LABORATORY MANUAL

CONTROL SYSTEMS

II B.TECH -II Semester (EEE)

AY-2018-2019

Prepared by

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Prepared by
Mr.T.Ramesh
Assistant Professor

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CERTIFICATE

This is to certify that this manual is a bonafide record of practical work in the **Control Systems** in **Second Semester of II year B.Tech (EEE) programme** during the academic year **2018-19**.Thismanual is prepared by **, Mr.T.Ramesh (Assistant Professor)** Department of Electrical and Electronics Engineering.

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PREFACE

Here we describe our considerations in designing the control systems laboratory component of around an apparently simple DC motor control testbed. In addition to helping the students practice paper-based or PC-based design techniques, most of which they may have seen in their lecture course on control systems, we believe that controls experiments need to help the students acquire the following skills associated with converting the paper-based or PC-based design into a practical system:

1. Ability to identify the hardware and software that are needed in a basic control system.
2. Ability to make this hardware and software work together.
3. Ability to debug small errors that may appear during practical implementation.

This knowledge comes only through at least a few weeks of work on problems, all of which may be related to one or two hardware setups that are not — and do not look — complex.

Overall, the lab experiments need to give the student confidence enough to say, “I have practical experience with implementing control systems in addition to designing and simulating them”.

By

Mr.T.Ramesh,
Assistant.professor

ACKNOWLEDGEMENT

It was really a good experience, working with ***Control Systems*** lab. First we would like to thank Dr.Isaac,Professor & HOD of Department of Electrical and Electronics Engineering, Marri Laxman Reddy Institute of Technology & Management for his concern and giving the technical support in preparing the document.

We are deeply indebted and gratefully acknowledge the constant support and valuable patronage of Dr.R.Kotaiah, Director, Marri Laxman Reddy Institute of technology & Management for giving us this wonderful opportunity for preparing the ***Control Systems*** laboratory manual.

We express our hearty thanks to Dr.K.Venkateswara Reddy, Principal, Marri Laxman Reddy Institute of technology & Management, for timely corrections and scholarly guidance.

At last, but not the least I would like to thanks the entire EEE Department faculties those who had inspired and helped us to achieve our goal.

By

Mr.T.Ramesh,
Assistant.professor

GENERAL INSTRUCTIONS

1. Students are instructed to come to Basic Electrical Engineering laboratory on time. Late comers are not entertained in the lab.

2. Students should be punctual to the lab. If not, the conducted experiments will not be repeated.

3. Students are expected to come prepared at home with the experiments which are going to be performed.

4. Students are instructed to display their identity cards before entering into the lab.

5. Students are instructed not to bring mobile phones to the lab.

6. Any damage/loss of system parts like Meters, Components during the lab session, it is student's responsibility and penalty or fine will be collected from the student.

7. Students should update the records and lab observation books session wise. Before leaving the lab the student should get his lab observation book signed by the faculty.

8. Students should submit the lab records by the next lab to the concerned faculty members in the staffroom for their correction and return.

9. Students should not move around the lab during the lab session.

10. If any emergency arises, the student should take the permission from faculty member concerned in written format.

11. The faculty members may suspend any student from the lab session on disciplinary grounds.

12. Never copy the output from other students. Write down your own outputs.

Instructions to the students to conduct an experiment:

1. Students are supposed to come to the lab with preparation, proper dress code and the set of tools required (1. Cutter, 2. Tester (small size), 3. Plier (6-Inches)).
2. Dress code:

   Boys: Shoe & Tuck.

   Girls: Apron & Cut

   shoe.
3. Don't switch on the power supply without getting your circuit connections verified.
4. Disciplinary action can be taken in the event of mishandling the equipment or switching on the power supply without faculty presence.
5. All the apparatus taken should be returned to the Lab Assistant concerned, before leaving the lab.
6. You have to get both your Observation book and your Record for a particular experiment corrected well before coming to the next experiment.

Guidelines to write your Observation book:

1. Experiment title, Aim, Apparatus, Procedure should be right side.
2. Circuit diagrams, Model graphs, Observations table, Calculations table should be left side.
3. Theoretical and model calculations can be any side as per convenience.
4. Result should always be at the end (i.e. there should be nothing written related to an experiment after its result).
5. You have to write the information for all the experiments in your observation book.
6. You are advised to leave sufficient no of pages between successive experiments in your observation book for the purpose of theoretical and model calculations.

INSTITUTION VISION AND MISSION

VISION

To be as an ideal academic institution by graduating talented engineers to be ethically strong, competent with qualityresearch and technologies

MISSION

To fulfill the promised vision through the following strategic characteristics and aspirations:

- Utilize rigorous educational experiences to produce talented engineers
- Create an atmosphere that facilitates the success of students
- Programs that integrate global awareness, communication skills and Leadership qualities
- Education and Research partnership with institutions and industries to prepare the students for interdisciplinary research

DEPARTMENT VISION, MISSION , PROGRAMME EDUCATIONAL OBJECTIVES AND SPECIFIC OUTCOMES

VISION

To impart high qulality technical knowledge in Electrical and Electronics Engineerimg and to transform them imto globally competent engineers,researchers and entrepreneurs and to make them ethically,emotionally strong enough to meet the technological challenges, to excel globally and thus excel to greater hights in their career.

MISSION

1. To provide the state of the art resources to achieve excellence in all apheres of Electrical Engineering related domains.
2. To bridge the gap between academics and industries through proper teaching and learning processes .
3. To inculcate moral and ethical values & environment among the students through knowledge centric education & research.

PROGRAMME EDUCATIONAL OBJECTIVES

The Programme Educational Objectives (PEOs) that are formulated for the Electrical engineering programme are listed below;

PEO1: To provide the sstudents with a sound foundation in the mathematics,science and engineering fundamentals necessarynto become employable.

PEO2: Graduates are able to apply their technical knowledge to take up higher responsibilities in industry,academics and create innovative ideas in the field of Electrical and Electronics Engineering.

PEO3: Equip graduates with the communication skills, leadership qualities and team wirk with multi disciplinary approach and zeal to provide solutions for engineering problems.

PEO4: to inculcate ethical values and aptitude for lifelong learning needed for a successful professional career of the graduates.

PROGRAM SPECIFIC OUTCOMES

PSO 1: The ability to analyze, design, implement and maintenance of the electrical & power systems for various industrial application.

PSO 2: The ability to apply analytical & experimental techniques for optimization of electrical and Power systems.

PSO 3: The ability to analyze electrical/electronic(s) systems with the help of analogous & discreet mathematical tools.

PROGRAMME OUT COMES

The Program Outcomes (POs) of the department are defined in a way that the Graduate Attributes are included, which can be seen in the Program Outcomes (POs) defined. The Program Outcomes (POs) of the department are as stated below:

PO1. Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2. 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 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. 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. 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.

PO6. 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. Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8. Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. 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. 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. 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.

COURSE OBJECTIVES & OUTCOMES

COURSE OBJECTIVES:

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

COURSE OUTCOMES:

After completion of this lab the student is able to

1. How to improve the system performance by selecting a suitable controller and/or a compensator for a specific application
2. Apply various time domain and frequency domain techniques to assess the system performance
3. Apply various control strategies to different applications(example: Power systems, electrical drives etc)
4. Test system controllability and observability using state space representation and applications of state space representation to various systems

Department of Electrical & Electronics Engineering

EE406ES: CONTROL SYSTEMS

List of Experiments

S.No	Name of the Experiment
Any eight experiments should be conducted	
1	Time response of Second order system
2	Characteristics of Synchros
3	Programmable logic controller – Study and verification of truth tables of logic gates, simple Boolean expressions, and application of speed control of motor.
4	Effect of feedback on DC servo motor
5	Transfer function of DC motor
6	Transfer function of DC generator
7	Temperature controller using PID
8	Characteristics of AC servo motor
Any two experiments should be conducted	
9	Effect of P, PD, PI, PID Controller on a second order systems
10	Lag and lead compensation – Magnitude and phase plot
11	(a) Simulation of P, PI, PID Controller. b) Linear system analysis (Time domain analysis, Error analysis) using suitable software
12	Stability analysis (Bode, Root Locus, Nyquist) of Linear Time Invariant system using suitable software
13	State space model for classical transfer function using suitable software -Verification.
14	Design of Lead-Lag compensator for the given system and with specification using suitable software

EXPERIMENT:1

TIME RESPONSE OF SECOND ORDER SYSTEM

AIM : To find the time response of the first order and second order systems.

Apparatus required Linear system simulator trainer kit.

1) Cathode ray oscilloscope
2) BNC probes
3) Patch cords

Theory:

Second Order Systems

These systems are characterized by two poles and up to two zeros. For the purpose of transient response studies, zeros are usually not considered primarily because of simplicity in calculations and also because the zeros do not affect the internal modes of the systems.

A second order system is represented in the standard form as

$$G(8)=\frac{©n^{2}}{s^2+2\delta\omega n^S+\omega n.^2}$$

Where 6 is called the damping ratio and $©_n$ the undamped natural frequency. Depending upon the value of 6, the poles of the system may be real, repeated or complex conjugate, which is reflected in the nature of its step response. Results obtained for various cases are:

a) **Under damped case** ($0<\delta<1$)

$$c(t)= 1- \frac{e^{-\delta\omega_n t}}{\sqrt{(1-\delta^2)}}.\sin\{\omega d^t + \tan^{-1}\frac{\sqrt{(1-S^2)}}{\delta}\}$$

Where $\omega d = \omega n\, V(1-\delta^2)$ is termed as the damped natural frequency. A sketch of the unit step response for various values of δ

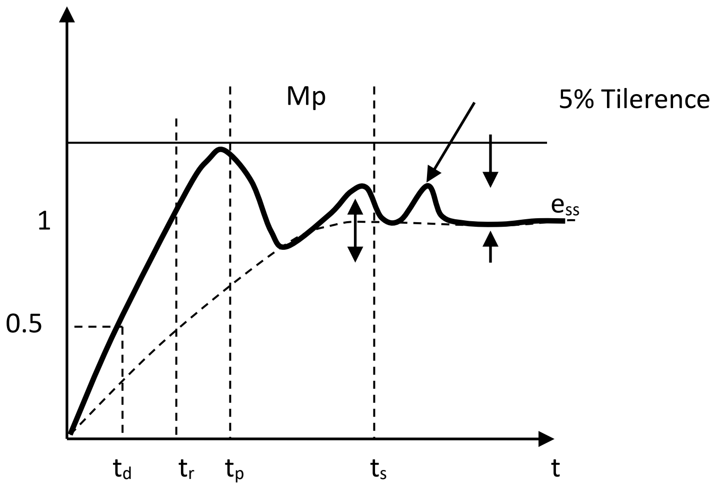
b) **Critically damped case** ($\delta>1$)

$$c(t) = 1- e^{-\delta\omega_n t}(1+\omega_n t)$$

C) **Over damped case** ($\delta>1$)

$$c(t) = 1 + \frac{\omega_n}{2\sqrt{(\delta^2-1)}} \left\{ \frac{e^{-s_1 t}}{S1} - \frac{e^{-s_2 t}}{S_2} \right\}$$

where $s_1 = (\delta + \sqrt{(\delta^2-1)})\,\omega_n$ and $s_2 = (\delta + \sqrt{(\delta^2-1)})\,\omega_n$



1. Delay time (td)
2. Rise time (t_r)
3. Peak time (t_p)
4. Maximum peak overshoot (Mp)
5. Settling time (t_s)

DELAY TIME (t_d)

It is the time taken to reach 50% of the final value for the response, for ti .e very first time.

$$td = \frac{1+0.7\delta}{\omega_n}$$

RISE TIME (t_r)

It is time to taken for the response to raise from 0 to 100% for the very first time.

$$t_r = \frac{\pi-\theta}{\delta} \qquad \text{where } \theta = \tan^{-1}\frac{\sqrt{(1-\delta^2)}}{\omega_d}$$

PEAK TIME (t_p)

It is the time taken for the response to *reach* the peak value for the very first time

$$t_p = \frac{\pi}{\omega_d}$$

MAXIMUM PEAK OVERSHOOT (Mp)

It is defined as the ratio of the maximum peak value measured from input final value to the out final value.

$$\%M_P = \frac{C(t_p)-C(\alpha)}{C(\alpha)} x100$$

SETTLING TIME (t_s)

It is defined as time taken by the response to reach and stay within a specified error.

t_s =4T=4/$\delta\omega_n$ for 2% tolerance =3T=3/$\delta\omega_n$

for 5% tolerance

PROCEDURE

1. Connections are given as per the circuit diaaram
2. A unit step signal is applied at the *input* and the correspondiny output has to be observed in the cathode ray oscilloscope.
3. Find the *toia* amplitude of the wave and multiply with .632 corresponding that time to get the time constant.
4. Now increase the gain of the system and find the time constant for each gain and tabulate the values obtained.

TO FIND STEADY STATE ERROR (e_{ss})

1. Change the input of the system from step signal to the ramp signal.
2. Connect the input signal to X channel of the CRO, and connect out put to the Y channel of the CRO then put CRO knob in X-Y mode
3. Find the amplitude of the pattern which gives the ready state error.
4. Increase the gain of the system and find the e_{ss} for each gain.

FOR SECOND ORDER SYSTEM

1. Connections are given as per the second order circuit diagram.
2. A unit step signal is applied at the input and the corresponding out is observed in the CRO.

3. Note down the td, t_r, t_p, t_s, M_p from CRO. For different gains
4. Find the 8, co_n for each gain and compare them with theoretical values

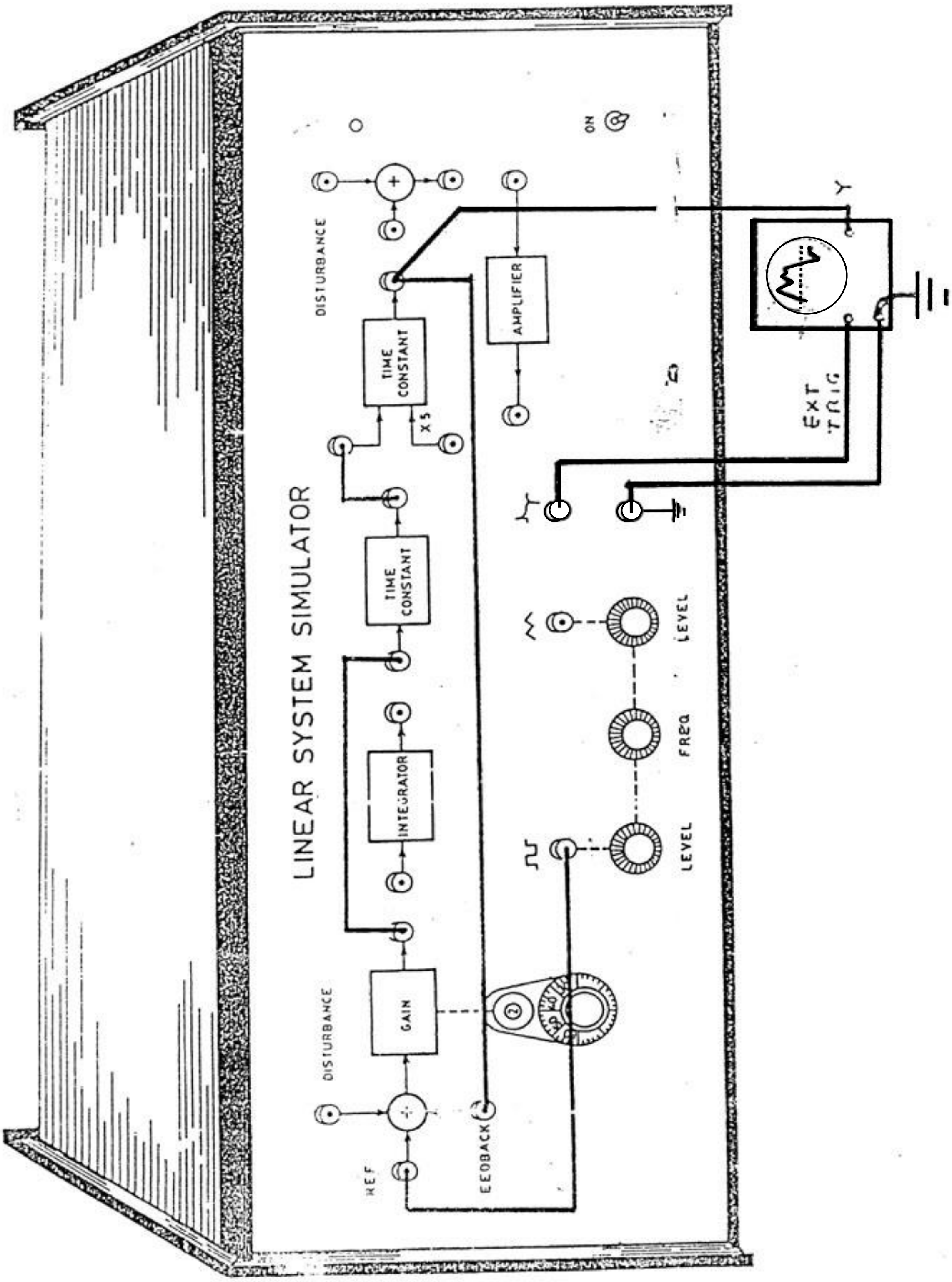
TYPICAL RESULTS

S.NO.	GAIN	t_r t_p (ms) (ms)	t_s (ms)	M_p%	ωn(pr) rad	δ(pr)	ωn(th) rad	δ(th)

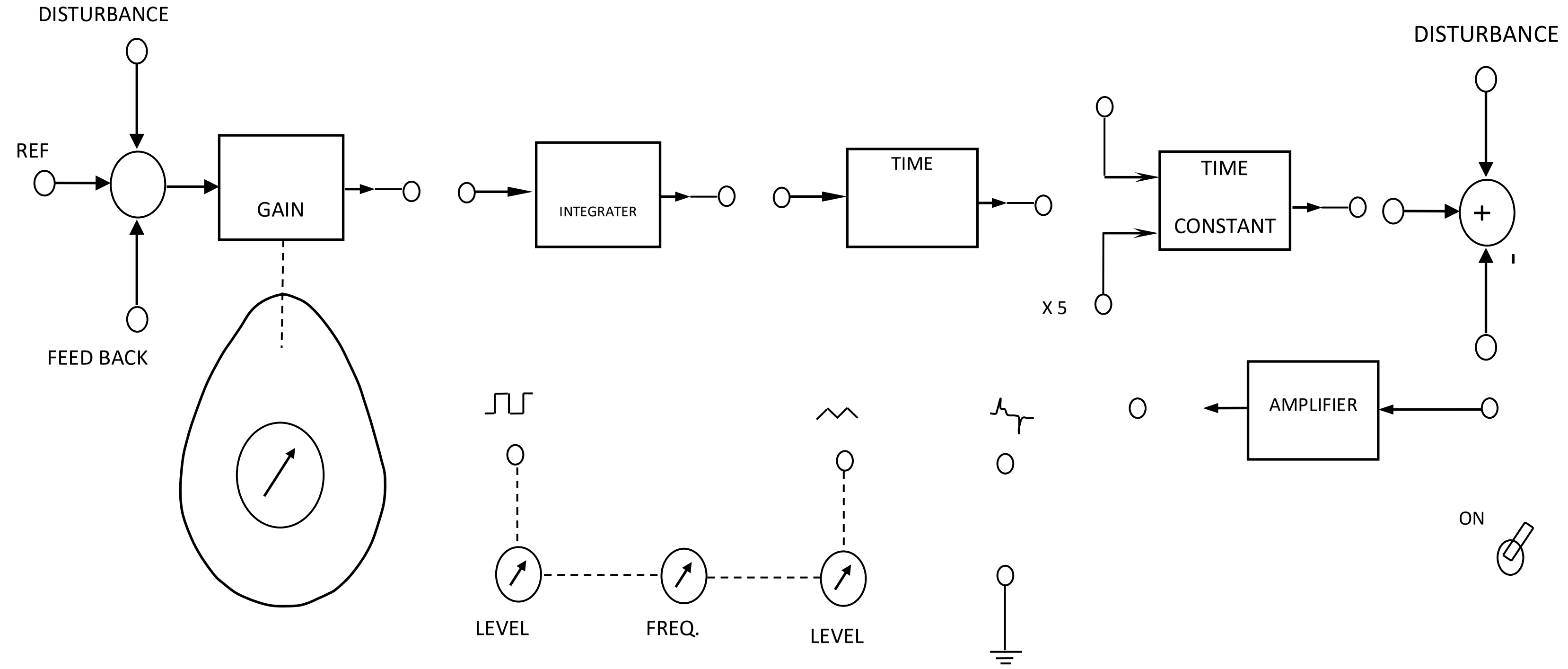
Result:

CIRCUIT DIAGRAM:

Second Order System



PANAL DRAWING



EXPERIMENT:2

SYNCHRO TRANSMITTER & RECEIVER PAIR

Aim:

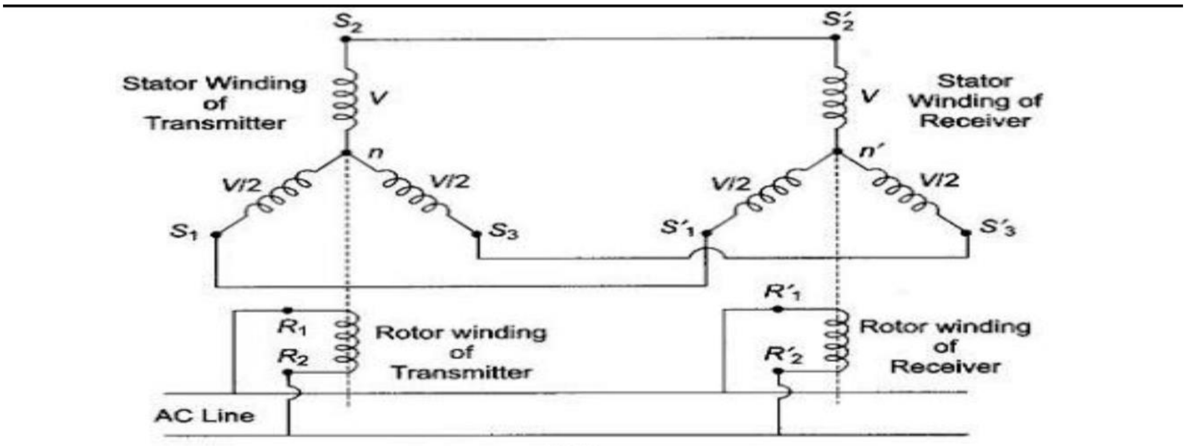
(1) To obtain the stator voltages corresponding to the given rotor positions for the given Synchro transmitter and

(2) To study Synchro transmitter and receiver pair as error detector.

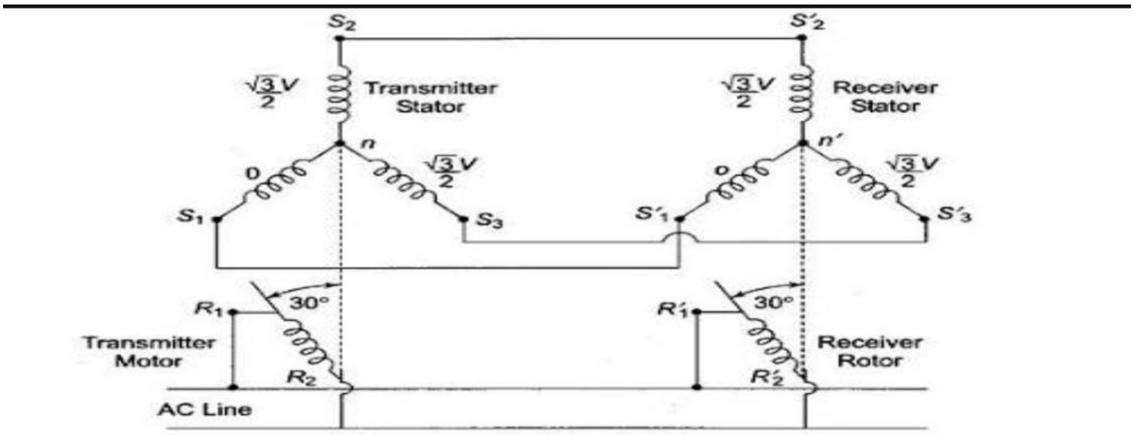
Apparatus:

1. Synchro transmitter and receiver pair
2. Voltmeter (0-300V)
3. Dc power supply
4. Connecting wires

2.CircuitDiagram



(a)

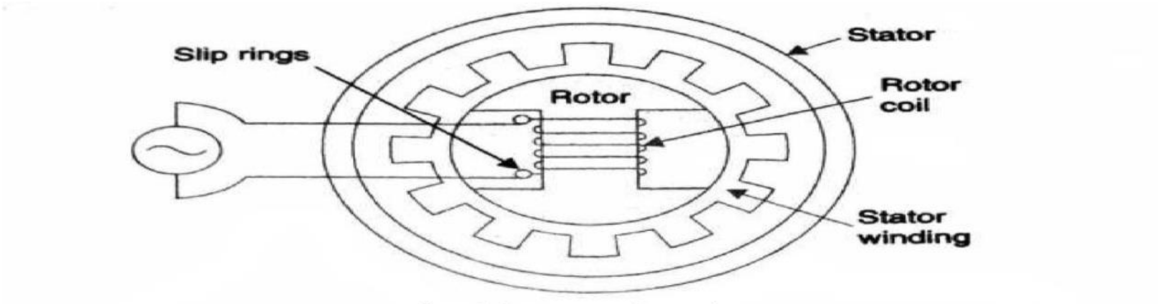


(b)

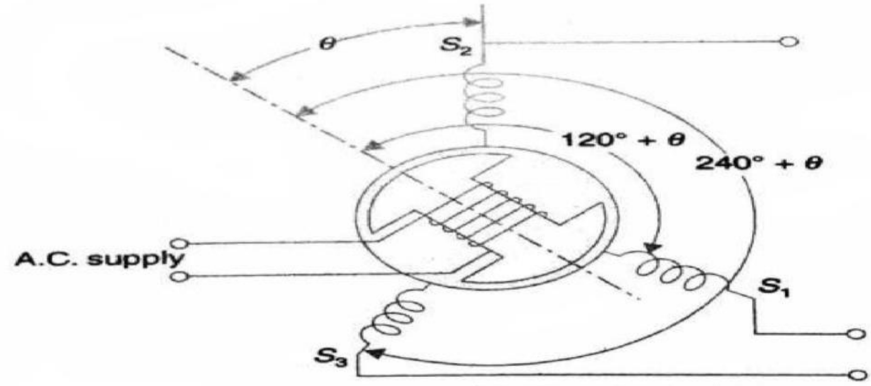
(a) Torque Transmission Using Synchro Trans
(b) Follow Up Conditions of Transmitter-Receiver System

Theory:

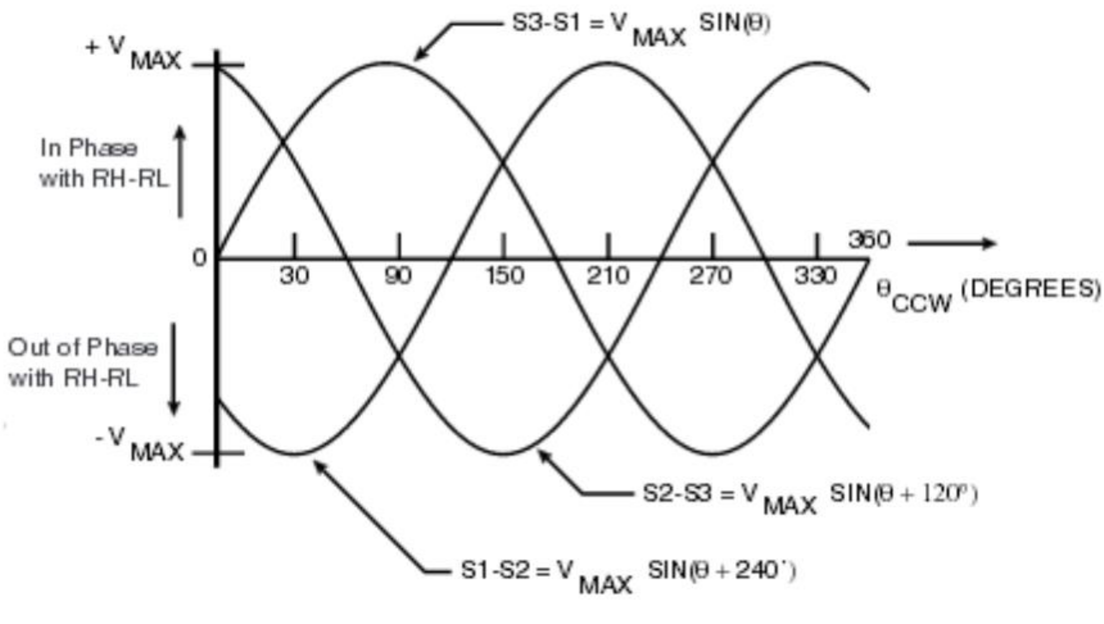
SYNCHRO TRANSMITTER & RECEIVER PAIR:-



contructional features of synchro transmeter



schematic diagram of synchro transmitter



A Synchro is an electromagnetic transducer commonly used to convert an angular position of a shaft into an electric signal.

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 (three identical coils are placed in the stator with their axis 120 degree apart) and is star connected. The rotor is a dumb bell construction and wound with a concentric coil. AC voltage is applied to the rotor winding through slip ring

Let an A.C Voltage $V_r(t)= V_r$ sin Wet

be supplied to the rotor of the Synchro transmitter. This voltage causes a flow of magnetizing current in the rotor coil which produces a sinusoidal time varying flux directed along its axis and distributed nearly sinusoidal in the air gap along stator periphery. Because of transformer action, voltages are induced in each of the stator coils. As the air gap flux is sinusoidal distributed, the flux linking any stator coil is proportional to the cosine of the angle between rotor and stator coil axis and so is the voltage induced in each stator coil.

The stator coil voltages are of course in time phase with each other. Thus we see that the Synchro transmitter acts like single phase transformer in which rotor coil is the primary and the stator coil *form* three secondaries.

Let V_{s1} N. V_{s2} N and V_{s3} N respectively be the voltages induced in the stator coils S_1, S_2 and S_3 with respect to the neutral. Then for the rotor position of the Synchro transmitter showed in figure, where the rotor axis makes an angle 0 with the axis of the stator coil S_2.

Let $V_{s2}N = KV_r \cos(\theta) \sin \omega_{et}$

$V_{S3}N = KV_r \cos(\theta + 120) \sin \omega_{et}$

$V_{S1}N = KV_r \cos(\theta + 240) \sin \omega_{et}$

The three terminal voltages of the stator are

$V_{S1S2} = V_{SL}N - V_{S2}N$
$=\sqrt{3}\, KE_r \sin(\theta + 240^0)\, sin\omega t$

$V_{S2S3} = V_{S2}N - V_{S3}N$
$=\sqrt{3}\, KE_r \sin(\theta + 120^0)\, sin\omega t$

$V_{S3S1} = V_{S3}N - V_{S1}N$
$=\sqrt{3}\, KE_r \sin\theta\, sin\omega t$

When 0 is zero, it is seen that maximum voltage is induced in the stator coil S_2 while it follows that the terminal voltage V_{S3S1} is zero. This position of rotor is defined.

As the electrical zero of the T_X and is used as a reference for specifying the angular

Position of the rotor.

Thus is seen that the Synchro transmitter is the angular position of its rotor shaft and the output is a set of three **SINGLE** phase voltages.1 he magnitude of these voltages are functions of a shaft position.

The classical Synchro system consists of two units.

1. Synchro transmitter.
2. Synchro receiver.

The Synchro receiver is having almost the same constructional features. The two units are connected as shown in figure. Initially the winding S2 of the stator of transmitter is positioned for maximum coupling with rotor winding. Suppose its voltage is V, the coupling between S1 and S2 of the stator and primary [ROTOR] wincing is a cosine function. Therefore the effective voltages in these winding are proportional to 60 degrees or they are V/2 each. So long as the rotors of the transmitters and receivers remain in this position, no current will flow between windings because of voltage balance.

When the rotor of TRANSMITTER is moved to a new position, the voltage balance is distributed, Assume that the rotor of TRANSMITTER is moved through 30 degrees, the stator winding voltages will be changed to zero 0.866V and 0.866V respectively. Thus there is a voltage imbalance between the windings cause's currents to flow through the close circuit producing torque that tends to rotate the rotor of the receiver to a new position where the voltage balance is again restored. This balance is restored only if the receiver turns through the same angle as the transmitter and also the direction of the rotation is the same as that of TRANSMITTER.

The TRANSMITTER & RECEIVER pair thus serves to transmit information regarding angular position at one point to a remote point.

PROCEDURE:

1. Connect the mains supply to the system with the help of cable provide! Do not interconnect S_I, S_2 and S_3 to $S_{1'}$&$S_{2'}$ and $S_{3'}$.
2. Switch ON mains supply for the unit and transmitter rotor supply.
3. Starting from zero position, note down the voltage between stator winding terminals i.e. $V_{S1S2}V_{S1S3}$ and V_{S2S3} in a sequential manner. Enter readings in a tabular form and plot a graph of angular position V/S rotor voltages for all three phases.
4. Note that zero position of the stator rotor coincide with $V_{S3\,S1}$ voltage equal to zero voltage. Do not disturb this condition.

Study of Synchro transmitter and receiver pair:-

PROCEDURE:'

1. Connect mains; supply cable.
2. Connect S_I, S_2, S3 terminals of transmitter to S_I, S_2 and S_3 of Synchro receiver by patch cords provided respectively.
3. Switch on Rotor supply of both transmitter and receiver and also switch on the mains supply.
4. Move the pointer i.e. rotor position of Synchro transmitter in steps of 30 degrees and observe the new rotor position. Observe that whenever Transmitter rotor is rotated, the Receiver rotor follows it for both the directions of rotations and their *positions* are in good agreement.
5. Enter the input angular position and output angular position in the tabular form and plot a graph.

PREACAUTIONS:

1. Handle the pointers for both the rotors in a gentle manner.
2. Do not attempt to pull out the pointers.
3. Do not short rotor or stator terminals.

TABLE - 1

SYNCHRO TRANSMITTER ROTOR POSITION VERSUS STATOR

ROTOR VOLTAGE = VOLTS.

SI.no.	Rotor position in degrees	Vs3sl	Vsls2	Vs2s3
1.	00			
2.	30			
3.	60			
4.	90			
5.	120			
6.	150			
7.	180			
8.	210			
9.	240			
10.	270			
11.	300			
12.	330			

TABLE- 2

SI.No.	Transmitter angular position	Receiver angular posilicn
1.	00	
2.	30	
3.	60	
4.	90	
5	120	
6.	150	
7.	180	
8.	210	
9.	240	
10.	270	
11.	300	
12.	330	

Result:

Experiment:3

PROGRAMMABLE LOGIC CONTROLER

Aim: To study and verification of truth tables of logic gates, simple Boolean expressions and application of speed control of motor with PLC.

APPARATUS:

1. PLC kit
2. PC
3. Boolean Algebra kit
4. Logical gate kit
5. Connecting wires

FRONT PANEL FEATURES:

- Switches - S_1,S_2,S_3,& S_4
- Inputs - I_1, I_2, I_3, I_4, I_5,& I_6
- Analogy switches - S_5,& S_6
- Analogy inputs - I_7,& I_8
- Output - Q_1,Q_2, Q_3,& Q_4
- Indicators - red ,yellow ,green and white
- External voltage - 0-10v-2no's

Theory:

PLC HISTORY

In the late 1960's PLCs were first introduced. The primary reason for designing such a device was eliminating the large cost involved in replacing the complicated relay based machine control systems. Bedford Associates (Bedford, MA) proposed something called a Modular Digital Controller (MODICON) to a major US car manufacturer. Other companies at the time proposed computer based schemes, one of which was based upon the PDP-8. The MODICON 084 brought the world's first PLC into commercial production.

When production requirements changed so did the control system. This becomes very expensive when the change is frequent. Since relays are mechanical devices they also have a limited lifetime, which required strict adhesion to maintenance schedules. Troubleshooting was also quite tedious when so many relays are involved. Now picture a machine control panel that included many, possibly hundreds or thousands, of individual relays. The size could be mind boggling. How about the complicated initial wiring of so many individual devices! These relays would be individually wired together in a manner that would yield the desired outcome. Were there problems? You bet!

These "new controllers" also had to be easily programmed by maintenance and plant engineers. The lifetime had to be long and programming changes easily performed. They also had to survive the harsh industrial environment. That's a lot to ask! The answers were to use a programming technique most people were already familiar with and replace mechanical parts with solid-state ones.

In the dominant PLC technologies were sequencer state-machines and the bit-slice based CPU. The AMD 2901 and 2903 were quite popular in Mod icon * * and A-B PLCs. Conventional microprocessors lacked the power to quickly solve PLC logic in all but the smallest PLCs. As conventional microprocessors evolved, larger and larger PLCs were being based upon them. However, even today some are still based upon the 2903. (Ref A-B's PLC-3) Modicon has yet to build a faster PLC than their 984A/B/X which was based upon the 2901.

Communications abilities began to appear in approximately 1973. The first such system was Modicon's Modbus. The PLC could, now talk to other PLCs and they could be far away from the actual machine they were controlling. They could also now be used to send and receive varying voltages to allow them to enter the analog world. Unfortunately, the lack of standardization coupled with continually changing technology has made PLC communications a nightmare of incompatible protocols and physical networks. Still, it was a great decade for the PLC!

The 80's saw an attempt to standardize communications with General Motor's manufacturing automation protocol (MAP). It was also a time for reducing the size of the PLC and making them software programmable through symbolic programming on personal computers instead of dedicated programming terminals or handheld programmers. Today the world's smallest PLC is about the size of a single control relay!

The 90's have seen a gradual reduction in the introduction of new protocols, and the modernization of the physical layers of some of the more popular protocols jtiat survived the 1980's. The latest standard (IEC 1131-3) has tried to merge PLC programming languages under one international standard. We now have PLCs that are programmable in function block diagrams, instruction lists, C and structured text all at the same time! PC's are also being used to

What is a PLC?

A PLC (i.e. Programmable Logic Controller) is a device that was invented to replace the necessary sequential relay circuits for machine control. The PLC works by looking at its inputs and depending upon their state, turning on/off its outputs. The user enters a program,, usually via software, that gives the desired results.

PLCs are used in many "real world" applications. If there is industry present, chances are good that there is a PLC present. If you are involved in machining, packaging, material handling, automated assembly or countless other industries you are probably already using them. If you are not, you are wasting money and time. Almost any application that needs some type of electrical control has a need for a PLC.

For example, let's assume that when a switch turns on we want to turn a solenoid on for 5 seconds and then turn it off regardless of how long the switch is on for. We can do this with a simple external timer. But what if the process included 10 switches and solenoids? We would need 10 external timers. What if the process also needed to count how many times the switches individually turned on? We need a lot of external counters.

As you can see the bigger the process the more of a need we have for a PLC. We can simply program the PLC to count its inputs and turn the solenoids on for the specified time.

We will take a look at what is considered to be the "top 20" PLC instructions. It can be safely estimated that with a firm understanding of these instructions one can solve more than 80% of the applications in existence.

That's right, more than 80%! Of course we'll learn more than just these instructions to help you solve almost ALL your potential PLC applications,

PROCEDURE:

- Switch 'on' the main supply
- Any previous program delete
    1. Select the program
    2. Select the delete option and deleted the program

- Control unit indications, display shows.
    a) Program
    b) Run
    c) Parameters
    d) Utilities
- Selected the program, display shows.
    a) edit
    b) delete
    c) transfer
    d) mod-bus configuration

AND GATE:

- if any program want to feed select the option
- Select the option alt (alternate), display shows.
  I_1
- Three times press the alt and use also the arrow keys, display shows.
  I_1— I_1
- Use arrow key (Z_3) select the second I_1 change the input I_2
  I_1— I_2
- Use arrow key (Z_3) go to the row last
- Select the alt, display shows.
  I_1— I_2--------- Q_1
- Select the esc button and use the arrow keys and select the save&exit and ok
- The program was saved in the control unit.
- The program wants to run to select the run option.
- Select the continue option.

CONNECTION OF WRING FRONT PANEL:

- Connect the switch S_1 to I_1
- Connect the switch S_2 to I_2
- Connect the output Q_1 of the led indicator

- When the switch S_1, S_2 press to signal is given in to the input(I_1 &I_2)
- Switch didn't press signal is not given to input

    1-signal
    0-no signal

AND GATE TABULAR DIAGRAM:

I_1--- I_2------ Q_1

I1	I2	Q1
1	1	1
1	0	0
0	1	0
0	0	0

I_1---I_2--I_3------ Q_1

I1	I2	I3	Q1
1	1	1	1
1	0	1	0
0	1	1	0
1	1	0	0
0	0	0	0

- Press the esc button display shows.
    a) Pause
    b) Stop
    c) Program
    d) Run parameters
- Select the stop option and press the ok button.
- Want to delete the program
    1. Enter the program select the delete option and press the ok button.

NAND GATE:

- if any program want to feed select the option
- Select the option alt (alternate), display shows.

    I_1
- Three times press the alt and use also the arrow keys, display shows.

    I_1— I_1
- Use arrow key (z3) select the second I_1 change the input I_2

    I_1— I_2
- Use arrow key (z3) go to the row last
- Select the alt, display shows.

    I_1— I_2--------- Q_1
- Select the esc button and use the arrow keys and select the save&exit and ok
- The program was saved in the control unit.
- The program wants to run to select the run option.
- Select the continue option.

- Select the arrow keys scroll bar and move the I_1 down press the alt display shows

    I_1--- I_2------ Q_1
    I_1
- Press the alt button display shows I_1, I will be bilking to change the I to q(small) using arrow keys (Z_2,Z_4)
- Using arrow keys (Z_1,Z_3) move the scroll bar second row or row last on Q_1 down
- Press the alt button again, display shows

    I_1--- I_2------ Q_1
    q_1 ---------- Q_1

- Again press the alt button the (1) will be bilked using the arrow keys(Z_2,Z4) and change the (1) to the (2)

    I_1--- I_2------ Q_1
    q_1 ---------- Q_2

- Press the esc button select the save&exit option and press ok button
- Using arrow select the run option and press the ok button and program should continue
- Press ok button
- NAND gate program was feed in the control unit.

CONNECTION OF WRING FRONT PANEL:

- Connect the switch S_1 to I_1
- Connect the switch S_2 to I_2
- Connect the output Q_2 of the led indicator
- When the switch S_1,S_2 press to signal is given in to the input(I_1&I_2)
- Switch didn't press signal is not given to input

  1-signal

  0-no signal

NAND GATE TABULAR DIAGRAM:

I_1--- I_2------ Q_1

q_1 ---------- Q_2

I_1	I_2	Q_1
1	1	0
1	0	1
0	1	1
0	0	1

I_1--- I_2—I_3---- Q_1

q_1 ------------- Q_2

I_1	I_2	I_3	Q_1
1	1	1	0
1	0	1	1
0	1	1	1
1	1	0	1
0	0	0	1

- Press the esc button display shows.
  e) Pause
  f) Stop
  g) Program
  h) Run parameters
- Select the stop option and press the ok button.
- Want to delete the program

  1. Enter the program select the delete option and press the ok button.

OR GATE:

- Select the program option with ok button
- Select the edit option to feed the program
- Press the alt button display shows.

  I_1
- And using the arrow key Z_3 move the scroll bar row last.
- Press the alt button display shows.

  I_1—--------Q_1
- Using arrow key (Z_3) move the scroll bar i1 down or second row.
- Press the alt button display shows i1

I_1—-------Q_1
I_1

- (i) Will bilks using arrow keys (Z_3) (1) will be bilks so change the (1) to (2) using the arrow keys (Z_2, Z_4).

I_1—-------Q_1
I_2

- Press the arrow key Z_3.
- Press the ok button the scroll bar will bilks then use the arrow keys Z_3 and again press the arrow key Z_3, and press ok button.

I_1—┬-----Q_1
I_2----┘

CONNECTION OF WRING FRONT PANEL:

- Connect the switch $S_1$to I_1
- Connect the switch S_2 to I_2
- Connect the output Q_1 of the led indicator
- When the switch S_1&S_2 press to signal is given in to the input(I_1&I_2)
- Switch didn't press signal is not given to input

1-signal
0-no signal

OR GATE TABULAR DIAGRAM:

I_1—┬-----Q_1
I_2----┘

I_1—┬-----Q_1
I_2----┤
I_3----┘

I_1	I_2	Q_1
1	1	1
1	0	1
0	1	1
0	0	0

I_1	I_2	I_3	Q_1
1	1	1	1
1	0	1	1
0	1	1	1
1	1	0	1
0	0	0	0

- Press the esc button display shows.
  - i) Pause
  - j) Stop
  - k) Program
  - l) Run parameters
- Select the stop option and press the ok button.
- Want to delete the program
  1. Enter the program select the delete option and press the ok button.

NOR GATE:

- Select the program option with ok button
- Select the edit option to feed the program
- Press the alt button display shows.

I_1

- And using the arrow key Z_3 move the scroll bar row last.
- Press the alt button display shows.

I_1—-------Q_1

- Using arrow key (Z_3) move the scroll bar I_1 down or second row.
- Press the alt button display shows I_1

I_1—--------Q_1
I_1

- (I) Will bilks using arrow keys (Z_3) (1) will be bilks so change the (1) to (2) using the arrow keys (Z_2, Z_4).

I_1—--------Q_1
I_2

- Press the arrow key Z_3.
- Press the ok button the scroll bar will bilks then use the arrow keys Z_3 and again press the arrow key Z_4, and press ok button.

I_1—┬-----Q_1
I_2----┘

- Select the arrow keys scroll bar and move the I_1 down press the alt display shows

I_1—I_2-------Q_1
I_1

- Press the alt button display shows I_1, I will be bilking to change the I to q(small) using arrow keys (Z_2,Z_4)
- Using arrow keys (Z_1,Z_3) move the scroll bar second row or row last on Q_1 down
- Press the alt button again, display shows

I_1—I_2-----Q_1
q_1---------Q_1

- Again press the alt button the (1) will be bilked using the arrow keys(Z_2, Z_4) and change the (1) to the (2)
- Press the esc button select the save&exit option and press ok button
- Using arrow select the run option and press the ok button and program should continue
- Press ok button
- NOR gate program was feed in the control unit.

<u>CONNECTION OF WRING FRONT PANEL</u>

- Connect the switch S_1 to I_1
- Connect the switch S_2 to I_2
- Connect the output Q_2 of the led indicator
- When the switch S_1 &S_2 press to signal is given in to the input(I_1 &I_2)
- Switch didn't press signal is not given to input

1-signal
0-no signal

<u>NOR GATE TABULAR DIAGRAM</u>

I_1—┬-----Q_1
I_2----┘
q_1---------Q_2

I_1	I_2	Q_1
1	1	0
1	0	0
0	1	0
0	0	1

I_1—┬-----------Q_1
I_2----┤
I_3----┘
q_1--------------Q_2

I_1	I_2	I_3	Q_1
1	1	1	0
1	0	1	0
0	1	1	0
1	1	0	0
0	0	0	1

- Press the esc button display shows.
  - m) Pause
  - n) Stop
  - o) Program
  - p) Run parameters
- Select the stop option and press the ok button.
- Want to delete the program
  1. Enter the program select the delete option and press the ok button.

What does each part do?

- INPUT RELAYS-(contacts) these are connected to the outside world. They physically exist and receive signals from switches, sensors, etc. Typically they are not relays but rather they are transistors.
- INTERNAL UTILITY RELAYS-(contacts) these do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays. There are also some special relays that are dedicated to performing only one task. Some are always on while some are always off. Some are on only once during power-6Ti and are typically used for initializing data that was stored.
- COUNTERS-The fee again do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down. Since they are simulated they are limited in their counting speed. Some manufacturers also include high-speed counters that are hardware based. We can think of these as physically existing. Most times these counters can count up, down or up and down.
- TIMERS-These also do not physically exist. They come in many varieties and increments. The most common type is an on-delay type. Others include off-delay and both retentive and non-retentive types. Increments vary from 1ms through 1s.
- OUTPUT RELAYS-(coils)These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights, etc. They can be transistors, relays, or triads depending upon the model chosen.
- DATA STORAGE-Typically there are registers assigned to simply store data. They are usually used as temporary storage for math or data manipulation. They can also typically be used to store data when power is removed from the PLC. Upon power-up they will still have the same contents as before power was removed. Very convenient and necessary!!

  .

<u>Result:</u>

EXPERIMENT:4

EFFECT OF FEEDBACK ON DC SERVO MOTOR

AIM: To study the performance characteristics of a dc motor angular position control system

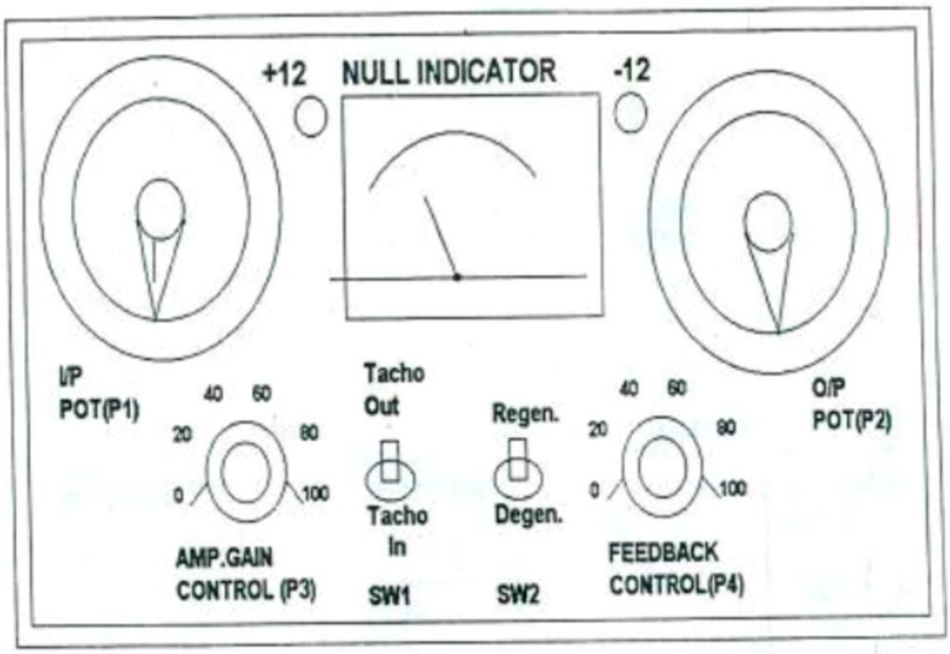
APPARATUS:

DC Servo Motor kit 1 no s

DMM 2 no s

Connecting wires Required

CIRCUIT DIAGRAM & BLOCK DIAGRAM:



THEORY:

The DC servo motors resemble a dc shunt motor turned inside out. Dc servo motors feature permanent magnets, located on the rotor, or a wound rotor excited by dc voltage through slip rings, requires that the flux created by the current carrying conductors in the stator rotate around the inside of the stator in order to achieve servo motor action. The servo motor features a rotating field is obtained by placing three stator windings around the interior of the stator punching. The windings are then interconnected so that introducing a three-phase excitation voltage to the three stator windings (which are separated by 120 electrical degrees) produces a rotating magnetic field. Brushless dc servo motor construction speeds heat dissipation and reduces rotor inertia.

The DC servo motor features permanent magnet poles on the rotor, which are attracted to the rotating poles of the opposite magnetic polarity in the stator creating torque. As in the dc shunt motor, the dc servo motor offers torque, which is proportional to the strength of the permanent magnetic field and the field created by the current carrying conductors. The magnetic field in the dc servo motor stator rotates at a speed proportional to the frequency of the applied voltage and the number of poles.

The rotor rotates in synchronism with the rotating field, thus the name synchronous motor is often used to designate servo motors of this design. More recently, this servo motor design has been called an electrically commutated motor (ECM) due to its similarity to the dc shunt motor. In the dc shunt motor, the flux generated by the current carrying winding (rotor) is mechanically commutated to stay in position with respect to the field flux. In the synchronous dc servo motor, the flux of the current carrying winding rotates with respect to the stator; but, like the dc motor, the current carrying flux stays in position with respect to the field flux that rotates with the rotor. The major difference is that the synchronous dc servo motor maintains position by electrical commutation, rather than mechanical commutation.

PROCEDURE:

OPERATION WITH OUT FEEDBACK:

(SW1 in OFF position i.e., Tacho out)

1). Now slowly advance the input potentiometer P1 in clockwise direction. The output potentiometer along with load will be seen to be following the change in the input potentiometer.

2). When the input is disturbed, the null indicator will be showing some indication but when it may be noted that when input pot is moved in anticlockwise direction, the output pot P2 also moves in the reverse direction.

3). Keep the pot P1 at around 180 degree position. Pot P2 also will be in the same position.

4). Now change the input pot in a step fusion by 60 to 80 degrees. The output will be observed to change in oscillatory mode before it settles to a final position. The tendency for oscillations is found to be dependent on the amplifier gain setting. For high gain there are too many oscillations where as low gain oscillations are reduced but with static error.

OPERATION WITH STABILIZING FEEDBACK:

1. Now put the SW1switch in lower position i.e., Tacho in position. SW2 must be in down position i.e., degeneration mode.

2. Keep P4 in fully anticlockwise direction, output again indicates oscillations.

3. Now take the pot P1 to 1800 position and effect step input change in one of the directions, O/P gain indicates oscillations is found to be dependent on the amplifier gain setting. For high gain there are too many oscillations where as for low gain oscillations are reduced but with static error.

OPERATION WITH STABILIZING FEEDBACK:

1. Now put the Sw1 in lower position.

2. Sw2 must be in down ward position i.e degeneration mode. Keep P4 in fully anti clock wise direction.

3. Now take the pot P1 to 180^0 position, effect the step input change in one of the direction, output again indicates oscillations.

4. Now advance the tachogain pot P4 in clockwise direction, the output now is observed to follow the input in a smooth fashion without oscillation. If the tachogain pot P4 is too much advanced, the output now follows input in a sluggish fashion indicating over damped system.

5. Now the switch SW2 in upward position i.e., regenerative mode. Now if the pot P1 is disturbed, the output pot P2 is found to oscillate continuously around the desired position. As the amount of feedback is adjusted the frequency and the amplitude of output is observed to vary.

6.Bring the switch SW2 in down ward position.

Warning: Do not operate the DC position control in regenerative mode for long time. This can damage the potentiometers

OBSERVATION TABLES:

Without stabilizing feedback(SW1 upward):

S.No.	Input angular position in degrees	Output angular position in degrees	Remarks

With stabilizing feedback (SW1 downward):

S.No.	Input angular position in degrees	Output angular position in degrees	Remarks SW2 in regenerative mode

With stabilizing feedback (SW1 downward):

S.No.	Input angular position in degrees	Output angular position in degrees	Remarks SW2 in degenerative mode

PRECAUTIONS:

1. Please do not cross zero degree position by moving pot P1 i.e., do not operate between 330 and 10 degrees.
2. Do not try to rotate output potentiometer by hand. This may damage the potentiometer.
3. Students should note the following: Try to understand the function of output potentiometer.
4. The null indicator indicates a small deviation from zero indication at various positions of angle 1 and 2. This is so because of backlash in the gear, friction and the fact that some definite torque is required to be produced by the motor, so that the system can be set in to rotation. More over this torque goes on changing from position to position. Hence this causes error.
5. Observe the effect of change in amplifier gain. Higher the gain, smaller is the error.
6. When system is not using, keep SW3 and SW4 in OFF position (upward position) to avoid heating and possible damage of the power stage.

RESULT:

IVA VOCE QUESTIONS:

1. What is meant by servo motor?
2. How it is different from DC motor?
3. Explain the advantages of DC servo motor.
4. Draw the characteristics of DC servo motor.

Experiment:5

TRANSFER FUNCTION OF DC MOTOR

Aim: Transfer Function Of Dc Motor

Appartus:

CONTROLLER FOR DC MOTOR

FRONT PANEL DETAILS:

1. **AC IN** : Transfer to connect 230volts ***AC*** mains supply.
2. **MCB** : 1 pole / 6 ***A MCB*** to turn ***OFF / ON AC*** supply to the Controller.
3. **ARMATURE**
   - **V_a** : Potentiometer to vary the armature voltage from 0-220V.
   - **ON/OFF** : ***ON/OFF*** switch for armature voltage with soft start.
   - **0-220V DC** : 0-220V variable ***DC*** supply for armature 1-phase half controlled bridge rectifier with neon lamp indicator.
   - **0-230VAC** : 0-230V variable ***AC*** supply to find inductance of Field coil with Neon Lamp ***(AC*** voltage controller).

4. FIELD

- **V_f** : Potentiometer to vary the field voltage from 100V to 200V.
- **100-220V DC** : Variable ***DC*** supply from 100V to 200V approximately with Neon Lamp indicator for field.
- **220V DC** : 220V ± 10% @ ***@A*** rectified ***DC*** supply for field supply of ***DC*** motor or generator with Neon Lamp indicator.

DIGITAL VOLTMETER : 3 1/2 digit voltmeter to measure ***AC/DC*** voltage with ***AC/DC*** selector switch.

DIGITAL AMMETER : 3 1/2 digit ammeter to measure ***AC/DC*** current with ***AC/DC*** selector switch.

TRANSFER FUNCTION OF ARMATURE CONTROLLED DC MOTOR:

This setup consists of the following units to conduct the above experiments:

a. DC motor - 0.5HP/220V/1500 rpm with mechanical loading arrangement.

b. Controller unit suitable for the above motor to vary the armature voltage and field voltage with Digital meters.

c. Tachometer: Digital non-contact Tachometer to measure the speed of DC motor.

DC motor - 0.5HP/220V/1500 rpm

Armature Resistance – R_a = …… Ohms

Armature Inductance – L_a = 136 mH

Field Resistance - R_f = 7300 Ohms

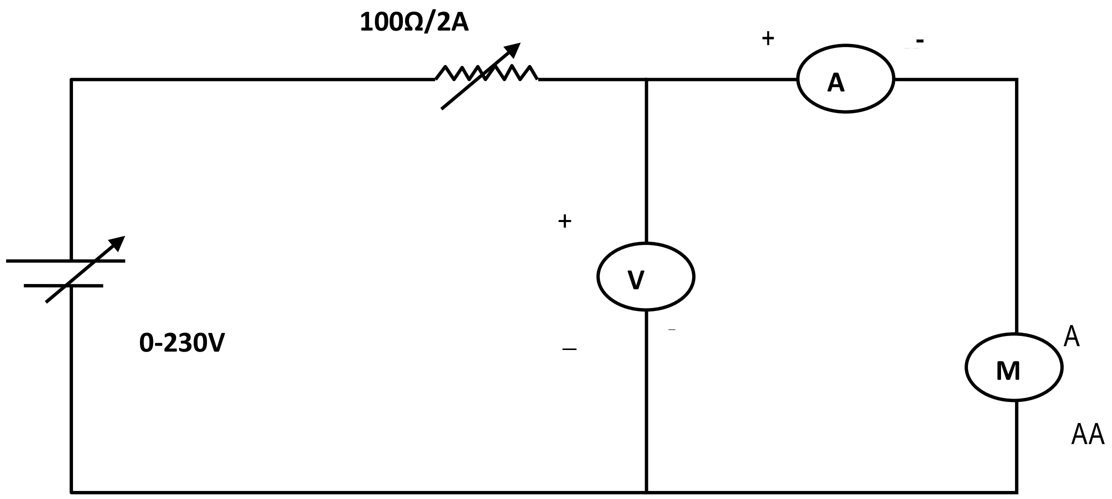
Field Inductance - L_f = 28 H

Moment of Inertia - J = 0.024 Kg- m^2

Friction Co-efficient - B = 0.8

Circuit Diagram:

Measerment Of Armature Resistance



Procedure:

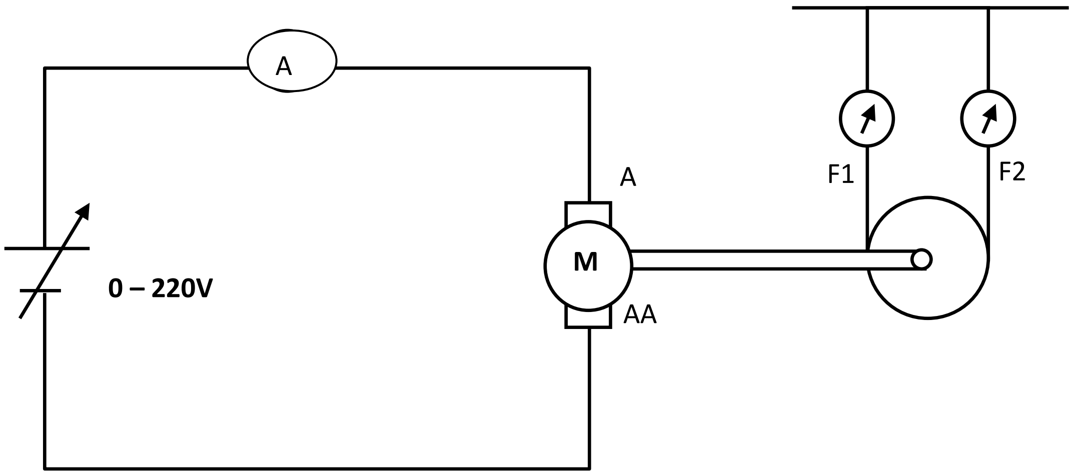
1. Connect the circuit as shown in the figure. Keeping field circuit open.
2. Motor shaft should not rotate.
3. Vary the input voltage from 0-100V from the controller and note down ammeter and voltmeter readings and enter in the tabular column.
4. Calculate the Resistance = V/I
5. Repeat the same for different input voltages.
6. The average resistance value gives the armature resistance.

Table:

V_a *Volts*	1_a *Amps*	R_a = *VJh Ohms*

ARMATURE CONTROLLED DC MOTOR

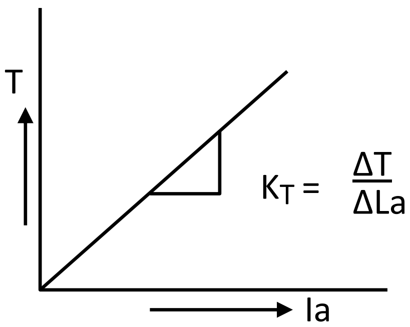
Load **Test on DC Motor:-**



1. Circuit connections are given 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, and F1and F_2 readings.

Switch OFF the armature DCsupply using Armature supply ON/OFF switch and them switch OFF the MCB. *Radius: R= 6.5 cm*

Model Graph



TABLE

SLNo.	*h*		*F_2*	*N rpm*	*T=(F1~F2)* *6.5X9.81N-cm*

Calculations:

Transfer Function of Armature Controlled DC Motor = $\frac{K_t}{S([R_a+SL_a][SJ_m+F_m]+K_tK_b)}$

R_a = Armature resistance

L_a = Armature inductance

I_a = Armature current

E_b = Back emf

T = Torque development

J = Moment of inertia =0.024 Kg-m^2

B = Frictional co-efficient – 0.8

K_b = Back emf constant

K_t = Torque constant

By Kirchhoff's law

$$I_aR_a + L_a\frac{dla}{dt} + E_b = V$$

Since flux is constant torque is proportional to Ia.

T_m α Ia

T_m α K_TIa

Also for Mechanical System

$$J\frac{d\theta m^2}{dt^2} + B\frac{d\theta m}{dt} - T_m$$

Also Back emf Eb **dto** angular velocity of shaft

$E_b = K_b \frac{d\theta m}{dt}$

Dynamic Equation	Laplace Equipment
Tm = K_T Ia Eb = Kb Wm Va - Eb = Ra Ia + La Tm =	Tm (s) - K_T Ia (s) Eb (S) = Kb Wm (s) Va(s) - Eb(s) = Ra Ia (s) + S1a Ia(s) T_m(s) = JmS^2 Θ_m (s) + Sfm Θ_m(s)

By solving the Laplace equation we obtain the transfer function as

$$\frac{\theta(s)}{V(s)} = \frac{k_j}{S([R_a+SL_a][SJ_m+F_m]+k_t k_b)}$$

Result:

Experiment-6

TRANSFER FUNCTION OF DC GENERATOR

Aim: Transfer Function Of Dc - Generator*(Separately excited and Self Excited)*

Apparatus:

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

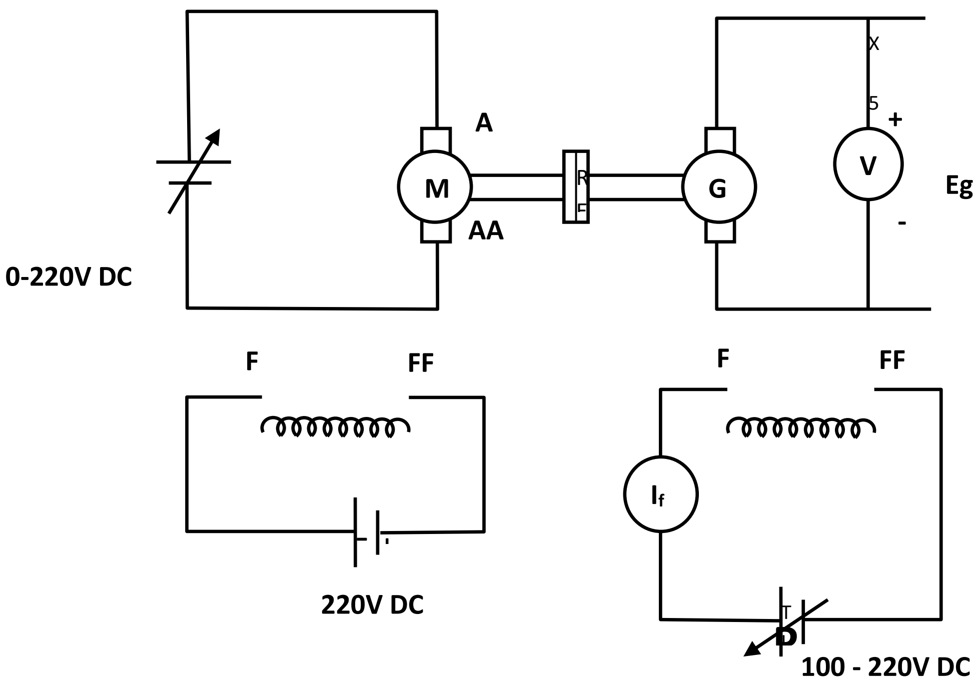
Field Resistance R_f - …….ohms

Field Inductance L_f- 13.5H

Circuit Diagram:

TRANSFER FUNCTION OF DC GENERATOR

(Separately Excited)



Procedure:

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

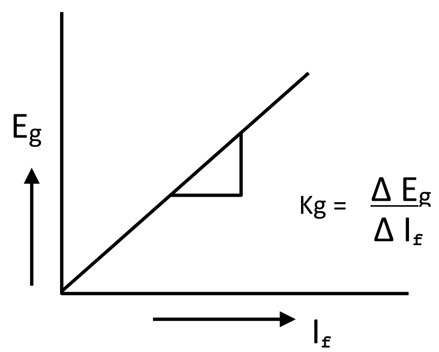
6. Now switch ON the Armature control switch and vary the armature control potentiometer till the motor rotates at its rated speed.

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.

Model Graph:



Tabular Column:

Sl. No.	If Amps	Eg Volts

Results:

Experiment:7

TEMPERATURE CONTROLLER using PID

AIM: To study the temperature performance of an oven using P, PI, PID controller‘s.

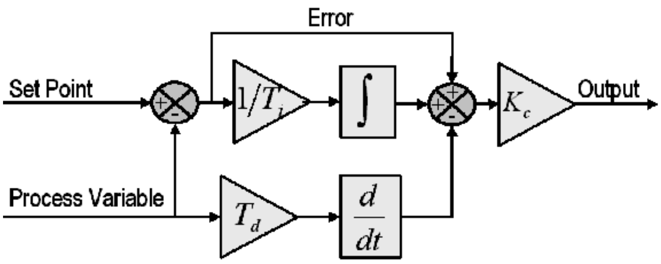
APPRATUS:

S.NO	Equipment	Quantity
1	Temperature control kit	1
2	Oven	1
3	Patch Cards	As Required
4	Stop Watch	1

THEORY

Proportional-Response

The proportional component depends only on the difference between the set point and the process variable. This difference is referred to as the Error term. The proportional gain (K_c) determines the ratio of output response to the error signal. For instance, if the error term has a magnitude of 10, a proportional gain of 5 would produce a proportional response of 50. In general, increasing the proportional gain will increase the speed of the control system response. However, if the proportional gain is too large, the process variable will begin to oscillate. If K_c is increased further, the oscillations will become larger and the system will become unstable and may even oscillate out of control.



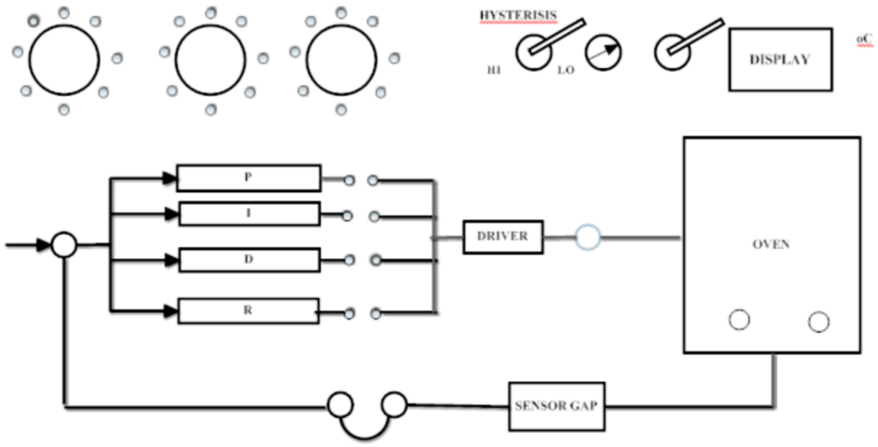
Block diagram of a basic PID control algorithm.

Integral-Response The integral component sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero. Steady-State error is the final difference between the process variable and set point. A phenomenon called integral windup results when integral action saturates a controller without the controller driving the error signal toward zero.

Derivative-Response

The derivative component causes the output to decrease if the process variable is increasing rapidly. The derivative response is proportional to the rate of change of the process variable. Increasing the derivative time (T_d) parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response. Most practical control systems use very small derivative time (T_d), because the Derivative Response is highly sensitive to noise in the process variable signal. If the sensor feedback signal is noisy or if the control loop rate is too slow, the derivative response can make the control system unstable

CIRCUIT DIAGRAM:



Block Diagram of Temperature Control Systems

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 60o 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.

PI 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 60o.

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 60₀.
5. Keep switch S1 to RUN position and record the temperature readings every 15/30 sec about 20 min.

TABULAR COLUMN:

Time in (sec)	Temperature in degrees		
	P	PI	PID

RESULT:

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?

EXPERIMENT:8

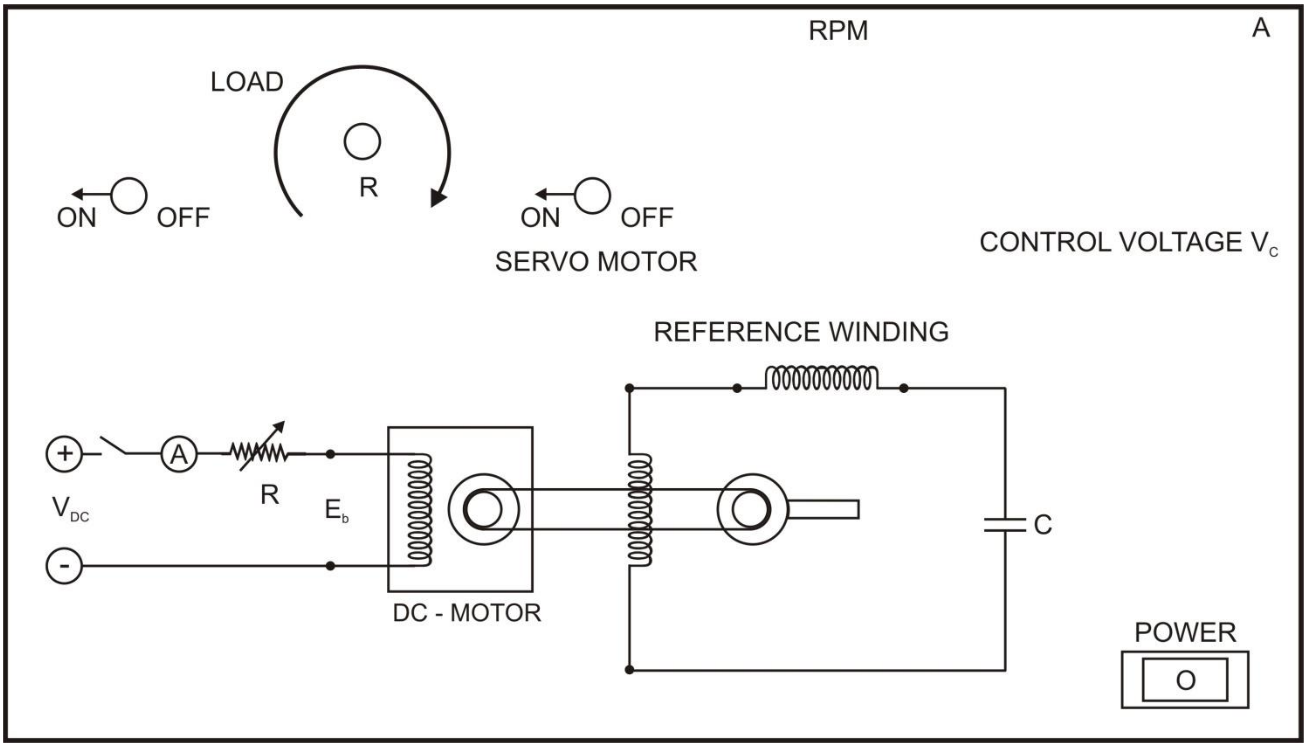
CHARACTERISTICS OF AC SERVOMOTOR

AIM: To find speed torque characteristics of an A.C servomotor

APPARATUS:

1. A.C servomotor training kit
2. Digital multi Meters

CIRCUIT DIAGRAM:



PROCEDURE:

1. Study all the components on the front panel carefully
2. Initially keep load control switch at OFF position. Indicating that the armature circuit of DC machine is not connected to auxiliary DC supply 12Volts. Keep Servo Motor supply switch at OFF Position only.
3. Ensure load potentiometer knob and control voltage knob at minimum position.
4. Now switch ON main supply to the unit and also AC Servo Motor supply switch. Vary the control voltage knob and observe the AC Servo Motor will start rotating

and speed will be indicated by Tachometer on the front panel.

5. With load switch in OFF position vary the speed of AC Servo Motor by moving the control voltage. Note down back e.m.f generated by DC machine.
6. Now note down the values in the table.
7. Now with load switch at OFF position, switch on AC Servo Motor and keep the speed in minimum position you can observe that the AC Servo Motor starts moving with speed being indicated by Tachometer.
8. Now vary the control winding voltage by adjusting control winding voltage knob and set the speed at maximum. Now apply gradually on AC Servo Motor by varying load potentiometer knob slowly.
9. And also note down values of IA, Speed and Control Voltage and calculate Power and Torque, Mechanical Power and Torque.

CALCULATIONS:

Power P = Eb X Ia

$$P = \frac{2pi \times N \times T}{60}$$

TABULAR COLUMN:

Plot Speed Vs Back emf:

Sl. No.	Speed – rpm	Back emf - eb

Speed Torque Characteristics Table:

Sl. No.	Ia mA	N rpm	Eb-Backemf	P-watts	T-Torque (Gm-cm)
1.					

PRECAUTIONS:

1. Before switch on P_1 and P_2 should be always brought to most anti-clock wise position.
2. Control P_1 and P_2 should be operated in gentle fashion.

RESULT:

VIVA QUESTIONS:

1. AC servo motor is which type of motor?
2. Draw the torque speed characteristics?
3. For Ac servo motor $\frac{X}{R}$ ratio is more or less?
4. What type of rotor is used in AC servo motor?
5. How the AC servo motor produces phase displacement of 90^0.

+

EXPERIMENT:9

PID CONTROLLER

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

APPARTUS REQUIRED

1. PID controller kit.
2. Cathode ray oscilloscope
3. Connecting patch cards
4. BNC probes.

THEORY

Proportional Controller (P-Controller)

The proportional controller produces an out put 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 draw back is proportional control action is that it produces a constant steady state error.

Proportional plus Integral Controller (Pi-Controller)

The proportional plus integral controller produces an out put signal consisting of two terms one proportional to error signal and the other proportional to the integral of the error signal.

The transfer function of PI controller is

$$K_c = (1 + \frac{1}{T_{is}})$$

where K_c is equal to proportional gain and T,s is equal to integral time

$$Ki = \frac{Kc}{Tj}$$

Proportional plus Integral plus Derivative Controller (PID-Controller)

A simulate combination of the three basic modes proportional, integral, and derivative (PID) can improve all aspects of the system performance.

The proportional controller stabilizes the gain but produces a steady state error. The integral controller reduces or eliminates the steady state error. The derivative controller reduces the rate of change of error. The combined effect of all three can not be judged from the parameters K_c, K_i & K_d .

$$K_d = K_c T_d$$

The equation of PID controller is given by

$$m(t) = K_c e(t) + K_j \int e(t)\,dt + K_d \frac{de(t)}{dt} \qquad (1)$$

where

e(t) =error signal

.m(t) = PID out put or plant input

Kc = Proportional gain

Kj = integral gain

K_d = Derivative gain

In the Laplace domain, the above equation is written as

$$M(s) = K_c E(s) + \frac{K_i}{s} E(s) + sK_d E(s) \qquad (2)$$

which may be written as the block diagram of Fig.3.

An alternative representation of the, above which is more commonly used in process control literature, is as under:

$$M(s) = K_c \{1 + \frac{1}{T_i S} + T_d s\} E(s)$$

where

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

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

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

$$G_{PID}(S) = \frac{M(s)}{E(s)} = \frac{K_d s^2 + K_c s + K_i}{s}$$

$$= \frac{K_d}{s}(S + \boldsymbol{\omega_1})(S + \boldsymbol{\omega_2})$$

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 seen 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.

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

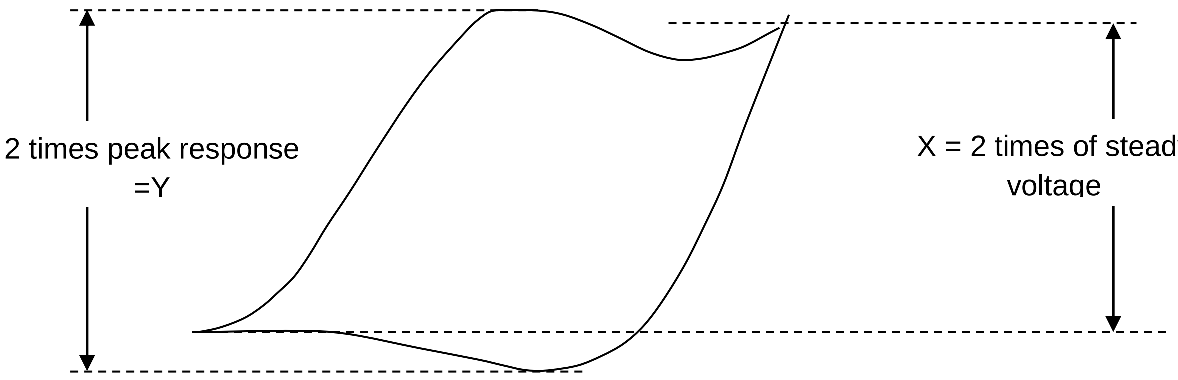
1. Make the connections as shown in Fig (a) with proportional integral and derivative blocks connected.
2. Set input amplitude to 1V(p-p) frequency to a low value K_c =0.6, K_l =0.06, K_d =0
3. The system shows a fairly large over shoot record the peak over shoot and steady state error. Repeat the above steps for a non-zero value K_d.

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

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

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

OUTPUT WAVE FORM



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

% peak overshoot = $\frac{Y - X}{}$ %

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

TABULAR FORM

For P-Controller

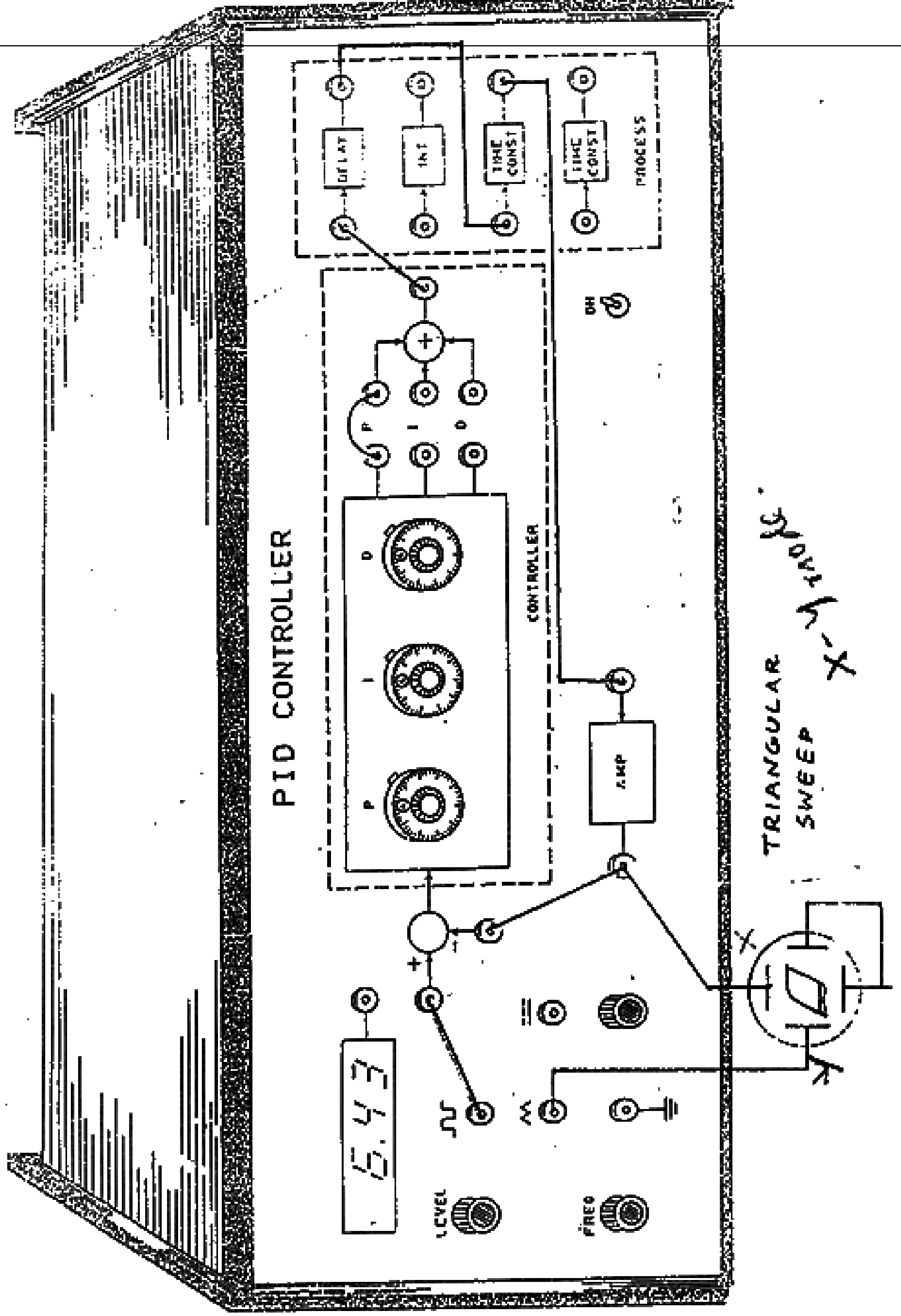
S. NO.	K_P	X	Y	Stedy state Error	% peak overshot

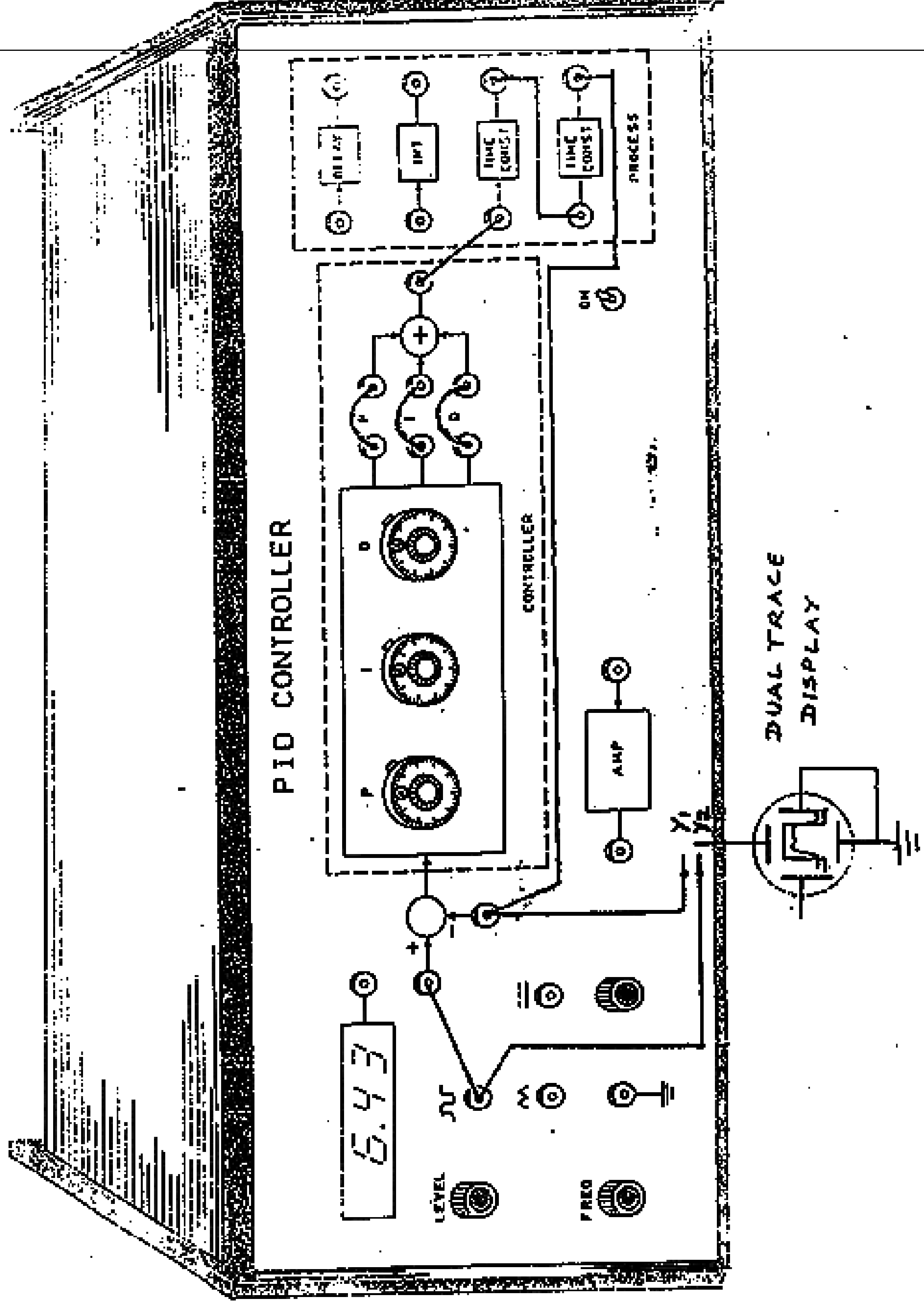
For PI-Controller P=0.6

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

For PID-Controller P=0.6, I=0.06

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


PID CONTROLLER
CONTROLLER
P
I
D
PROCESS
DELAY
INT
TIME CONST
TIME CONST
AMP
ON
6.43
LEVEL
FREQ
TRIANGULAR SWEEP


PID CONTROLLER
6.43
LEVEL
FREQ
P
I
D
CONTROLLER
AMP
DELAY
INT
TIME CONST
TIME CONST
PROCESS
ON
DUAL TRACE
DISPLAY

Experiment:10

COMPENSATION DESIGN

Aim:

To design implement and study the effect of lag and lead compensation network for a given system.

Apparatus required:

1. Compensation design kit-1.
2. Cathode ray oscilloscope
3. BNC probes.
4. Decade resistance boxes (DRB) -2
5. Decade Capacitance box-1
6. Patch cords.

Theory:

Practical control system uses a range of mechanical, electrical, hydraulic, thermal and other type of components for their operation. Examples include motors, gears, amplifiers, control valves, heat exchangers etc. The design of these components is usually based upon requirements other than those, which might be prescribed by the control engineer. Compensation network is designed to modify the system characteristics and to force it to meet the specifications. Although compensation elements are used at the output (load compensation) and in the feedback path (feed back compensation), the most common form of compensation is the cascade compensation where the compensation acts on the error signal. The principal advantage of this configuration is that the signal level of the error is very low and the error is commonly electrical in nature. Thus the compensation network needs to be a low power electrical network, which is very easy to implement.

In general there are two situations in which compensation is squired, In first case, the system is absolutely unstable and the compensation is required to stabilize it as well as to achieve a specified performance. In second case, the system is stable but the compensation required obtaining the desired performance. The systems, which are type- 2 or higher type systems are usually absolutely unstable for these types of systems; clearly lead compensation is required because only the lead compensator increases the margin of stability.

In type-1 and type-0 systems, stable operation is always possible if the gain is sufficiently reduced. In such cases any of the three compensators lag, lead and lag-lead May be used to obtain the desired performance. The choice of the type of components to be used for compensation depends upon the systems structure.

Frequency - domain performance criterion:

These are specifications indicated on the open loop frequency response curves of the system i.e. Bode plot, Nyquist diagram, Gain magnitude - phase shift plot or the closed loop frequency response of the system. Referring to fig 3 (a) (open loop Bode plot) and fig 3(b) (closed-loop frequency response), the various performance criterion in the frequency-domain are given below.

(i) Gain Margin, is the amount by which the open loop gain may be increased at the phase cross over frequency, cop to bring it to '0' dB.

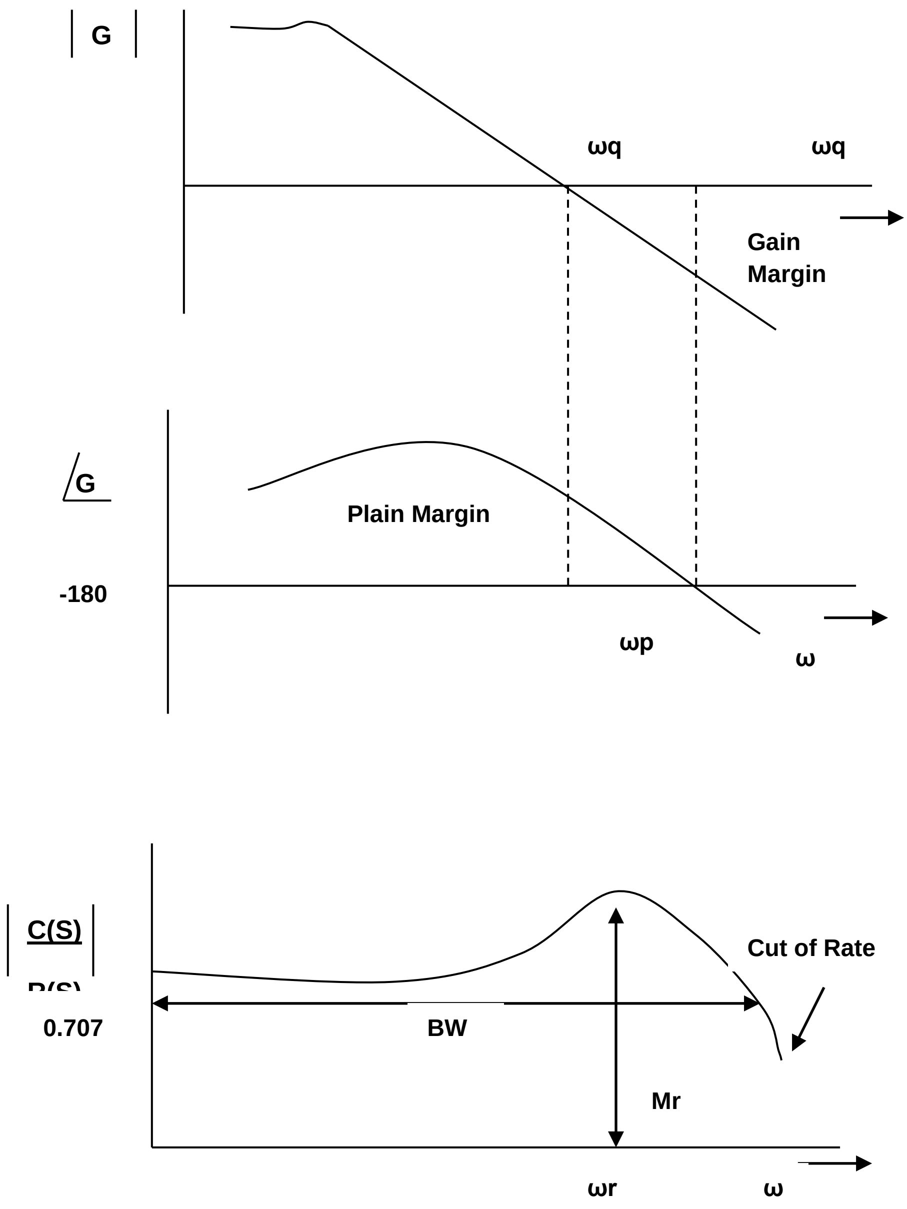


FIG.3. FREQUENCY DOMAIN PERFORMANCE CRITERION

(ii) Phase Margin is the amount by which the open loop transfer function at the gain crosses over frequency. ω_g may be increased in the negative direction to bring it to 180°

(iii) Peak value of the close loop frequency response. Mr

(iv) Frequency at which the peak occurs ωr.

(v) Bandwidth of the close loop frequency *response*.

(vi) Cut-off rate of the closec loop response at the high frequency end

All the above specifications may not be satisfied in a given problem unless these are consistent. Usually the steady state error along with phase margin specifications is required to be satisfied.

In a control system the forward path gain K is frequently adjustable. In general, therefore, the gain may be chosen such that the system either satisfies the steady state specification or the transient specification, but not both the design of the compensation network must then ensure that the other specification is now met without disturbing the first. The most common form of compensation network is an R-C passive network having a pole and a zero. This gives rise to lag' and lead' network depending upon the relative locations of the pole and the zero. The characteristics of the networks are given below.

1) Lag network representation in s-plain is consists of a pole at - 1 /βT and a zero at -1/T with zero located at left of the pole on the negative real axis. The general form of the transfer function of the lag compensator is

$$G_c(s) = (s+zc)/(s+pc) = (s+1/T)/(s+1/\ \beta T);\ \beta = zc/pc>1,1 >0$$

The realization of the transfer function is achieved with an electric lag form which we can write

$$E_0(s)/Ei(s) =(R_2+1/sC)/(R_1+R_2+1/sC) = (s + 1/T)/(s+1/\beta T)$$

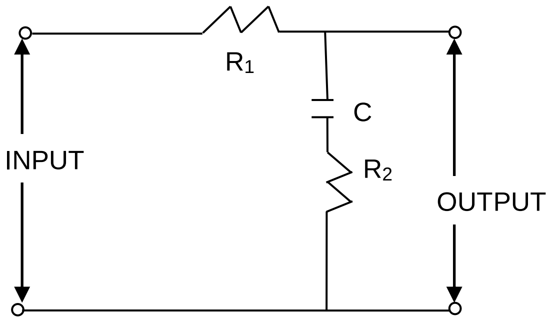
Where, $T = R_2C$, $\beta= (R_1+R_2)/R_2 >1$

$$G_c(s) = Ts+1/\beta Ts+1$$

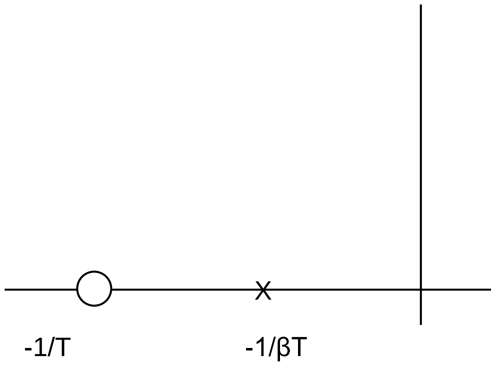
The frequency domain transfer function of the lag network is given by

$$Gc(j\omega) = (1+j\omega T)/(1+J\beta\omega T)$$

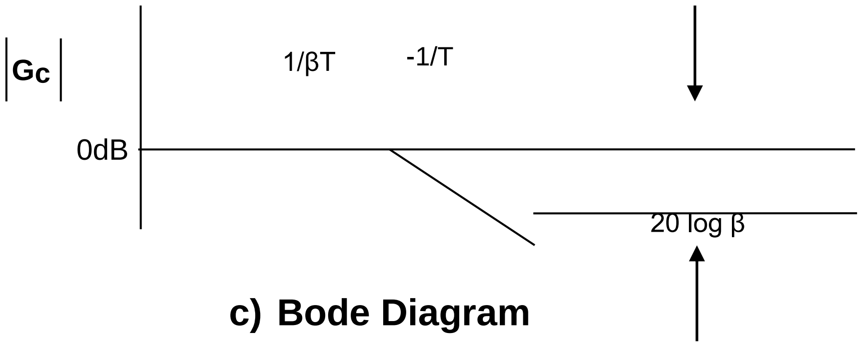
Since β>1, the steady-state output has a lagging phase angle with respect to the sinusoidal input and hence the name lag network. A high frequency noise is attenuated in passing through the network where by the signal to noise ratio is improved in contrast to the lead network.



a) Network Structure



b) Pole – Zero Configuration



c) Bode Diagram

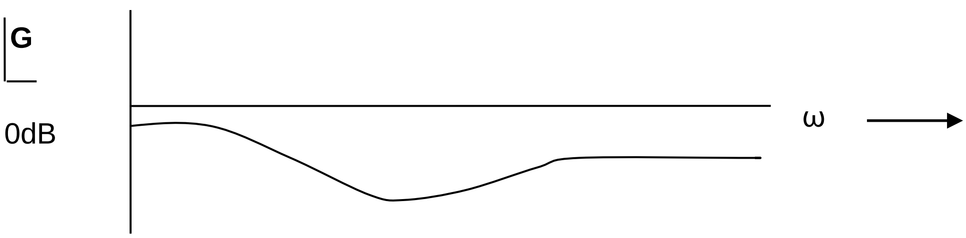
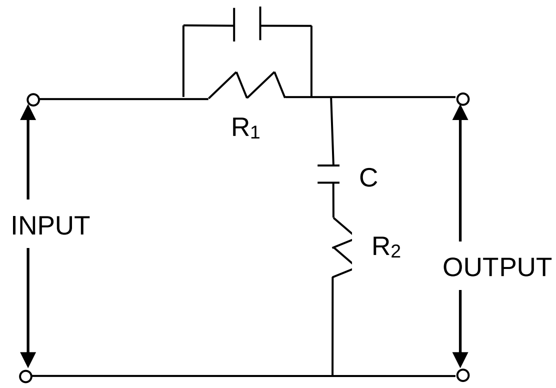
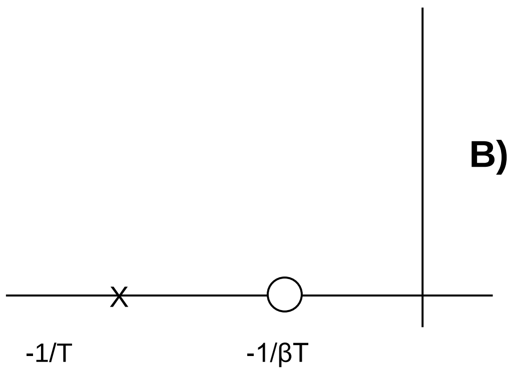


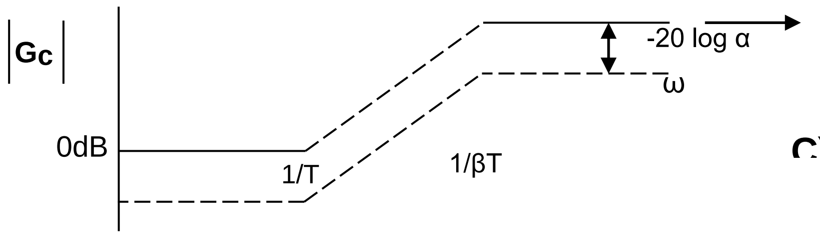
FIG.4. LAG NETWORK CHARECTERISTICS



A) Network Structure



B) Pole – Zero Configuration



C) Bode Diagram

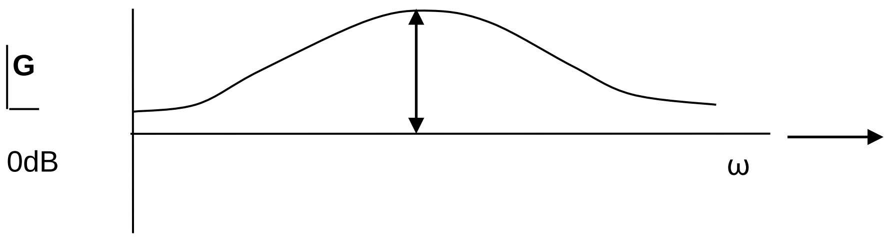


FIG.4. LEAD NETWORK CHARECTERISTICS

Lead network:

The compensator having a transfer function of the form as shown below is known as a lead compensator.

$G_c(s) = (s+zc)/(s+pc) = (s+1/T)/(s+1/\alpha T)$: $\alpha = zc/pc<1, T>0$

It has a zero at $s= -1/T$ and a pole at $s = -1/\alpha T$ with the zero closer to the origin than the pole. An electric lead network can realize the lead compensator with the transfer function above. The transfer function is given by

$$E_0(s)/Ei(s) = R_2/\{R_2+[(Ri/sC)/(R_1+1/sC)]\} = (s + 1/T)/(s+1/\alpha T)$$

Where, $T = R1C$, $\alpha = R_2/(Ri+R_2) <1$

It is to be noted that the values of the three network components R1R2 and C are to be determined from the two lead compensator parameters by using T and a from the equations. Thus there is an additional degree of freedom in the choice of the values of the network components, which is used to set the impedance level of the network

The frequency domain representation of lead network is given below.

$Gc(j\omega) = (1+j\omega T)/(1+j\alpha\omega T)$; $\alpha<1$

Since $\alpha<1$ the network output leads the sinusoid input under steady-state and hence the name lead compensator.

PROCEDURE:

Bode Plot of the Plant

As a first step the magnitude -frequency and phase-frequency plots are to be sketched from experimental data.

- Disconnect the COMPENSATION terminals and apply an input, say 1V p-p to the plant from the built in sine-wave source. Vary the frequency and calculate plant gain in dB and phase angle in degree at each frequency. Sketch the Bode diagram on a semi-log graph paper.
- From low frequency end of the magnitude plot, obtain the error coefficient and the Steady error.
- Calculate the forward path gain K necessary to meet the steady state error specifications.
- Set the above value of K, short the COMPENSATION terminals and observe the step response of the closed loop system. Compute the time-domain performance specifications, namely, Mp, tp, e_{ss} and ζ.
- Shift up the magnitude curve by 20 $\log_{10}$ and obtain the value of margin compare with the given specifications of phase margin.

For lag network

- From the Bode plot find a frequency where PM actual - PM specified + safety margin (5° to 10°). From that find the new gain cross over frequency ω_{gnew}
- Measure gain at ω_{gnew} this must equal the high frequency attenuation of the network i.e. 20log β Compute β.
- Choose zc=-1/T at approx 0.1 ω_{gnew} and P_c=-1/βT accordingly. -
- Write the transfer function $G_c(s)$ and calculate R_1, R2 and C.
- Implement $G_c(s)$ with the help of a few passive components and the amplifier provided for this purpose. The gain of the amplifier must be set at unity.
- Insert the compensator and determine experimentally the phase margin of the plant.
- Observe the step response of the compensated system. Obtain the values of M_P t_P and e_Ss and ζ

For lead network

- From the Bode diagram obtained calculate the required phase lead as Phase lead needed (Φ_m) = $PM_{specified}$ – $PM_{available}$ + safety margin (5° to 10°).

- calculate a for the lead network from a = (1 - sin Φ_m)/ (1 + sin Φ_m)
- Calculate new gain cross-over frequency ω_{gnew} such that

$$|G|\,\omega_{gnew} = 10 \log\alpha$$

This step ensures that maximum phase lead shall be added at the new gain cross-over frequency.

- The corner frequencies are now calculated from l/T = vαω_m and 1/αT=ω_m/vα.
- Implement $G_c(s)$ with the help of a few passive components and the amplifier provided for this purpose. The gain of the amplifier is to be set to 1/α.
- Insert the compensation and determine experimentally the phase margin of the plant with compensator.
  - Observe the step response of the compensated system. Obtain the values of M_P t_P and e_Ss and ζ

In addition to the above experiments, the measurement of frequency response of closed loop system, both before and after compensation, would provide further insight.

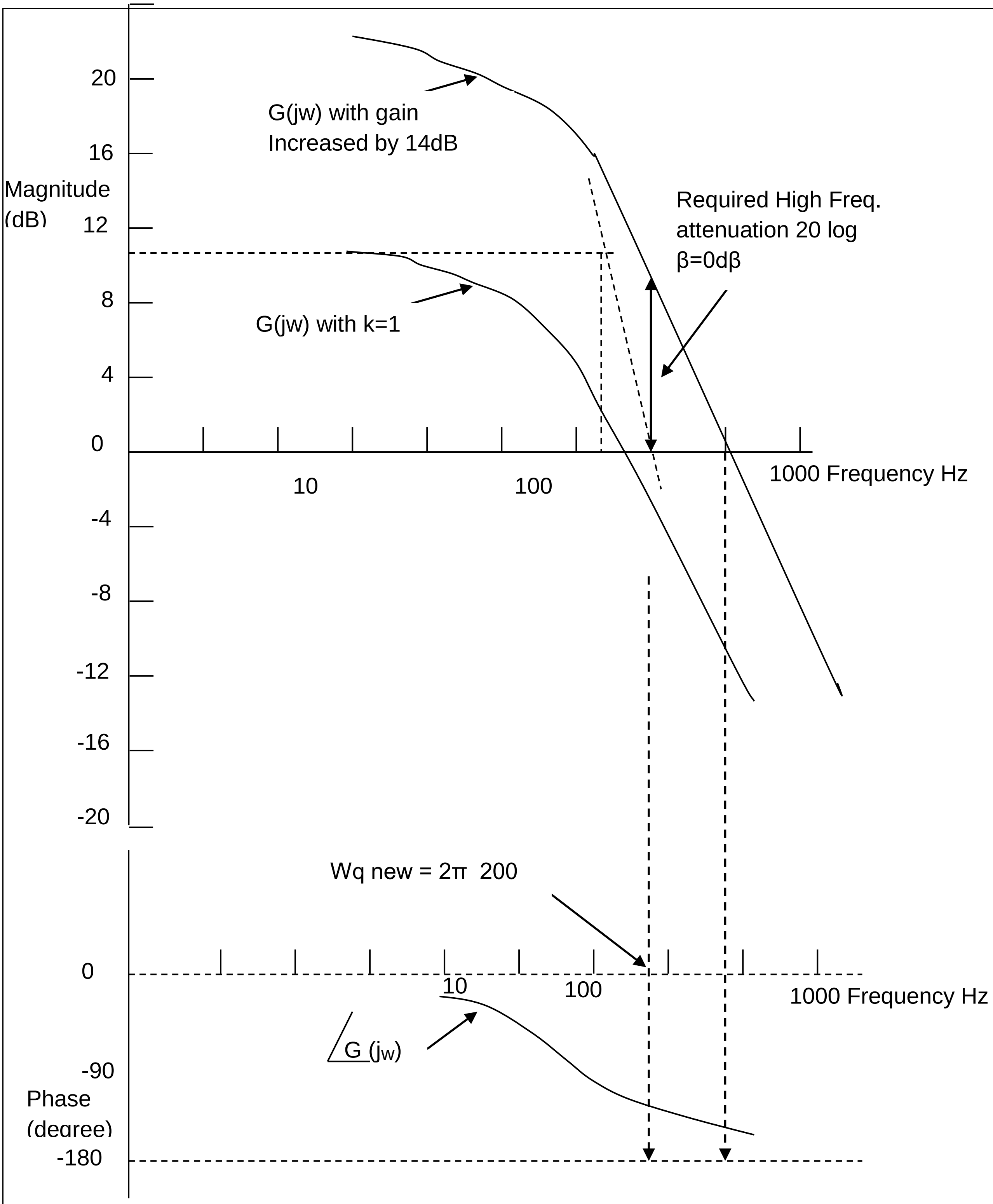


FIG. 7. LAG COMPENSATION DESIGN EXAMPLE

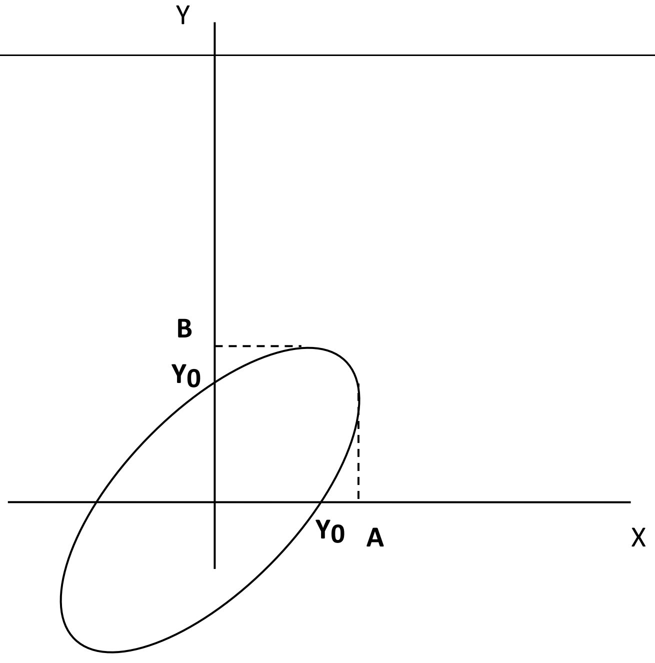


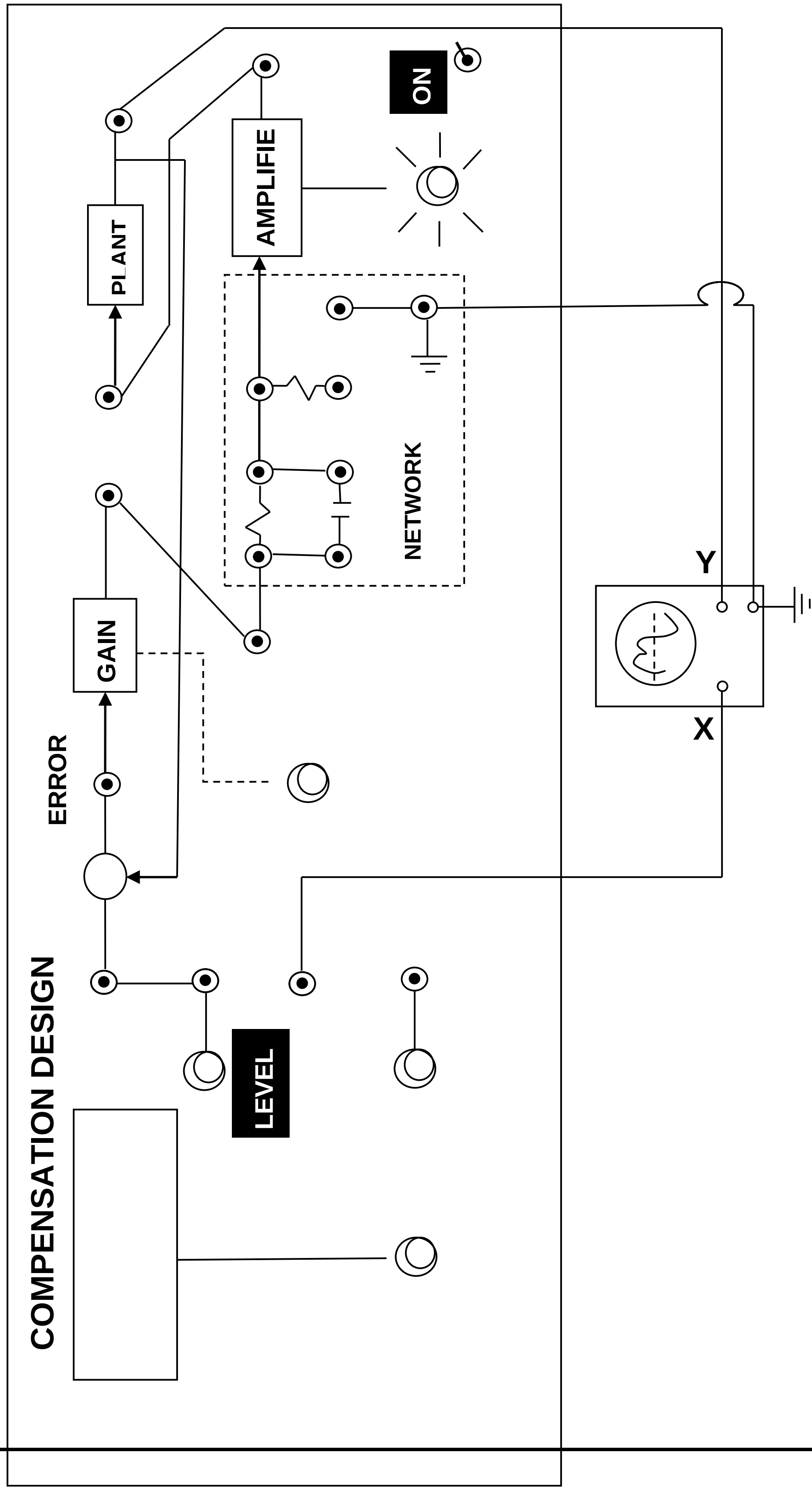
FIG. 6. PHASE AND GAIN MEASURMENT OF CRO

TABULAR FORM:

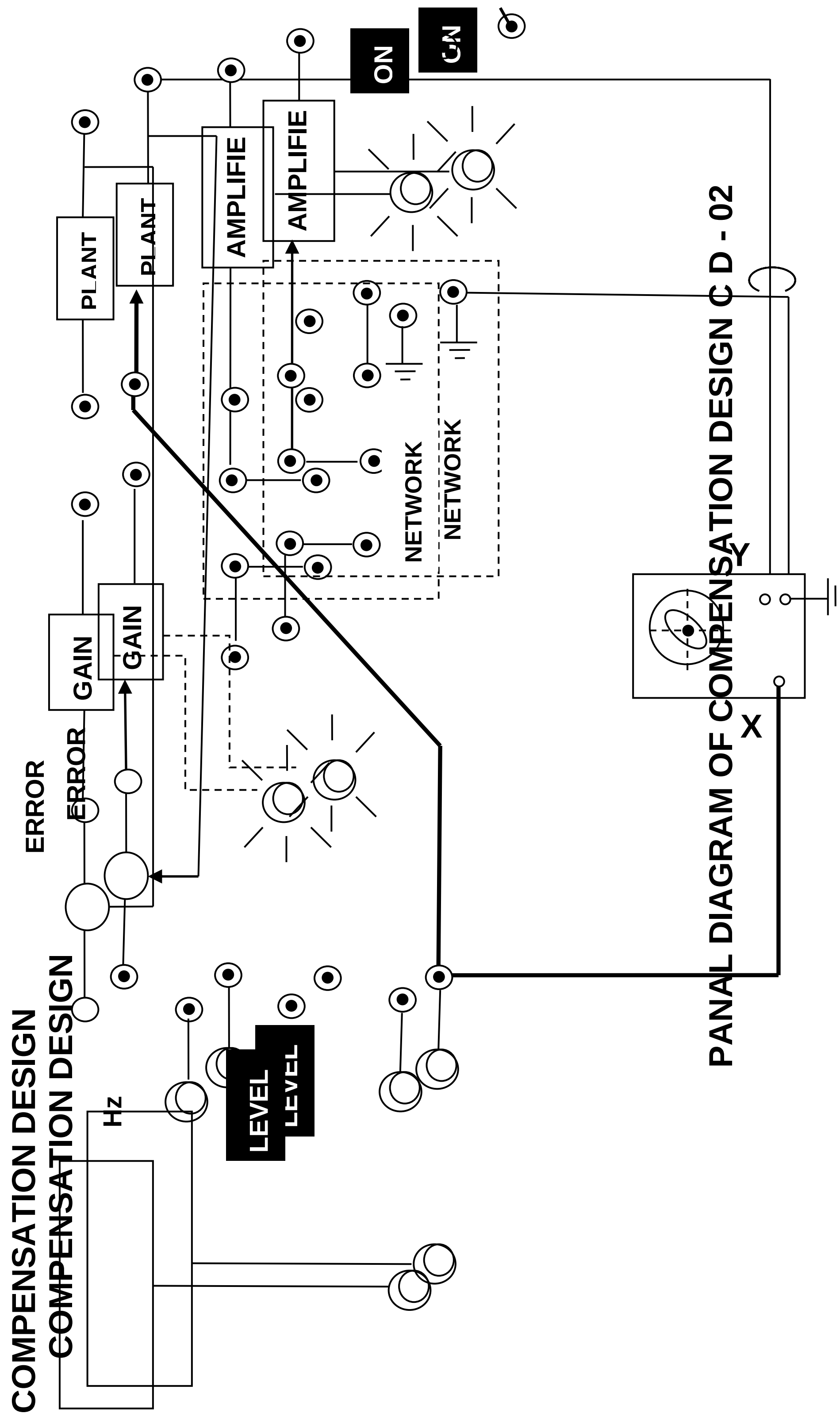
Input 2Volts p-p sine wave, CRO in x-y mode.

Frequency	A	B	Xo	Yo	Gain dB	Phase in degree

Gain =20log(B/A) dB and phase 0—$\sin^{-1}(x_o/A)=-\sin^{-1}(y_0/B)$. Example



COMPENSATION DESIGN FOR LEAD COMPENSATION



CONNECTION DIAGRAM FOR OPEN LOOP RESPONCEC

Experiment:11

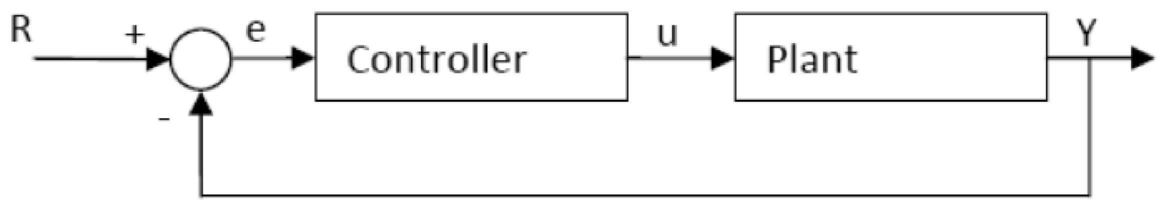
SIMULATION OF P, PD, PI, PID CONTROLLER

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

SOFTWARE REQUIRED:

MATLAB – Personal 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 PIDcontroller, 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 themagnitude of the error plus the integral gain (KI) times the integral of the error plus thederivative 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 various values into the above transfer function

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

Program:

```
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)
```

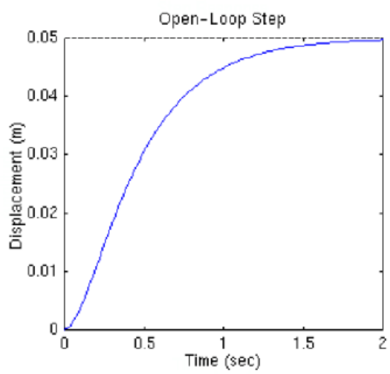
Proportional-Integral control:

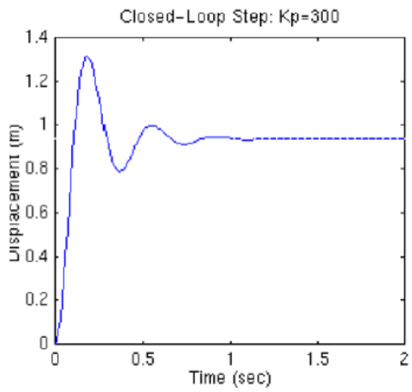
```
Kp=30;
Ki=70;
contr=tf([Kp Ki],[1 0]);
sys_cl=feedback(contr*plant,1);
t=0:0.01:2;
step(sys_cl,t)
```

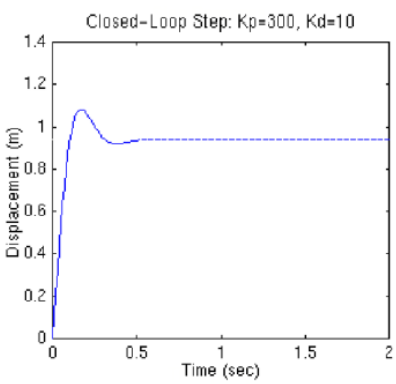
Proportional-Integral-Derivative control:

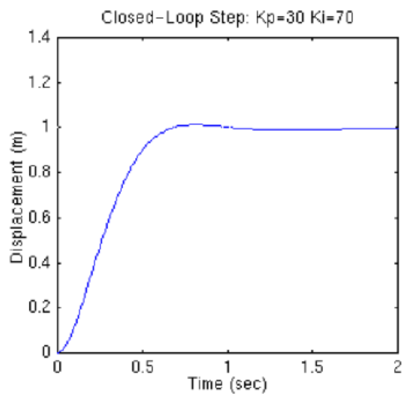
```
Kp=350;
Ki=300;
Kd=50;
contr=tf([Kd Kp Ki],[1 0]);
sys_cl=feedback(contr*plant,1);
t=0:0.01:2;
step(sys_cl,t)
```

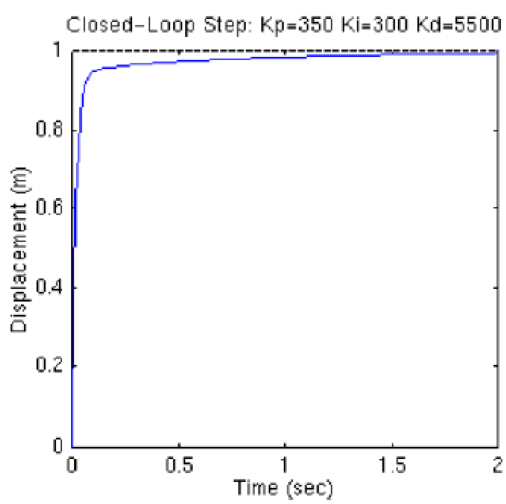
Model graphs











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

Results:

EXPERIMENT:12

STABILITY ANALYSIS [BODE, ROOT LOCUS AND NYQUIST PLOTS] OF LINEAR TIME INVARIANT SYSTEM USING MATLAB

AIM: Construct the root locus, and nyquist plots using MATLAB and verify the same theoretically.

SOFTWARE: MATLAB R 2010a Package

PROGRAMS:

Program 1:

Construction of root – locus for the given transfer function

$$\frac{S^2+2s+4}{s(s+4)(s+6)(s^2+1.4s+1)}$$

Multiplication of all the terms in denominator gives its polynomials: to get this we use convolution command.

Define

a = s(s+4) = S^2 +4s; a = [1 4 0]

b = s+6; b = [1 6]

c = S^2+1. 4s+1 ; c = [1 1.4 1]

Then use the following command

a = conv (a, b); c = conv (c, d)

a = [1 4 0]

b = [1 6]

c=[1 1.4 1]

d = [conv (a,b)

e = 1, 10, 24, 0

f = conv (c, d)

e = 1.000 11.400 39.000 43.60000 24.00000

The denominator polynomial is thus found to be

den = [1111.4 39 43.6 24 0]

To find the open loop of the given transfer function.

P = [1234]

R = roots 9P0

E [124]

R = roots (P)

S = -1.000+1.7321

= -1.000 – 1.7321

Similarly to find the complex conjugate open loop poles (the roots of $S^2 + 1.4s + 1 + 0$). We may enter the roots commands as follows.

Q = roots ©

S = -0.700 + 0.7141 I

-0.700 – 0.7141 I

Thus the system has the following open-loop zeros and open loop poles:

O.L. Zeros : S = -1 + J1.7321; S = -1-J1.732

O/L/ Zeros: S = -0.7 + J07141; S = -0.7 – J0.7141

S = 0; S = -4; S = -6

MATLAB Procedure:

% ………………………………….. Root Locus Plot…………

num = [000124]

den = [1 11.4 39 43.6 24 0]

r locus (num, den)

warning: divide by zero

V = [-10 10 -10 10]; axis (v)

Grid

Title (root Locus plot of GCS) = K(S 2+2s+4) / [s(s+4) (s+6) (s 2+1, 4s+3])

Program 2

Construct the root locus plot for the given function

$$\frac{k(s+1)}{s(s-1(s^2+4s+16)}$$

% ……… Root locus plot.

Num = [00011];

Den = [1 3 12 -16 0]

Locus (num, den)

V = [-6 6 -6 6]; axis (v) axis (‘Square’)

Grid

Title (‘root locus plot of GCS) = K(s+1) / [s(s-1) (s 2 + 4s + 16)}[1]

Program 3

Construct the root locus plot for the given function

G(s) t(s) = $\frac{K}{s(s+0.5(s^2+0.6s+10)}$

$$= \frac{K}{s^4+1.1s^3+10.3s^2+5s}$$

%...........Root Locus plot……………………

Num = [0 0 0 0 1]

Den = [1 1.1 10.3 5 0]

R locus (num, den)

Grid

Time (root locus plot of gls) = K / [s(s+0.5) (s∧2+0.6s+10)][1])

Program 4

Construct the root locus plot for the given function

CL8) = K / [s(s+0.5)(s∧2+0.6s+10)]

```
%...root locus plot……

Num = [      0     0     0     0     1];

Den = [ 1    1.1   10.3  5     0];

K1 = 0  :    0.2:  20;

K2 = 20      :     0.1   30;

K3 = 30      :     5     :     1000;

K = [k1 k2   k3];

R = r locus (num, de, k);

Plot (r, 0b)

V = [-4 4    -4    4]; axis (v)

Grid
```

Title (‘Root – Locus plot of GCS) = K / [s(s+0.5)(S∧2+0.6s+10)][1])

X Label (‘Real axis’)

Y Label (‘imag Axis’)

%..... Note that the command ‘Plot (r, ‘ob’) gives small circles

% in the screen plot in blue color *********

Program 5:

Bode plots using MATLAB

L G (s) = $25/s^2$ +4s +25

Num = [0 0 25];

Den = [1 4 25];

Bode (num, den)

Subject (2, 1, 1)

Bode (Bode diagram of GCS) = 25 / (s∧2 + 4s+25)[1])

Consider the following open loop transfer functions

G (s) = 1 / S^2 + 0.8s + 1

Draw a nyquist plot with MATLAB

MATLAB PROGRAM

Num = [0 0 1];

Den = [1 0.8 1];

Nyquist – (num, den)

Grid

The (*nyquist plot og G(s) = 1 / S ∧ 2 + 0.8s+1)[1])

Consider the following system

$$\begin{bmatrix} \frac{x_1}{x_2} \end{bmatrix} = \begin{bmatrix} \frac{0}{-25} \frac{1}{-4} \end{bmatrix} \begin{bmatrix} \frac{x_1}{x_2} \end{bmatrix} + \begin{bmatrix} \frac{0}{25} \end{bmatrix} x$$

Y = [1 0] $\begin{bmatrix} \frac{x_1}{x_2} \end{bmatrix}$

Draw the bode plots using MATLAB

MATLAB Program:

A = [0 1]: -25 -4];

B = [0 : 25];

C = [1 0]

D = [0]:

Bode (A, B, C, D)

Single (2,1,1):

(Bode diagram)

RESULT:

VIVA QUESTIONS:

1. What is the root locus?
2. What is magnitude criterion?
3. What in angle Criterion?
4. How will you find the gain K at a point on root locus?
5. How will you find root locus on real axis?
6. What are asympotes? How will you find the angle of asympotes?
7. What is the importance of root locus?
8. Give the formula for angle of asympotes?
9. Give the expression for centroid.
10. Give the formula for the break away and break – in – points.
11. How to find the crossing point of root locus in imaginary axis.
12. What is dominant pole?

EXPERIMENT:13

STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING MATLAB – VERIFICATION

AIM: Verify the transfer functions of the systems defined by the state space equations using MATLAB and verify the same theoretically.

SOFTWARE: MATLAB package.

PROGRAM:

%***STATE SPACE MODEL*****%**

$$G(S) = \frac{S}{(S^3 + 14S^2 + 56S + 160)}$$

%****** TRANSFER FUNCTION TO STATE SPACE EQUATION ********%**

num=[0 0 1 0]

den=[1 14 56 160]

[A,B,C,D]=TF2SS(num,den)

%****** STATE SPACE EQUATION TO TRANSFER FUNCTION ********%**

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \end{bmatrix} = \begin{bmatrix} -14 & -56 & -160 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} [u]$$

$$Y = [0\ 1\ 0] \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + [0][u]$$

A=[-14 -56 -160; 1 0 0; 0 1 0]

B=[1; 0; 0]

C=[0 1 0]

D=[0]

[num,den]=SS2TF(A,B,C,D)

RESULT:

VIVA QUESTIONS:

1. Define state of system?
2. Define state variables?
3. What is expression for state transition matrix?
4. Write expression for state equation of linear system?
5. Define “State Space”?

6 For a given n^{th} order system, how many state equations will exist?

7. In physical variable method, which element is treated as state variables?

EXPERIMENT-14

DESIGN OF LEAD-LAG COMPENSATOR FOR THE GIVEN SYSTEM AND WITH SPECIFICATION USING SUITABLE SOFTWARE

AIM:

To design lag-lead compensator using closed loop system.

APPARATUS:

1.Matlab software

THEORY:

A **lead–lag compensator** is a component in a control system that improves an undesirable frequency response in a feedback and control system. It is a fundamental building block in classical control theory.

lagts delays a financial time series object by a specified time step. newfts = lagts(oldfts) delays the data series in oldfts by one time series date entry and returns the result in the object newfts. The end will be padded with zeros, by default.

newfts = lagts(oldfts, lagperiod) shifts time series values to the right on an increasing time scale. lagts delays the data series to happen at a later time. lagperiod is the number of lag periods expressed in the frequency of the time series object oldfts. For example, if oldfts is a daily time series, lagperiod is specified in days. lagts pads the data with zeros (default).

newfts = lagts(oldfts, lagperiod, padmode) lets you pad the data with an arbitrary value, NaN, or Inf rather than zeros by setting padmode to the desired value.

leadts advances a financial time series object by a specified time step. newfts = leadts(oldfts) advances the data series in oldfts by one time series date entry and returns the result in the object newfts. The end will be padded with zeros, by default.

newfts = leadts(oldfts, leadperiod) shifts time series values to the left on an increasing time scale. leadts advances the data series to happen at an earlier time. leadperiod is the number of lead periods expressed in the frequency of the time series object oldfts. For example, if oldfts is a daily time series, leadperiod is specified in days. leadts pads the data with zeros (default).

newfts = leadts(oldfts, leadperiod, padmode) lets you pad the data with an arbitrary value, NaN, or Inf rather than zeros by setting padmode to the desired value.

PROGRAAM:

```
num=input('enter the numerator')
den=input('enter the denominator')
h=tf(num,den)
kv=input('enter velocity error')
phm=input('enter the phase margin')
h1=tf([1 0],[1])
m=dcgain(h1*h)
k=kv/m
g=k*h
[mag phase w]=bode(g)
[gm pm wcg wcp]=margin(g)
e=input('enter margin of safety')
bode(g)
theta=phm+e;
bm=theta-180;
wcm=('enter wcm corresponding to bm')
a=input('enter gain corresponding to wcm')
beta=10^(a/20)
w21g=wcm/4
tou=1/w21g
w11g=1/(beta*tou)
g1=(h1+w21g)/(h1+w11g)
theta1d=theta1d*(pi/180);
alpha=(1-sin(theta1d)/(1+sin(theta1d)))
a=-20*log10(1/sqrt(alpha))
```

```
wcm1d=input('enter the value of wcmld corresponding to gain a1')

w11d=wcm1d*sqrt(alpha)

w21d=wcm1d/sqrt(alpha)

g3=tf([1/w11d1],[1/w21d 1])

g4=g3*g1*g

[mag3 phase3 w3]=bode(g2)

bode(g)

hold

bode(g4)
```

PROCEDURE:

1. Numerator of the given transfer function is assigned to num
2. Denominator of the transfer function is assigned to den
3. The value of the static velocity constant is assigned to the kv
4. Margin of the safty is assigned to e
5. Plot is obtained by in-build function bode()
6. Wcm values assigned to wcm which is obtained from above bode plot The

   gain corresponding to wcm is assigned to a
7. If wcg1>wcg orr wcp1>wcp, the network is compensated otherwise it is not compensated.

Result: