.

4. Switch S2 to measure and S1 to run position and record oven temperature every 30 sec for about 20 min.

5. Plot the graph between temperature and time on graph sheet.

P.I Controller:

1. Starting with cool oven, keep switch S1 to wait connect P,I output to drive input and disconnect R&D outputs and short feedback terminals.
2. Set P and I potentiometer to 0.5, 1.
3. Select and set desired temperature to $60^{o.}$
4. Keep switch S1 to run position and record the temperature readings every 15/30 sec about 20 min.
5. Plot the graph between temperature and time.

PID Controller:

1. Starting with cool oven, keep switch S1 to wait.
2. Connect P, I, D to driver input and disconnect R output, short feedback terminals.
3. Set P, I, D potentiometer to 0.5, 1.
4. Select and set the desired temperature to 60°.
5. Keep switch S1 to RUN position and record the temperature readings every 15/30 sec about 20 min.

10.5 TABULAR COLUMN:

Time in (sec)	Temperature in degrees		
	P	PI	PID

10.6 RESULT:

10.7   PRE LAB VIVA QUESTIONS:

1. What is control system?
2. Define closed loop and open loop control system.
3. What are the different types of controllers do we have?
4. Define P controller, PI controller and PID controller.

10.8   POST LAB VIVA QUESTIONS:

1. What is a driver circuit?
2. What are the applications of temperature controller system?
3. Which controller is most effective among P, PI, PID and why?
4. Define gain .

EXPERIMENT - 11

CHARACTERISTICS OF AC SERVO MOTOR

11.1   AIM:

To study AC servo motor and note it speed torque Characteristics

11.2   APPRATUS:

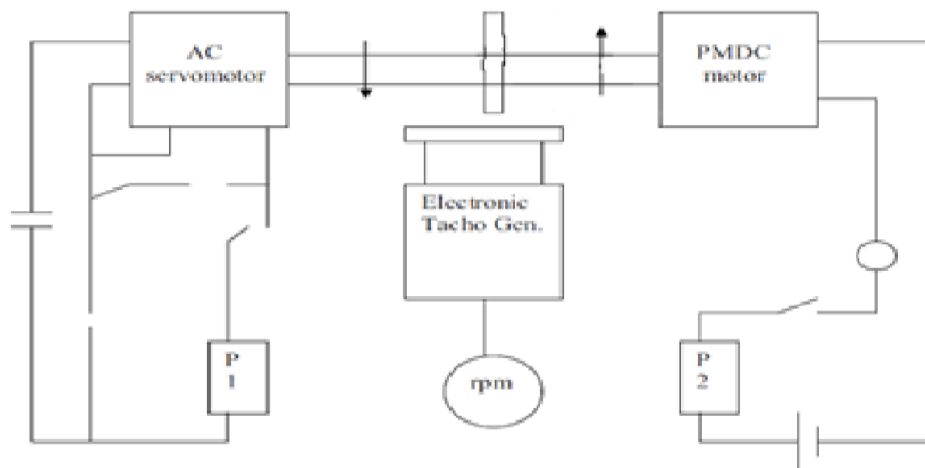| S. No.	Equipments
1	AC Servo Motor Setup
2	Digital Multimeter
3	Connecting Leads

11.3   CIRCUIT DIAGRAM:

Fig – 11.1 Block Diagram of Characteristics of AC servo motor

11.4   PROCEDURE:

1. Switch **O**N the power supply, switches ON S1. Slowly increase control P1 so that AC servomotor starts rotating. Connect DVM across DC motor sockets (red &black). Very the speed of servomotor gradually and note the speed N rpm and corresponding back emf Eb across DC motor.

2. Connect DVM across servo motor control winding socked (yellow) and adjust AC Servomotor voltage to 70V and note speed N rpm in table.

3. Switch on S2 to impose load on the motor due to which the speed of AC motor Decreases. Increase the load current by means of P2 slowly and note corresponding speed N rpm and Ia. Calculate P=Ia*Eb and Torque=P*1.019*10460/2.2.14Ngm/cm

11.5 TABULAR COLUMN:
TABLE - 1:

S.NO	SPEED (N) rpm	E_b volts
1		
2		
3		
4		

TABLE – 2

S.NO	Ia amp	E_b	Speed (N)rpm	P watt	Torque
1					
2					
3					
4					

11.6 PRECAUTIONS:

1 Apply voltage to servomotor slowly to avoid errors.

2 Impose load by DC motor slowly.

3 Take the reading accurately as the meter fluctuates.

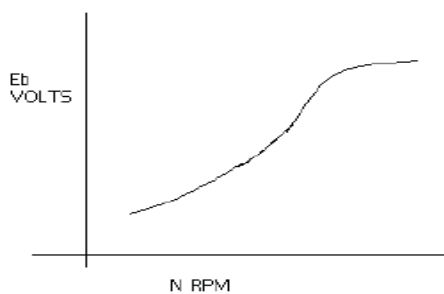4 Switch OFF the setup when note in use.
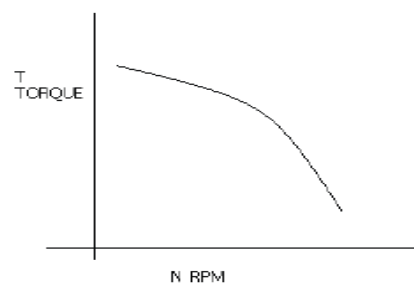
11.7 MODEL GRAPH:

Fig -11.2 Speed Vs E_b   **Fig – 11.3 Torque Vs Speed**

11.8 RESULT:

11.9   PRE LAB VIVA QUESTIONS:

1. What is AC servo motor?
2. What is the use of AC servo motor?
3. What are the advantages of AC servo motor?
4. What is the important parameter of AC servo motor?
5. On what factor does the direction of rotation of AC servo motor depend.

11.10   POST LAB VIVA QUESTIONS:

1. What is the drawback of AC servo motor?
2. How the drawback of positive in AC servo motor is overcome?
3. What is the input of AC servo motor in feedback control application?
4. What is the phase relationship between reference voltage and control Voltage?
5. What are the types of AC servo motor?

SIMULATION OF OP-AMP BASED INTEGRATOR & DIFFERENTIATOR CIRCUITS

12.1   AIM:

To simulate op-amp based integrator and differentiator circuits using PSPICE.

12.2   APPARATUS:

a)   Simulate the practical differentiator circuit given below(fig1) using PSPICE and plot the transient response of the output voltage for a duration of 0 to 40ms in steps of 50μsec the op-amp which is modeled by the circuit has $R_i = 2m\Omega$, $R_o = 75\Omega$, $R_1 = 10k\Omega$ and $C_1 = 1.5619\mu f$, $A_o = 2\times10^5$.

b)   Simulate the practical integrator circuit given below(fig2) using PSPICE and plot the transient response of the output voltage for a duration of 0 to 40ms in steps of 50μsec the op-amp which is modeled by the circuit has $R_i = 2m\Omega$, $R_0 = 75\Omega$, $R_1 = 10k\Omega$ and $C_1 = 1.5619\mu f$, $A_o = 2\times10^5$.

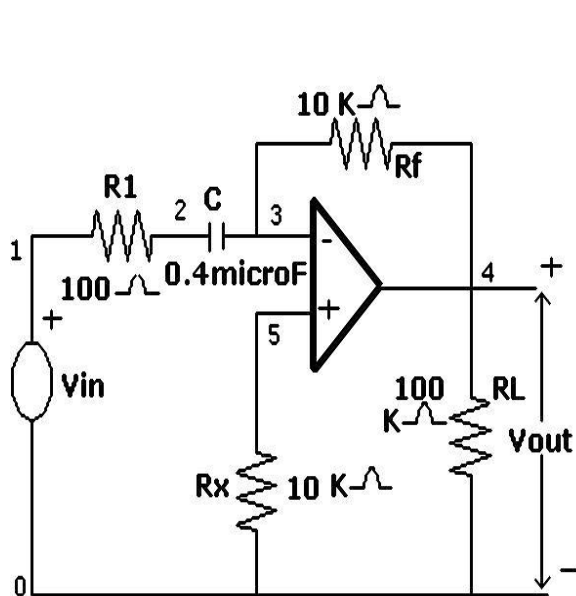**12.3   CIRCUIT DIAGRAM:**

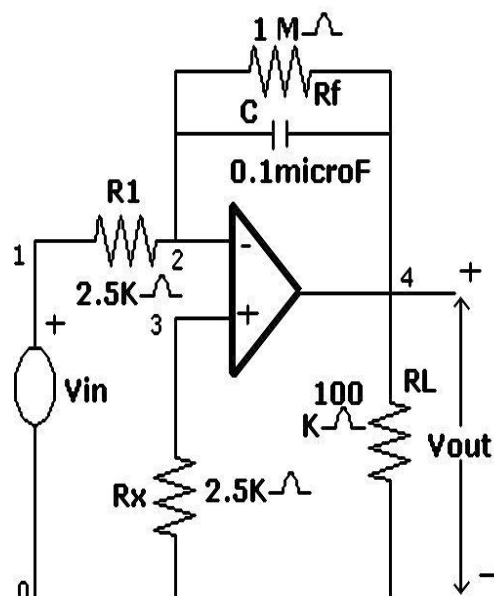**Fig.12.1 Differentiator**   **Fig. 12.2 Integrator**

12.4   PROCEDURE:

1.   Click on PSPICE icon.

2.   From FILE menu click on NEW button and select Text file to open untitled window

3.   Enter the following program in untitled window.

(a) Program (Differentiator)

```
VIN 10 PWL (0   0   1MS   1V   2MS   0V   3MS   1V   4MS   0V)
R₁   1   2   100
RF   3   4   10K
RX   5   0   10K
RL   4   0   100K
C₁   2   3   0.4UF
*SUBCKT CALL FOR OPAMP
XA1 3   5   4   0 OPAMP
.SUBCKT  OPAMP  1  2  7  4
RI 1   2   2.0E6
 *VOLTAGE CONTROLLED CURRENT SOURCE WITH GAIN OF 1m
 GB                    4   3   1   2   0.1M
 R₁                          3   4  10K
 C₁ 3     4  1.5619UF
 *VOLTAGE CONTROLLED VOLTAGE SOURCE WITH GAIN OF 2E5
 EA   4   5   3   4   2E5
 RO 5     7  75
 .ENDS
 .TRAN   50US   40MS
 .PRINT   TRAN     V(4,0)   V(1,0)
 .PROBE
 .END
```

(b) Program (Integrator)

```
VIN       1 0 PWL (0   0   1NS  -1V   1MS   -1V   1.0001MS   1V   2MS   +1V
                2.0001MS  -1V   3MS   -1V   3.0001MS   1V   4MS   1V)
R₁        1   2   2.5K
RF        2   4   1MEG
RX             3   0   2.5K
RL       4   0   100K
C₁       2   4   0.1UF
*SUBCKT CALL FOR OPAMP
XA1       2   3   4   0       OPAMP
.SUBCKT  OPAMP  1  2  7  4
RI       1   2   2.0E6
*VOLTAGE CONTROLLED CURRENT SOURCE WITH GAIN OF 0.1M
```

G_B	4	3	1	2	0.1M
R_1	3	4	10K		
C_1	3	4	1.5619UF		

*VOLTAGE CONTROLLED VOLTAGE SOURCE WITH GAIN OF 2E5

E_A	4	5	3	4	2E5
R_O	5	7	75		

.ENDS

.TRAN   50US   40MS

.PRINT   TRAN   V(4,0)   V(1,0)

.PROBE

.END

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) from Simulation menu select RUN button and clear the errors (if any).
6. Observe the output from View menu select output file.
7. Observe the required plots at respective points by selecting Add Trace from Trace Menu.
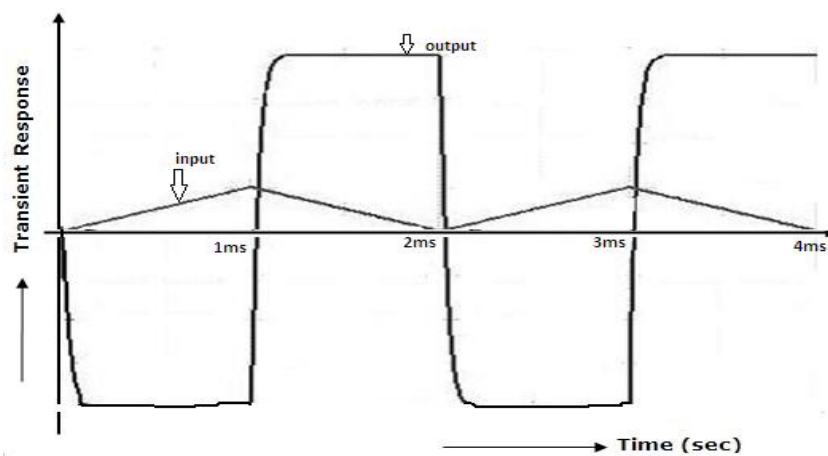
12.5   MODEL GRAPH:
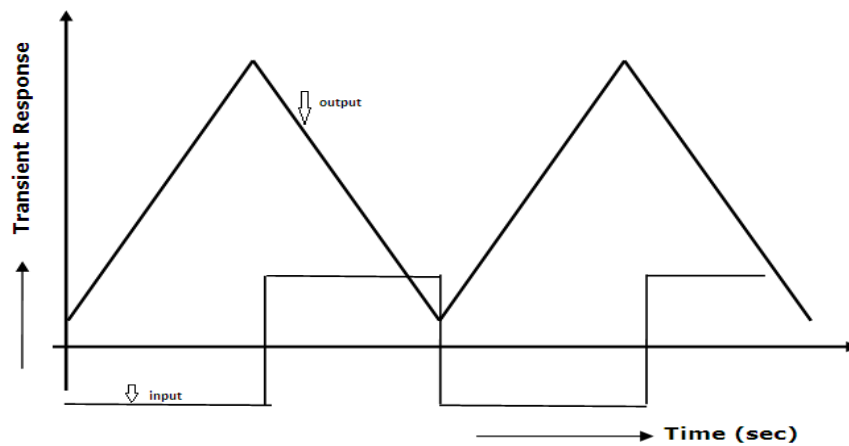

Fig – 12.3 Differentiator

Fig – 12.4 Integrator

12.6   RESULT:

12.7   PRE LAB VIVA QUESTIONS:

1. What is an Operational amplifier?
2. What are the ideal characteristics of op amp?
3. What is Virtual Short?
4. What are the applications of op amp?
5. What are the advantages and disadvantages of op amp?

12.8   LAB ASSIGNMENTS:

1. What is the output voltage for the differentiator if the input is sinusoidal?
2. What is the output voltage for the integrator if the input is sinusoidal?
3. How the op amp acts as voltage multiplier?

12.9   POST LAB VIVA QUESTIONS:

1. Explain how the waveform is converted in differentiator.
2. Explain how the waveform is converted in integrator.

EXPERIMENT - 13

ROOT LOCUS, BODE PLOT AND NYQUIST PLOT USING MATLAB

13.1   AIM:

To analyze frequency response of a system by plotting Root locus, Bode plot and Nyquist plot using MATLAB software.

13.2   APPRATUS:

S. No.	Equipment
1	MATLAB 7 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
```

For Nyquist Plot

```
% Nyquist Plot
Clear all;
clc;
disp(' Transfer function of given system is \n');
num = input (' enter numerator of Transfer function: \n ');
den = input (' enter denominator of Transfer function: \n ');
G= tf (num, den)
figure(1);
nyquist (G);
%margin(G);
[gm, pm, wpc, wgc] = margin (G)
Disp (' gain margin in degrees is: \n')
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.
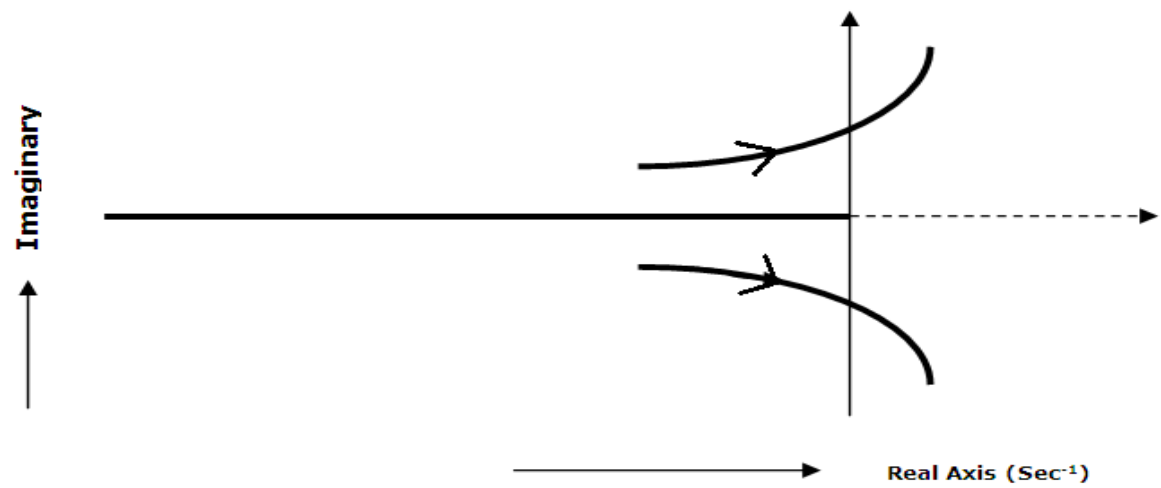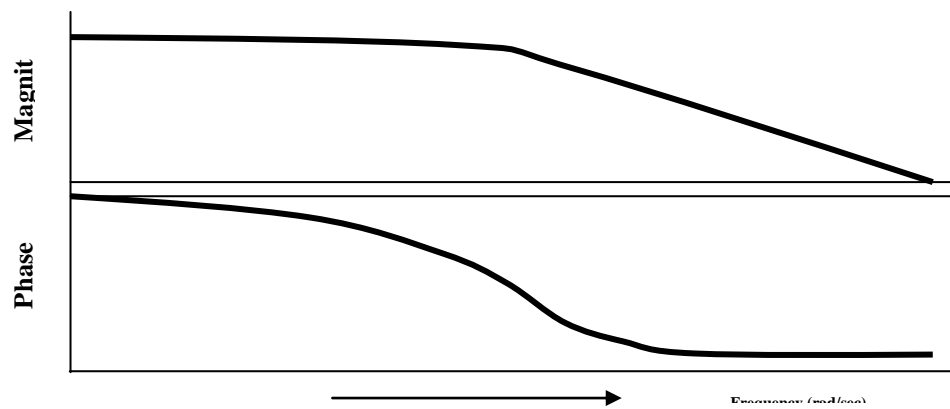
13.5   MODEL GRAPHS:
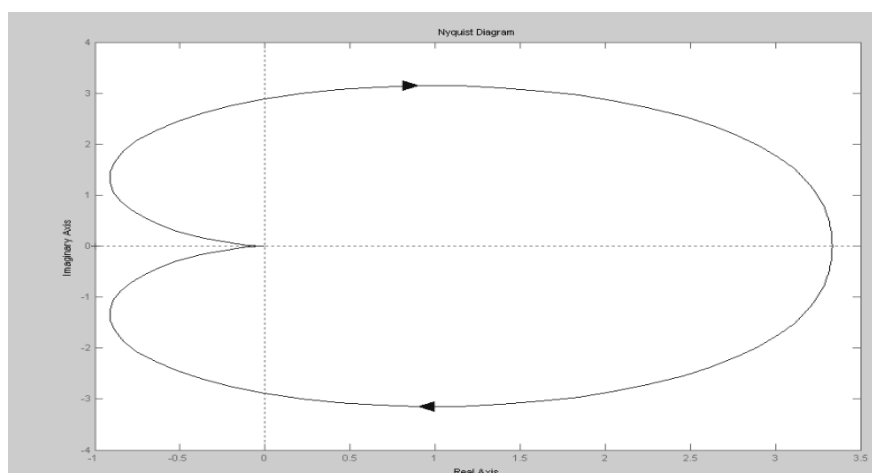

Fig – 13.1 Root Locus plot

Fig – 13.2 Bode Plot

Fig - 13.3 Nyquist 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:

13.9 PRE LAB VIVA 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 effected 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 effected for all the plots

13.11 POST LAB VIVA QUESTIONS

1. What is complementary Root Loci?
2. What are contours?
3. How can you analyze the stability of system with bode, nyquist?

<h1 style="text-align:center">EXPERIMENT - 14</h1>

<h1 style="text-align:center">STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING MATLAB</h1>

14.1   AIM:

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

14.2   APPRATUS:

S.No.	Equipment
1	MATLAB 7 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.

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
```

**14.6    RESULT:**




**14.7    PRE LAB VIVA 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?

**14.8    LAB ASSIGNMENTS:**

1. $$\frac{8s + 1}{9s^3 + s^2 + s + 2}$$ formulate state space model?

2. $$\frac{s^4 + s^3 + s^2 + s + 1}{9s^3 + s^2 + s + 2}$$ formulate state space model?

3. $$\frac{s}{9s^3 + s^2 + s + 2}$$ formulate state space model?

**14.9    POST LAB VIVA QUESTIONS**

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

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