INSTITUTE OF AERONAUTICAL ENGINEERING
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Lab Manual: AEEC14

Laboratory Name(CONTROL SYSTEMS LABORATORY)

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Contents

INTRODUCTION

Introduction

This laboratory course is intended to enhance the learning experience of the student in topics encountered in Control systems AEEB16. In this laboratory, students are trained to get hands-on experience on the usage of the basic measuring circuits used in electrical engineering and in interpreting the results of measurement operations in terms of the concepts introduced in the first electrical circuits course. The student performance in the lab depends on his/her preparation, participation, and teamwork. Each team member must participate in all aspects of the lab to insure a thorough understanding of the equipment and concepts. The student, lab assistant, and faculty coordinator all have certain responsibilities toward successful completion of the lab's goals and objectives.

0.0.1 Student Responsibilities

The student is expected to be prepared for each lab. Lab preparation includes reading the lab experiment and related textbook material. If you have questions or problems with the preparation, contact your faculty coordinator, but in a timely manner. Do not wait until an hour or two before the lab and then expect the faculty coordinator to be immediately available.

The students should wear lab apron and CLOSED TOE SHOES. The HAIR should be protected, let it not be loose. TOOLS, APPARATUS and COMPONENT sets are to be returned before leaving the lab. HEADINGS and DETAILS should be neatly written

1. Aim of the experiment
2. Apparatus required
3. Theory
4. Procedure
5. Theoretical Calculations
6. Circuit diagram
7. Tabulations/Waveforms
8. Result

The student after completing the experiment, the answer to post lab viva-voce questions should be neatly written in the worksheets and get it corrected by the faculty coordinator. After corrected by the faculty coordinator, upload in the college website under the same lab for final evaluation by the faculty.

Active participation by each student in lab activities is expected. The student is expected to ask the faculty coordinator any questions they may have. Do not make costly mistakes because you did not ask a question before proceeding. A large portion of the student's marks are determined in the semester end lab examination (SEE), resulting in a requirement of understanding the concepts and procedure of each lab experiment for the successful completion of the lab class. The student should remain alert and use common sense while performing a lab experiment. They are also responsible for keeping a professional and accurate record of the lab experiments in the lab manual wherever tables are provided. Students should report any errors in the lab manual to the faculty coordinator.

0.0.2 Responsibilities of Faculty Teaching the Lab Course

The Faculty shall be completely familiar with each lab prior to the laboratory. He/She shall provide the students with details regarding the syllabus and safety review during the first week.Lab experiments should be checked in advance to make sure that everything is in working order.The Faculty should demonstrate and explain the experiment and answer any questions posed by the students.Faculty have to supervise the students while they perform the lab experiments. The Faculty is expected to evaluate the lab worksheets and grade them based on their practical skills and understanding of the experiment by taking Viva Voce. Evaluation of work sheets has to be done in a fair and timely manner to enable the students, for uploading them online through their CMS login within the stipulated time.

0.0.3 Laboratory In-charge Responsibilities

The Laboratory In-charge should ensure that the laboratory is properly equipped, i.e., the Faculty teaching the lab receive any equipment/components necessary to perform the experiments.He/She is responsible for ensuring that all the necessary equipment for the lab is available and in working condition. The Laboratory In-charge is responsible for resolving any problems that are identified by the teaching Faculty or the students.

0.0.4 Course Coordinator Responsibilities

The course coordinator is responsible fo rmaking any necessary corrections in Course Description and lab manual. He/She has to ensure that it is continually updated and available to the students in the CMS learning Portal.

0.1 Lab Policy and Grading

The student should understand the following policy:

ATTENDANCE: Attendance is mandatory and any absence must be for a valid excuse and must be documented. If the faculty coordinator is more than 15 minutes late, students may consider lab for the day cancelled.

LAB RECORD's: The student must:

1. Write the work sheets for the allotted experiment and keep them ready before the beginning of eachlab.
2. Keep all work in preparation of and obtained during lab.
3. Perform the experiment and record the observations in the worksheets.
4. Analyze the resultsand get the work sheets evaluated by the Faculty.
5. Upload the evaluated reports online from CMS LOGIN within the stipulated time.

CREDIT SYSTEM:

The final marks of this course are determined using the criterion detailed in the Course Description:

In-class work will be determined by the faculty coordinator, who, at their discretion using information and observations of the students performing the lab. The final exam will contain a written part and a practical (physical operations) part along with viva-voce. COE shall invite 3 - 9 internal/external examiners to evaluate all the semester end examination answer books on a prescribed date(s). Practical laboratory exams are conducted involving external examiners.A minimum of 40

Pre-Requistes and Co-Requisties:

The lab course is to be taken during the samesemester as AHSC03, but receives a separate grade. Students are required to have completed both AHSC03 and AHSC05 with minimum passing grade or better grade in each.

0.2 Course Goals and Objectives

The Physics Laboratory course is designed as a foundation course to provide the student with the knowledge to understand the basic concepts in Physics which have lot of applications in the field of Engineering.

The experiments are designed to complement the concepts introduced in AHSC03. In addition, the student should learn how to record experimental results effectively and present these results in a written report.

More explicitly, the class objectives are:

1. To gain proficiency in the use of common measuring instruments.
2. To enhance understanding of theoretical concepts including:
   - Carrier concentration in semiconducting materials
   - Waves in one Dimension
   - Magnetic Induction
   - Hysteresis losses.
   - Energy Gap in a semiconductor.
   - Photo Diode and its working Principle
   - Numerical Aperture and Acceptance angle of an Optical Fiber.
   - Diffraction due to N Slits
   - Planck's constant
   - Light Emitting Diode and its Working Principle
   - Interference in thin Films
   - Diffraction due to Single slit
3. To develop communication skills through:
   - Verbal interchanges with the Faculty and other students.
   - Preparation of succinct but complete laboratory reports.
   - Maintenance of laboratory worksheets aspermanent, written descriptions of procedures, analysis and results.

4. To compare theoretical predictions with experimental results and to determine the source of any apparent errors.

0.3 Use of Laboratory Instruments

One of the major goals of this lab is to familiarize the student with the proper equipment andtechniques for conducting experiments. Some understanding of the lab instruments is necessaryto avoid personal or equipment damage.By understanding the device's purpose and following a fewsimple rules, costly mistakes can be avoided.

The following rules provide a guideline for instrument protection.

0.3.1 Instrument Protection Rules

1. Set instrument scales to the highest range before turning on the power/source.
2. Be sure instrument grounds are connected properly. Avoid accidental grounding of "hot" leads, i.e., those that are above ground potential.
3. Check polarity markings and connections of instruments carefully before connecting power.
4. Do not exceed the voltage and current ratings of instruments or other circuit elements. This particularly applies to wattmeters since the current or voltage rating may be exceeded with the needle still on the scale.
5. 6. Be sure the fuse and circuit breakers are of suitable value. When connecting electrical elements to make up a network in the laboratory, it is easy to lose track of various points in the network and accidentally connect a wire to the wrong place. A procedure to follow that helps to avoid this is to connect the main series part of the network first, then go back and add the elements in parallel. As an element is added, place a small check by it on your circuit diagram. Then go back and verify all connections before turning on the power. One day someone's life may depend upon your making sure that all has been done correctly

0.4 Data Recording and Reports

0.4.1 The Laboratory Worksheets

Students must record their experimental values in the provided tables in this laboratory manual and reproduce them in the lab worksheets. Worksheets are integral to recording the methodology and results of an experiment. In engineering practice, the laboratory notebook serves as an invaluable reference to the technique used in the lab and is essential when trying to duplicate a result or write a report. Therefore, it is important to learn to keep accurate data. Make plots of data and sketches when these are appropriate in the recording and analysis of observations. Note that the data collected will be an accurate and permanent record of the data obtained during the experiment and the analysis of the results. You will need this record when you are ready to prepare a lab report i.e worksheets.

0.4.2 The Laboratory Files/Reports

Worksheets are the primary means of communicating your experience and conclusions to other professionals. In this course you will use the lab worksheets to inform your faculty coordinator about what you did and what you have learned from the experience. Engineering results are meaningless unless they can be communicated to others. You will be directed by your faculty coordinator to prepare a lab report on a few selected lab experiments during the semester.

Your laboratory report should be clear and concise. The lab report shall be student hand written on a work sheets provided by the college. As a guide, use the format on the next page. Use tables, diagrams, sketches, and plots, as necessary to show what you did, what was observed, and what conclusions you can draw from this by using pencil and scale. Free hand diagrams and tables will reduce your marks. Even though you will work with one or more lab partners, your report will be the result of your individual effort in order to provide you with practice in technical communication.

0.5 Order of Lab Report Components

COVER PAGE - Cover page must include your name and roll number, experiment name and number, the date the lab was performed and signature of the faculty coordinator.

OBJECTIVE - Clearly state the experiment objective in your own words. EQUIPMENT USED - Indicate which equipment was used in performing the experiment.

FOR EACH PART OF THE LAB:
Firstly, describe the problem that you studied in this part, give an introduction of the theory, and explain why you did this experiment. Do not lift the text from the lab manual; use your own words.

Secondly, describe the experimental setup and procedures. Do not follow the lab manual in listing out individual pieces of equipment and assembly instructions. That is not relevant information in a lab report! Instead, describe the circuit as a whole (preferably with diagram), and explain how it works. Your description should take the form of a narrative, and include information not present in the manual, such as descriptions of what happened during intermediate steps of the experiment.

Thirdly, explain your findings. This is the most important part of your report, because here, you show that you understand the experiment beyond the simple level of completing it. Explain (compare expected results with those obtained). Analyse (analyze experimental error). Interpret (explain your results in terms of theoretical issues and relate to your experimental objectives). This part includes tables, graphs, and sample calculations. When showing calculations, it is usual to show the general equation, and one worked example. All the results should be presented even if there is any inconsistency with the theory. It should be possible to understand what is going on by just reading through the text paragraphs, without looking at the figures. Every figure/table must be referenced and discussed somewhere in the text.

Finally, provide a summary of what was learned from this part of the laboratory experiment. If the results seem unexpected or unreliable, discuss them and give possible explanations.

CONCLUSIONS - The conclusion section should provide a take-home message summing up what has been learned from the experiment:

- Briefly restate the purpose of the experiment (the question it was seeking to answer)
- Identify the main findings (answer to the research question)
- Note the main limitations that are relevant to the interpretation of the results
- Summarise what the experiment has contributed to your understanding of the problem.

FURTHER PROBING QUESTIONS - Questions pertaining to this lab must be answered at the end of laboratory report.sss

LAB-1 ORIENTATION

1.1 Introduction

In the first lab period,the students should become familiar with the location of equipment and components in the lab, the course requirements, and the teaching instructor.Students should also make sure that they have all of the co-requisites and pre-requisites for the course at this time.

1.2 Objective

To familiarize the students with the lab facilities, equipment, standard operating procedures, lab safety, and the course requirements.

1.3 Prelab Preparation:

Read the Introduction and procedure of the experiment of respective experiments which are given in this manual

1.4 Equipment needed

Lab Manual

1.5 Procedure

1. During the first laboratory period, the faculty will provide the students with a general idea of what is expected from them in this course. Each student will receive a copy of the syllabus, stating the instructor's contact information. In addition, the instructor will review the safety concepts of the course.

2. During this period, the faculty will briefly review the equipment which will be used through out the semester. The location of instruments, equipment, and components (e.g. resistors, capacitors, connecting wiring) will be indicated. The guidelines for instrument use will be reviewed.

1.6 Further Probing Experiments

Questions pertaining to this lab must be answered at the end of laboratory report

LAB-2 TIME RESPONSE OF SECOND ORDER SYSTEM

2.1 Introduction

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 system. A great deal of analytical results regarding second order systems is available in the text books

2.2 Objective

To determine response of first order and second order systems for step input for several of constant 'K' using linear simulator unit and compare theoretical and practical results.

2.3 Pre lab Preparation:

Theoretical background of second order system and time response at types of damping ratio.

2.4 Equipment needed

S.No	Equipments	Quatity
1	Second order system study unit.	1
2	Cathode Ray Oscilloscope	1
3	Multi meter	1
4	Connecting Leads	As Required

2.5 Background

The time response has utmost importance for the design and analysis of control systems because these are inherently time domain systems where time is independent variable. During the analysis of response, the variation of output with respect to time can be studied and it is known as time response. To obtain satisfactory performance of the system with respect to time must be within the specified limits. From time response analysis and corresponding results, the stability of system, accuracy of system and complete evaluation can be studied easily. Due to the application of an excitation to a system, the response of the system is known as time response and it is a function of time. The two parts of response of any system: (i) Transient response (ii)Steady-state response. Transient response: The part of the time response which goes to zero after large interval of time is known as transient response.

Steady state response: The part of response that means even after the transients have died out is said to be steady state response.

The total response of a system is sum of transient response and steady state response: C(t)=Ctr(t)+Css(t)

TIME RESPONSE OF SECOND ORDER CONTROL SYSTEM: A second order control system is one wherein the highest power of 's' in the denominator of its transfer function equals 2.

2.6 Procedure

1. Connections are given as per the block diagram.
2. Adjust the input square wave such that the magnitude of the wave is 1V (p-p). (Check the square wave in CRO by placing CRO in Channel 1 mode).
3. By varying gain note down the corresponding readings of Peak Time (Tp), Delay Time (Td), Rise Time (Tr), Settling Time (T), Maximum peak over shoot.
4. Take the corresponding values of Peak Time (Tp), Peak Over Shoot (µP) (i.e. Max Peak Value -1) using trace papers.
5. Calculate Damping Ratio (), Undamped Natural Frequency (Wn) from the formulae
6. Calculate the parameters L C of RLC system using the formulae
7. Now calculate Settling Time (Ts), and Damped Frequency (Wd) using the formulae

2.7 Results and Discussion

Table 2.1: Observation Table

S. No.	Gain	Peak Time (TP)	Rise Time (Tr)	Delay Time (Td)	Maximum Peak (P)	Undamped natural frequency (Wn)	SettlingTime (TS)

S. No.	**R**	L	C	Maximum Peak (µP)	Peak Time (TP)	Damping Ratio ()	Undamped natural frequency (n)	Damped Frequency (d)	Settling Time (TS)
1									
2									
3									
4									

2.8 Viva Questions

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

2. What are the Open loop and closed loop control systems?

3. Give the advantages of closed loop control systems

4. What do you mean by feedback and what are the types of feedback?

5. What are the different types of standard inputs

2.9 Further Probing Experiments

1. Perform the linear system circuit for second order for ramp input.

2. Design the linear system simulator for first and second order using LABVIEW.

Figure 2.1: Time Response of Second order System

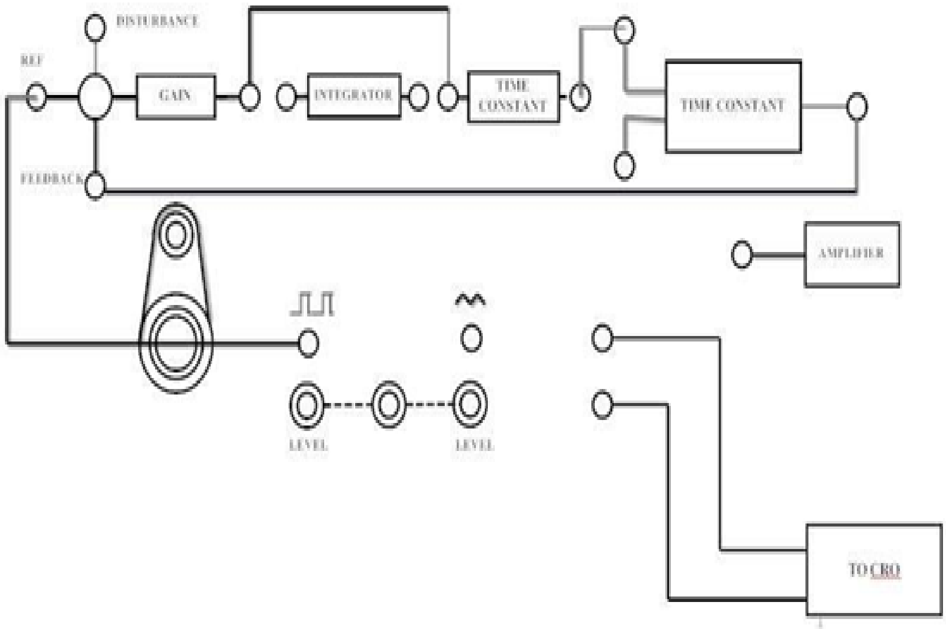


Figure 2.3: Series RLC second order Equivalent Circuit

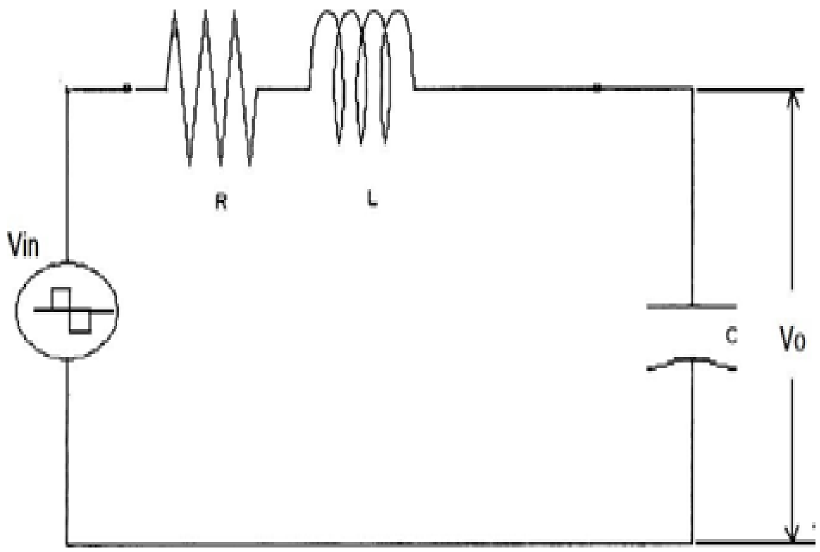
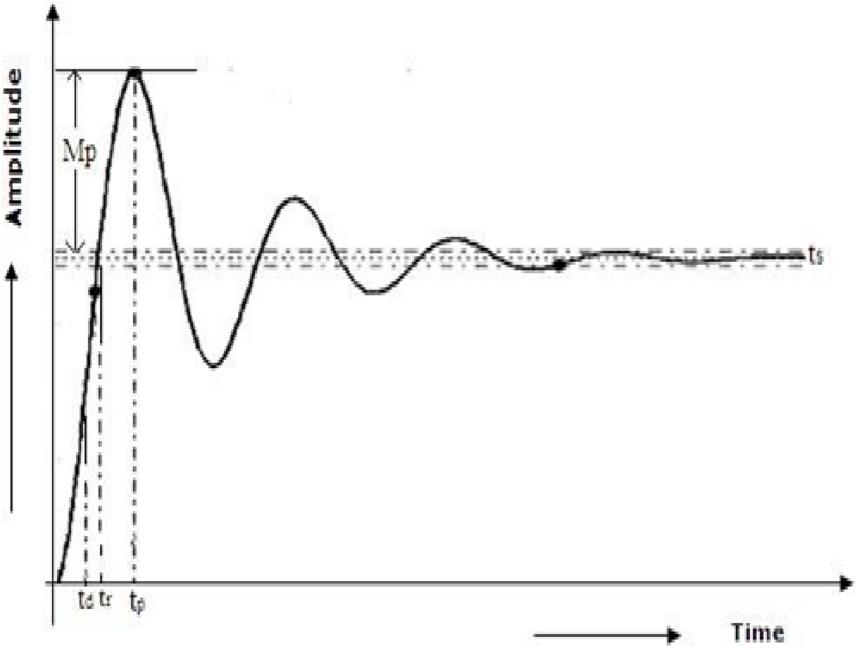


Figure 2.5: Model Graph



LAB-3 TRANSFER FUNCTION OF DC MOTOR

3.1 Introduction

Armature controlled DC shunt motor converts electrical energy into mechanical energy. The speed of the motor is directly proportional to the armature voltage. Armature current is varied to change the torque Tm(t) of the load connected to the motor shaft.

3.2 Objective

By the end of this lab, the student should learn Transfer function of armature controlled dc motor 1. By performing load test on dc motor and speed control by armature voltage control. 2. To plot characteristics between back e.m.f. and angular velocity and armature current Vs torque

3.3 Prelab Preparation:

Theoretical background of armature voltage control of dc motor and its characteristics

3.4 Equipment needed

S. No	Name of the Equipment	Quantity
1	Armature controlled DC motor	1
2	Patch cards	1
3	Tachometer	1

3.5 Background

The speed of DC motor is directly proportional to armature voltage and inversely proportional to flux in field winding. In armature controlled DC motor the desired speed is obtained by varying the armature voltage.The speed of DC motor is directly proportional to armature voltage and inversely proportional to flux in field winding.In armature controlled DC motor the desired speed is obtained by varying the armature voltage.This speed control system is an electro-mechanical control system.We will discuss transfer function of armature controlled dc motor.

The electrical system consists of the armature and the field circuit but for analysis purpose, only the armature circuit is considered because the field is excited by a constant voltage.The mechanical system consist of the rotating part of the motor and load connected to the shaft of the motor.

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

N is the speed of the motor in rpm.

Torque T = (S1 – S2) R x 9.81 N-m.

The slope of plot between Eb Vs w gives Kb.

The slope of plot between Torque Vs Ia gives Kt.

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

3.6 Procedure

LOAD TEST ON DC MOTOR

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

SPEED CONTROL BY ARMATURE VOLTAGE CONTROL

(a) Circuit connections are made as per the circuit diagram.
(b) Connect 220V fixed DC supply to the motor field. Keep the armature control pot at its Maximum position and switch at off position.
(c) Switch ON the MCB, Switch on the armature control switch. Vary the armature voltage and Note down the speed and the corresponding meter readings.
(d) Repeat the same for different armature voltages.

3.7 Results and Discussions

Load Test

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

Armature Voltage Control

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

3.8 Viva Questions

1. Why does the speed fall slightly when the D.C. shunt motor is loaded?

2. How will you avoid the breaking arrangements getting heated?

3. Why the motors are not operated to develop maximum power.

4. What will happen if the field current of the D.C. shunt motor gets interrupted?

5. By applying which law, the direction of rotation of d.c. motor can be determined

3.9 Further Probing Experiments

1. Develop the matlab circuit for transfer function of DC motor

2. Develop the matlab circuit for transfer function of Field controlled of DC motor

Figure 3.1: Load Test on DC Motor

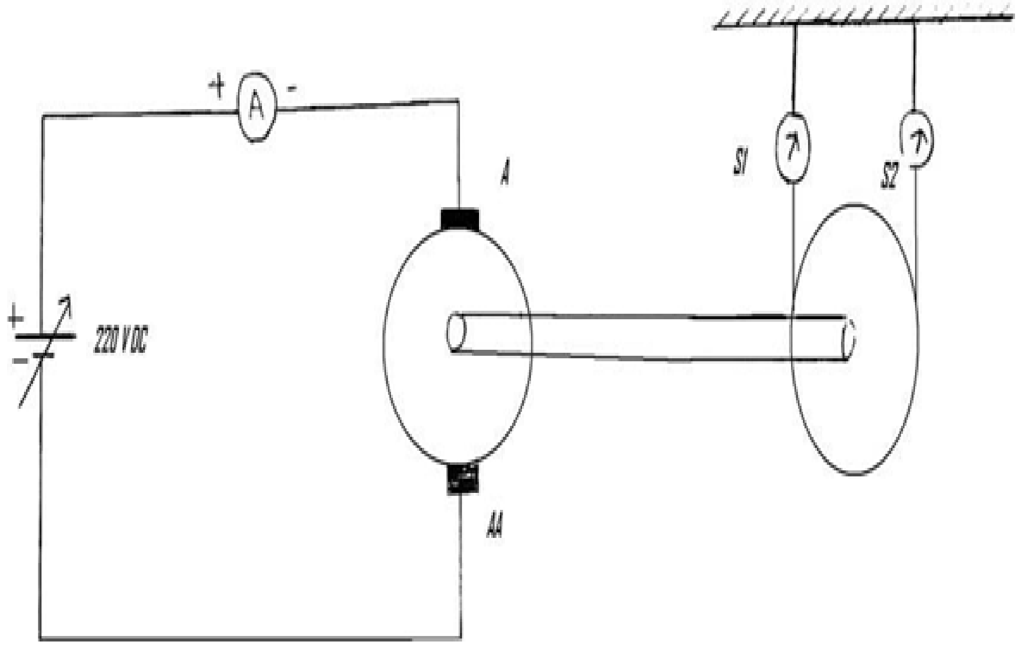


Figure 3.3: Armature voltage control

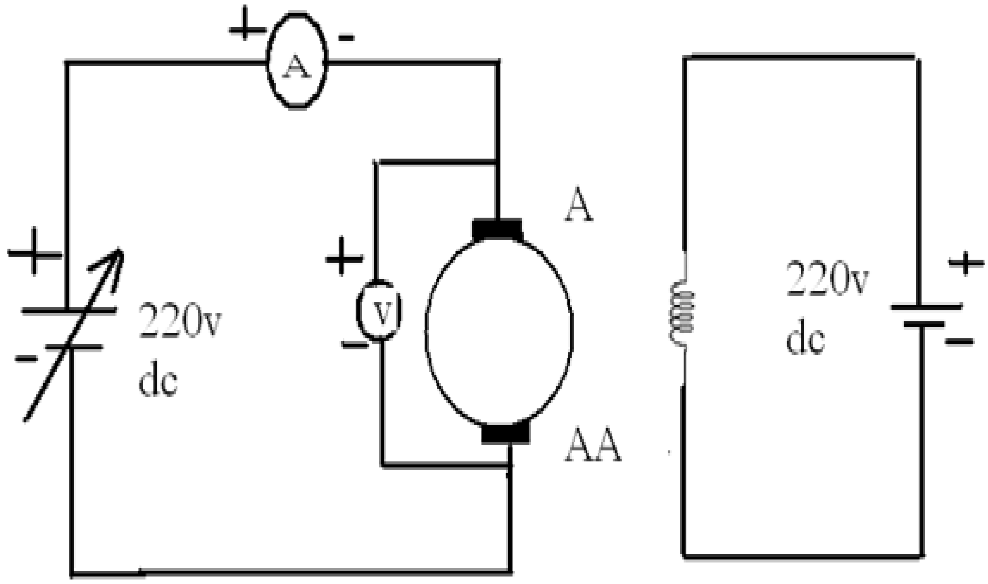
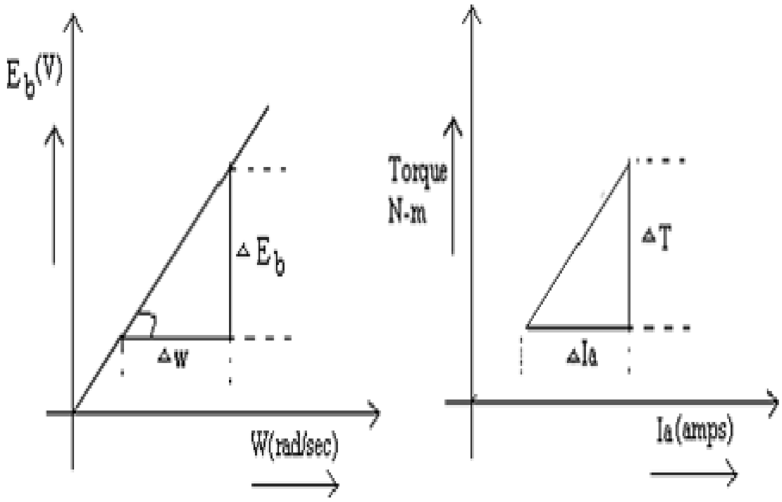


Figure 3.5: Model Graphs



LAB-4 CHARACTERISTICS OF AC SERVO MOTOR

4.1 Introduction

Most of the servomotors used in the low power servomechanism are a.c. servomotors. The a.c. servomotor is basically two phase induction motor. The output power of a.c. servomotor varies from fraction of watts to few hundred of watts. The operating frequency is 50 Hz to 400 Hz.

4.2 Objective

To study AC servo motor and note its speed torque Characteristics

4.3 Prelab

Understand the working performance of Servomotors

4.4 Equipment needed

S. No.	Equipments	Quantity
1	AC Servo Motor Setup	1
2	Digital Multi meter	1
3	Connecting Leads	As per requirement

4.5 Background

A servo motor is a linear or rotary actuator that provides fast precision position control for closed- loop position control applications. Unlike large industrial motors, a servo motor is not used for continuous energy conversion. Servo motors work on servo mechanism that uses position feedback to control the speed and final position of the motor. Internally, a servo motor combines a motor, feedback circuit, controller and other electronic circuit.

It uses encoder or speed sensor to provide speed feedback and position. This feedback signal is compared with input command position (desired position of the motor corresponding to a load), and produces the error signal (if there exist a difference between them).

The error signal available at the output of error detector is not enough to drive the motor. So the error detector followed by a servo amplifier raises the voltage and power level of the error signal and then turns the shaft of the motor to desired position.

Types of Servo Motors

Basically, servo motors are classified into AC and DC servo motors depending upon the nature of supply used for its operation. Brushed permanent magnet DC servo motors are used for simple applications owing to their cost, efficiency and simplicity.

These are best suited for smaller applications. With the advancement of microprocessor and power transistor, AC servo motors are used more often due to their high accuracy control.

4.6 Procedure

(a) Switch ON the power supply switches ON S1.

(b) Slowly increase control P1 so that AC servomotor starts rotating.

(c) Connect DVM across DC motor sockets (red black).

(d) Vary the speed of servomotor gradually and note the speed N rpm and corresponding back emf EB across DC motor.

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

(f) Switch on S2 to impose load on the motor due to which the speed of AC motor Decreases.

(g) Increase the load current by means of P2 slowly and note corresponding speed N rpm and Ia.

4.7 Results and Discussions

Table 4.1: Table 1

S. NO	**SPEED (N) rpm**	**Eb volts**
1		
2		
3		

Table 4.2: Table 2

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

4.8 Viva Questions

1. What is AC servo motor?

Figure 4.1: Block Diagram of characteristics of AC servo motor

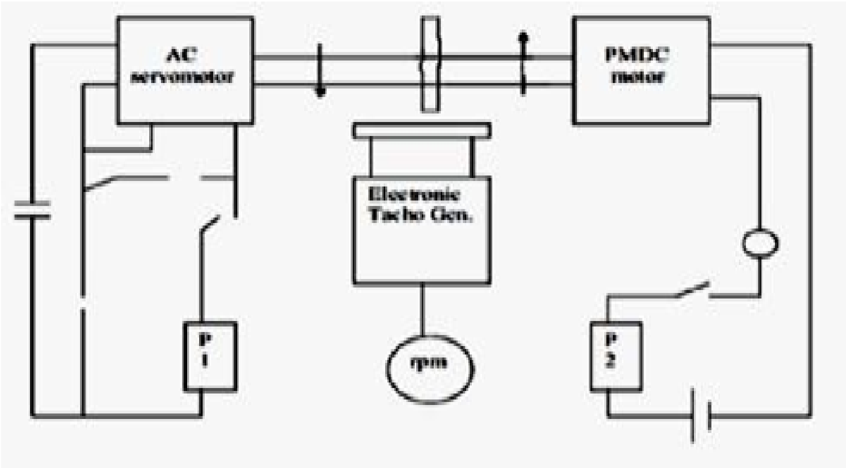
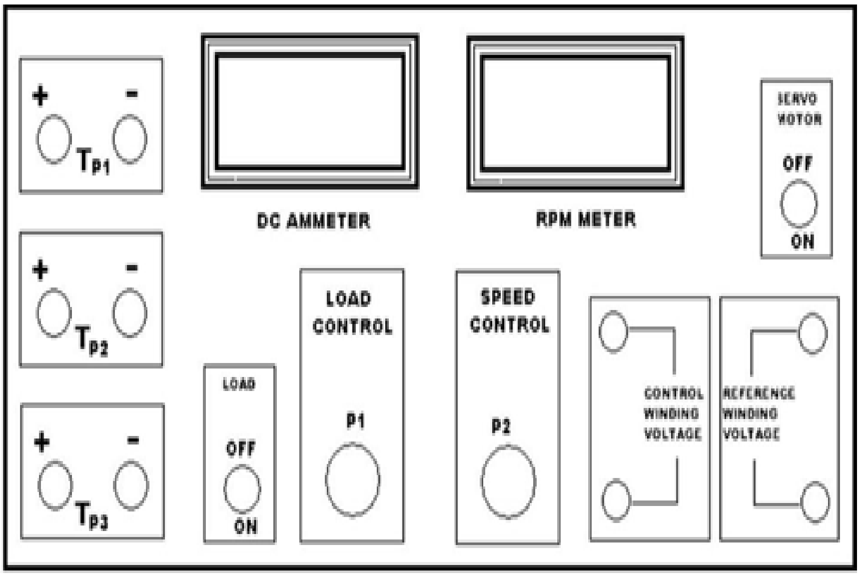


Figure 4.3: Front Panel of AC Servo-motor Controller



2. What is the use of AC servo motor?

3. What are the advantages of AC servo motor?

4. What is the important parameter of AC servo motor?

5. On what factor does the direction of rotation of AC servo motor depend.

4.9 Further Probing Experiments

1. Analyse the characteristics of DC Servomotors

2. Design and investigate the characteristics of AC Servomotors using MATLAB

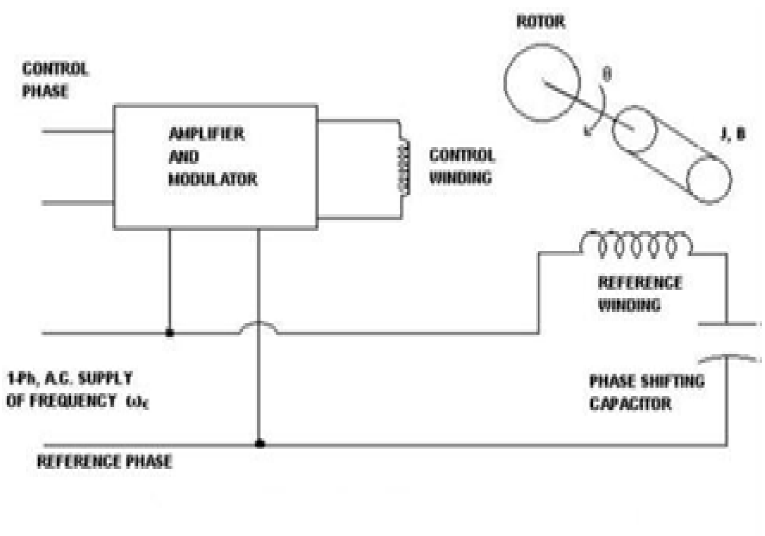
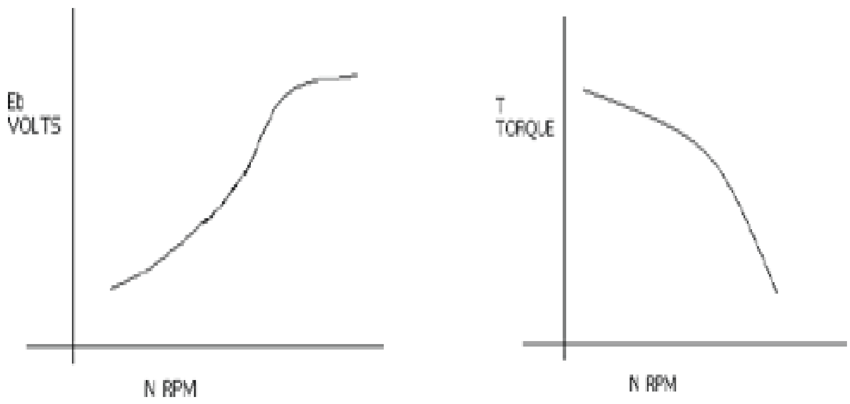

ROTOR
CONTROL
PHASE
AMPLIFIER
AND
MODULATOR
CONTROL
WINDING
J, B
REFERENCE
WINDING
1-Ph, A.C. SUPPLY
OF FREQUENCY ωc
PHASE SHIFTING
CAPACITOR
REFERENCE PHASE

Figure 4.6: Model Graph



LAB-5 EFFECT OF VARIOUS CONTROLLERS ON A SECOND ORDER SYSTEM

5.1 Introduction

Most PID controllers are adjusted on-site and many different types of tuning rules have been proposed in different literatures. Using these tuning rules, delicate and fine tuning of PID controllers can be made on-site. Also, automatic tuning methods have been developed and some of the PID controllers may possess on-line automatic tuning capabilities. Modified forms of PID control, such as I-PD control and two-degrees-of- freedom PID control, are currently in use in industry

5.2 Objective

To study the steady state performance of an analog P, PI PID controller

5.3 Prelab Preparation:

Students should have knowledge on Controllers and its types and applications

5.4 Equipment needed

S. No.	Equipment	Quantity
1	PID Controller	1
2	Patch Chords	As Required

5.5 Background

Proportional Controllers

With proportional controllers there are two conditions and these are written below:

1. Deviation should not be large; it means there should be less deviation between the input and output.

2. Deviation should not be sudden.

Now we are in a condition to discuss proportional controllers, as the name suggests in a proportional controller the output (also called the actuating signal) is directly proportional to the error signal. Now let us analyze proportional controller mathematically. As we know in proportional controller output is directly proportional to error signal. Where, Kp is proportional constant also known as controller gain. It is recommended that Kp should be kept greater than unity. If the value of Kp is greater than unity, then it will amplify the error signal and thus the amplified error signal can be detected easily.

Integral Controllers

As the name suggests in integral controllers the output (also called the actuating signal) is directly proportional to the integral of the error signal. Now let us analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal, Where Ki is integral constant also known as controller gain. Integral controller is also known as reset controller. Derivative Controllers

We never use derivative controllers alone. It should be used in combinations with other modes of controllers because of its few disadvantages which are written below: 1. It never improves the steady state error. 2. It produces saturation effects and also amplifies the noise signals produced in thesystem. Now, as the name suggests in a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal. Now let us analyze derivative controller mathematically. As we know in a derivative controller output is directly proportional to the derivative of the error signal, writing this mathematically we have,

Removing the sign of proportionality we have,

Where, Kd is proportional constant also known as controller gain. Derivative controller is also known as rate controller.

Proportional and Integral Controller

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal

Where, Ki and kp proportional constant and integral constant respectively.

Proportional and Derivative Controller

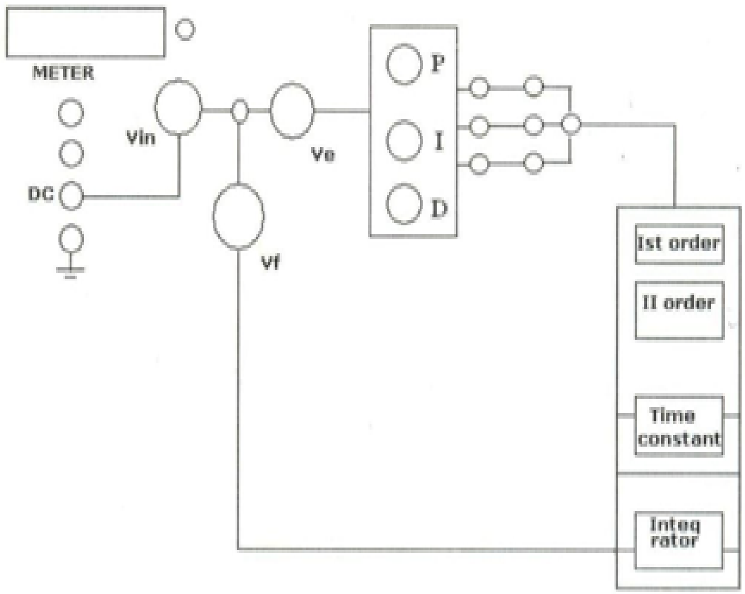
As the name suggests it is a combination of proportional and a derivative controller the output (also called the actuating signal) is equals to the summation of proportional and derivative of the error signal. Now let us analyze proportional and derivative controller mathematically. As we know in a proportional and derivative controller output is directly proportional to summation of proportional of error and differentiation of the error signal

Where, Kd and kp proportional constant and derivative constant respectively.

5.6 Procedure

(a) Make the connections as per the block diagram.

Figure 5.1: Block diagram Effect of P, PI, PID Controller on a second order system



(b) Set input DC amplitude to 1V.
(c) Adjust I, D to Zero.
(d) For various values of P, measure Vf, Vi and Ve using meter provided on the kit and note down the readings.

5.7 Results and Discussion

Table 5.1: **P Controller**

S. N	**P**	**Vi**	Vf	Ve
1				
2				
3				
4				

Table 5.2: **PI Controller**

S. No.	**I**	**Vi**	Vf	Ve
1				
2				
3				
4				

Table 5.3: **PID Controller**

S. No.	**D**	**Vi**	Vf	Ve
1				
2				
3				
4				

5.8 Viva Questions

1. What is a controller?

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

3. Write a brief note about Proportional Controller.

4. Write a brief note about Derivative Controller.

5. Write a brief note about Integral Controller

5.9 Further Probing Experiments

1. To observe open loop performance of building block and calibration of PID Controls

2. To study P, PI and PID controller with type 0 ,type 1,system with delay.

LAB-6 COMPENSATOR

6.1 Introduction

A lead compensator is commonly used for improving stability margins. Lag compensators are used to improve the steady state performance.The lead compensator achieves the desired results through the merits of its phase-lead contribution. The lag compensator accomplishes its result through the merits of its attenuation property at high frequencies.

6.2 Objective

To study of Lag, Lead,Lead - Lag compensation networks and obtain its frequency response.

6.3 Prelab Preparation:

Study the concept of lead,lag compensator, partially introduced aforehand. Write the text here

6.4 Equipment needed

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

6.5 Background

Generally the purpose of the Lead-Lag compensator is to create a controller which has has an overall magnitude of approximately 1. The lead-lag compensator is largely used for phase compensation rather than magnitude. A pole is an integrator above the frequency of the pole. A zero is a derivative above the frequency of the zero.

Adding a pole to the system changes the phase by -90 deg and adding a zero changes the phase by +90 deg. So if the system needs +90 deg added to the phase in a particular frequency band then you can add a zero at a low frequency and follow that zero with a pole at a higher frequency.

Lead or Lag Control: Lead and lag control are used to add or reduce phase between 2 frequencies. Typically these frequencies are centered around the open loop crossover frequency. A lead filter typically has unity gain (0 dB) are low frequencies while the lag provides a non unity gain at low frequencies.

6.6 Procedure

(a) Switch on the main supply to unit observes the sine wave signal by varying the frequency and amplitude potentiometer.

(b) Now make the network connections for Lag, Lead and Lead-Lag networks connect the sine wave output to the networks input.

(c) Note down the peak actuator input using digital voltmeter provided, now the meter will shows peak voltage.

(d) Set the amplitude of sine wave to some value ex: 3 Volts peak, 4Volts Peak etc.,

(e) Now vary the frequency and note down frequency, phase angle difference and output voltage peak for different frequencies and tabulate all the readings.

(f) Calculate the theoretical values of phase angle difference and gain compare these values with the practical values.

(g) Plot the graph of phase angle versus frequency (phase plot) and gain versus frequency (magnitude plot).

(h) Repeat the same for different values of R and C.

(i) Repeat the same for different sine wave amplitude.

(j) Repeat the same experiment for lead and lag-lead networks.

6.7 Results and Discussions

I Lag Network

S.No.	**Frequency (Hz)**	Phase angle in degrees	Output voltage VO (Volts)	Gain = Vo/Vin
1				
2				
3				

II Lead Network

S.No.	**Frequency (Hz)**	Phase angle in degrees	Output voltage VO (Volts)	Gain = Vo/Vin
1				
2				
3				

III Lag-Lead Network

S.No.	**Frequency (Hz)**	Phase angle in degrees	Output voltage VO (Volts)	Gain = Vo/Vin
1				
2				
3				

6.8 Viva Questions

1. Which compensation is adopted for improving steady response of a negative unity feedback system

2. What happens to the gain crossover frequency when phase lag compensator is used?

3. What is the effect of phase lag compensation on servo system performance?

4. Write a brief note about Lag Lead Compensator

5. study the open loop response on compensator and Close loop transient response

6.9 Further Probing Experiments

1. To design the open loop response on compensator and Close loop transient response.

2. The max. phase shift provided for lead compensator with transfer function G(s)=(1+6s)/(1+2s) using MATLAB

Figure 6.1: Lag Compensation Network

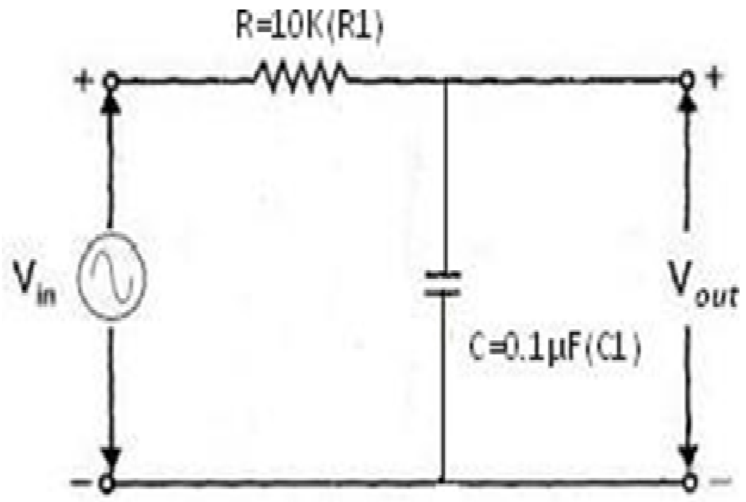


Figure 6.3: Lead Compensation Network

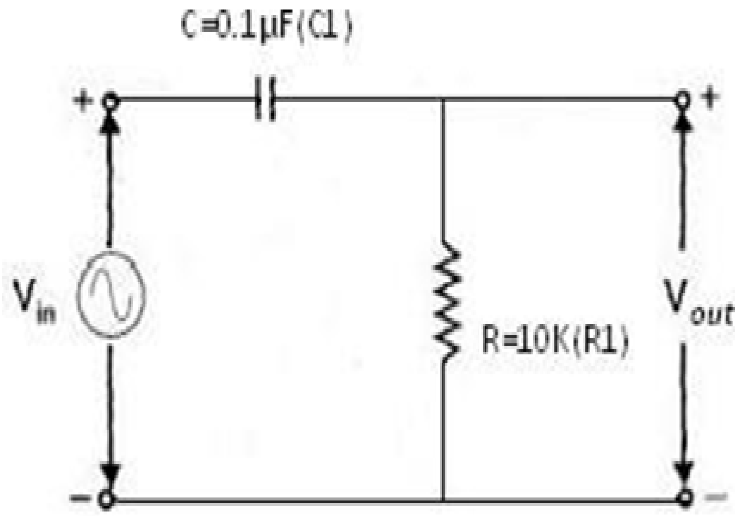
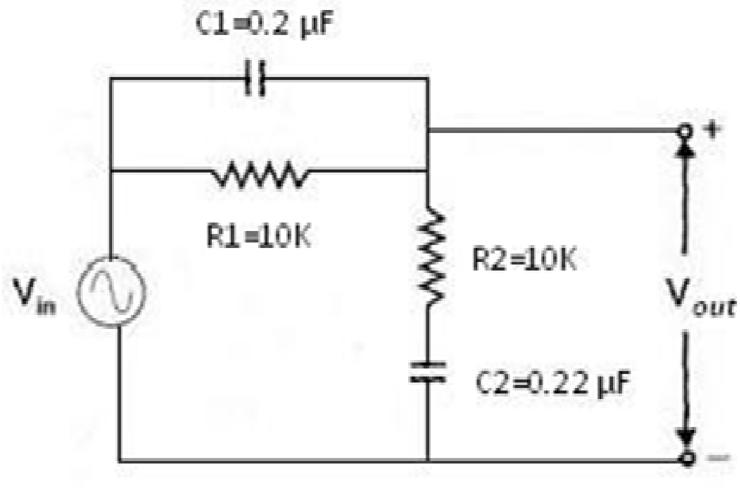


Figure 6.5: Laglead Compensation Network



LAB-7 TEMPERATURE CONTROLLER

7.1 Introduction

PID temperature control is a loop control feature found on most process controllers to improve the accuracy of the process. PID temperature controllers work using a formula to calculate the difference between the desired temperature setpoint and current process temperature, then predicts how much power to use in subsequent process cycles to ensure the process temperature remains as close to the setpoint as possible by eliminating the impact of process environment changes.

7.2 Objective

To study the temperature performance of an oven using P, PI, PID controllers.

7.3 Prelab Preparation:

Student should basic knowledge on the PID controllers

7.4 Equipment needed

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

7.5 Background

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 (Kc) 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 Kc is increased further, the oscillations will become larger and the system will become unstable and may even oscillate out of control.

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 (Td) 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 (Td), 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

7.6 Procedure

I Proportional controller:

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

(b) Keep S2 to set position and adjust the reference potentiometer to desired output temperature say 60o by seeing on the digital display.

(c) 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’.

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

(e) Plot the graph between temperature and time on graph sheet.

II PI Controller:

(a) Starting with cool oven, keep switch S1 to wait connect P,I output to drive input and disconnect RD outputs and short feedback terminals.

(b) Set P and I potentiometer to 0.5, 1

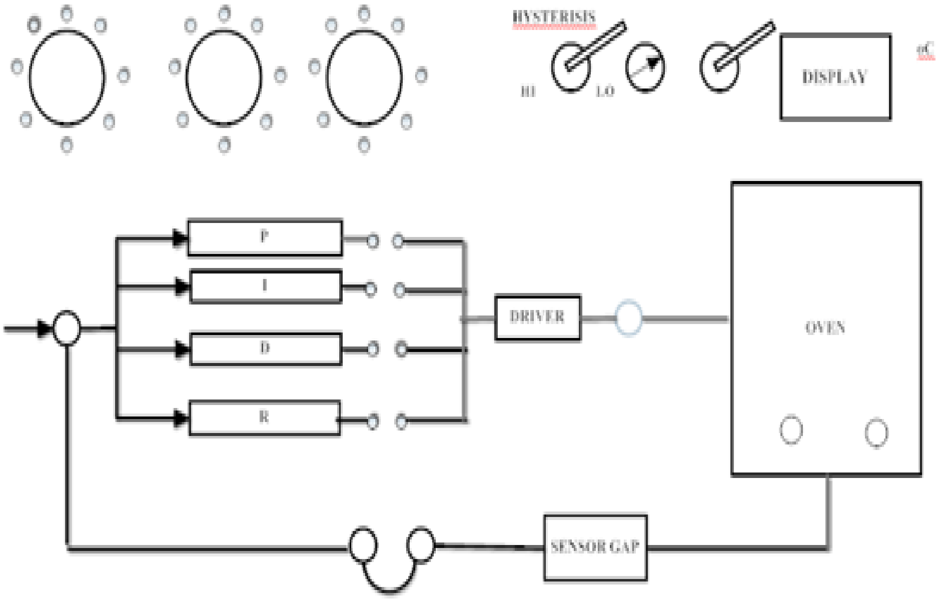
(c) Select and set desired temperature to 60o.

(d) Keep switch S1 to run position and record the temperature readings every 15/30 sec about 20 min.

(e) Plot the graph between temperature and time.

III PID Controller:

Figure 7.1: Block Diagram of Temperature Control Systems



(a) Starting with cool oven, keep switch S1 to wait.
(b) Connect P, I, D to driver input and disconnect R output, short feedback terminals.
(c) Set P, I, D potentiometer to 0.5, 1.
(d) Select and set the desired temperature to 60o
(e) Keep switch S1 to RUN position and record the temperature readings every 15/30 sec about 20 min.

7.7 Results and Discussions

Time in (sec)	**Temperature in degrees**		
	P	PI	PID

7.8 Viva Questions

1. What are the different types of controllers do we have?

2. Define P controller, PI controller and PID controller?

3. What is a driver circuit?

4. What are the applications of temperature controller system?

5. Which controller is most effective among P, PI, PID and why?

7.9 Further Probing Experiments

1. Design and analyse Temperature sensing circuit using LABVIEW

2. Perform Temperature controllers with PID with effective at dealing with process disturbances

LAB-8 DESIGN AND VERIFICATION OF OP-AMP BASED PID CONTROLLER

8.1 Introduction

The PID control is the most commonly known for control process utilized as a part of industries for controlling action. The basic technique for PID controllers makes it simple to coordinate the process output. The main focus of the experiment is about study of OPAMP and fabrication of an PID Controller using the three control parameters. The Controller design is demonstrated through simulation in order to get an output of better dynamic and static performance. The controller is fabricated on hardware after the test of individual terms:-proportional, integral and derivative.

8.2 Objective

To design and verify op-amp based PID Controller

8.3 Prelab Preparation:

students should have basic knowledge on OPAMP characteristics and principles of PID controllers

8.4 Equipment needed

S. NO	**Devices**	Quantity
1	OP-AMP based trainer kit	1
2	MATLAB 16a Software	1
3	Personal Computer	1

8.5 Background

Proportional-Integral-Derivative (PID) controllers are one of the most commonly used types of controllers. They have numerous applications relating to temperature control, speed control, position control, etc. A PID controller provides a control signal that has a component proportional to the tracking error of a system, a component proportional to the accumulation of this error over time and a component proportional to the time rate of change of this error. This module will cover these different components and some of their different combinations that can be used for control purposes. The proportional, integral and derivative terms are summed to calculate the output of the PID controller.

A proportional-integral-derivative controller is common feedback loop component.in industrial control system. The Controller compares a measured value from a process with a reference set point value. The difference is then used to calculate a new value for a manipulable input to the process that brings the process measured value back. to its desired set point. Unlike simpler control algorithms, the PID controller can adjust process outputs based on the history and rate of change of the error signal, which gives more accurate and stable control. It can be shown mathematically that a PID. loop will. Produce accurate, stable control in cases where a simple proportional control would either have a steady-state error or would cause the process to oscillate. In a PID loop, correction is calculated from the error in three way cancel out the current error directly (Proportional), the amount of time the error has continued uncorrected (Integral), and anticipate the future error from the rate of change of the error over time (Derivative)

A control loop consists of three parts:

a). Measurement by a sensor connected to the process .

b). Decision in a controller element.

c). Action through an output device such as an motor.

As the controller reads. a sensor, it subtracts this measurement from the "set point" to Determine the "error". It then uses the error to calculate a correction to the process's input Variable (the "action") so that this correction will remove the error from the process's Output measurement. In a PID loop, correction is calculated from the error in three ways: cancel out the current error directly (Proportional), the amount of. time the error has continued uncorrected (Integral), and anticipate the future error from the rate of change of the error over time Derivative.

8.6 Procedure

(a) Connect the circuit as per the circuit diagram.
(b) Connect a step function to controller and observe the output
(c) Change the P, I and D settings and observe the output. Record the results.
(d) Record your observations.

8.7 Results and Discussions

8.8 Viva Questions

1. Which controller is most effective among P, PI, PID and why

2. Define P controller, PI controller and PID controller
3. Write a brief note about PID Controller.

4. Compare the performance of PI and PD controller.

5. Which controller is used for improving the transient response of the system?

6. Whch controller is used for improving the steady state response of the system?

8.9 Further Probing Experiments

1. To design and verify op-amp based PID Controller using LABVIEW

2. verify op-amp based PID Controller by changing the Controller constants

Figure 8.1: CIRCUIT DIAGRAM OF OP-AMP BASED PID CONTROLLER

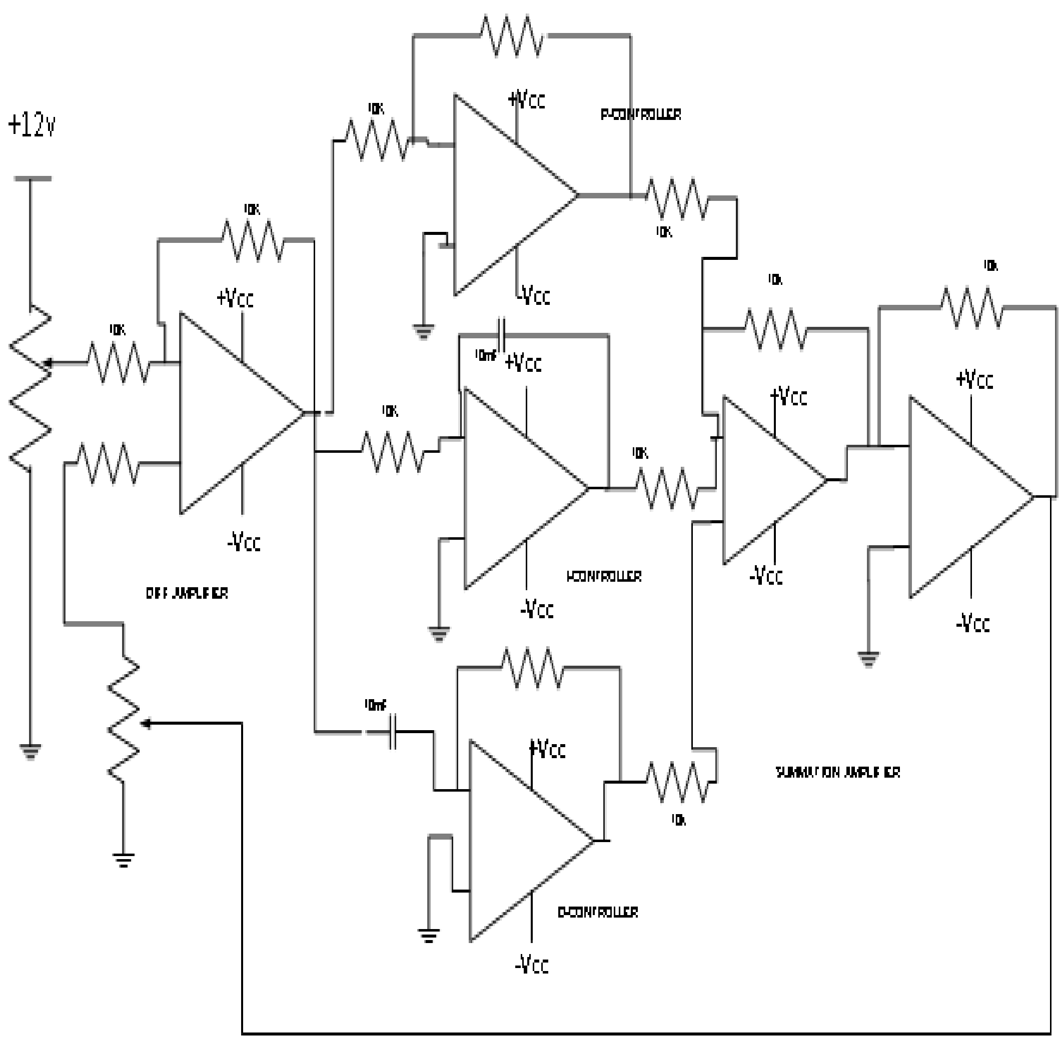


Figure 8.3: SIMULATION CIRCUIT DIAGRAM OF OP-AMP BASED PID CONTROLLER

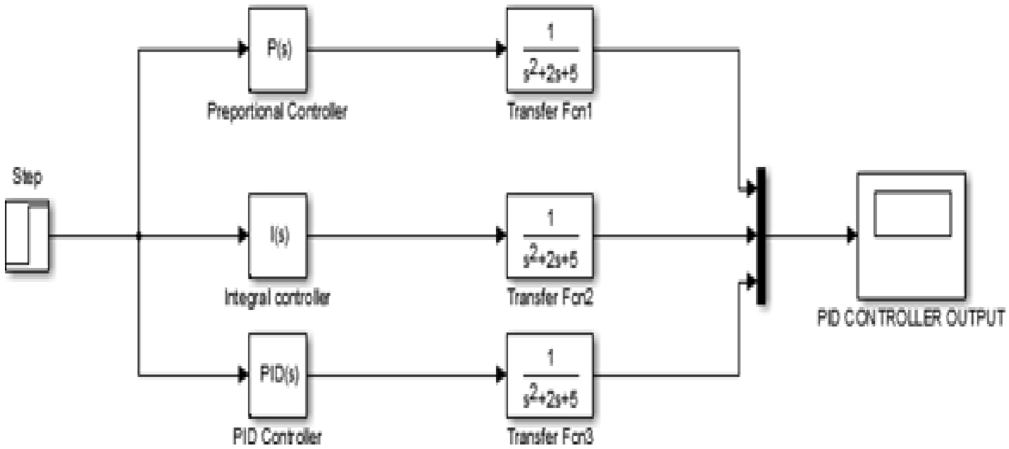
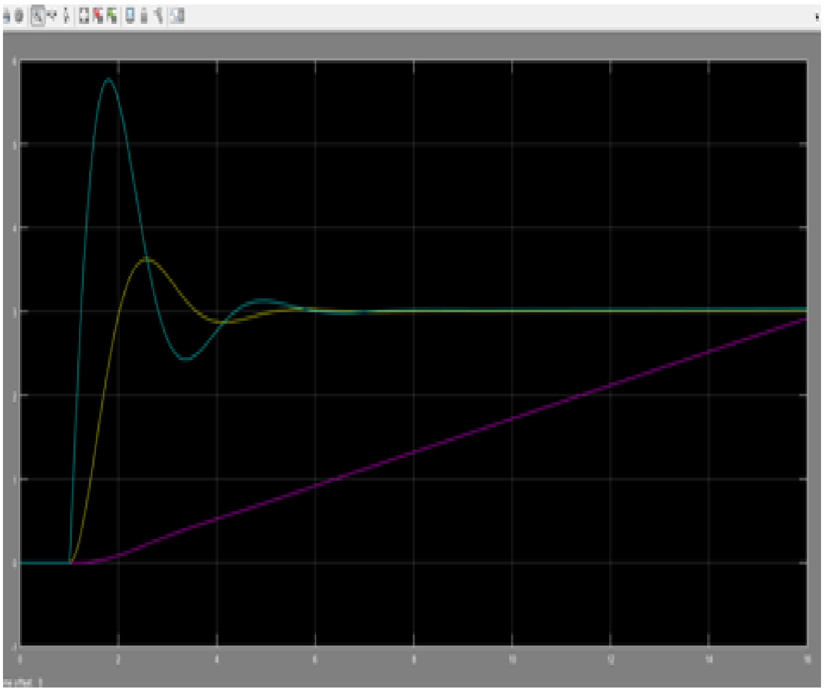


Figure 8.5: Expected Output



LAB-9 STABILITY ANALYSIS USING DIGITAL SIMULATION

9.1 Introduction

In this experiment the time and frequency domain of a given system's stability is analysed through Digital simulation(MATLAB)

9.2 Objective

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

9.3 Prelab Preparation:

students should known the concept of stability and also parameters like poles, zeros, gain margin, phase margin

9.4 Equipment needed

S. No.	**Equipment**	Quantity
1	MATLAB 16a Software	1
2	Personal Computer	1

9.5 Background

I ROOT LOCUS

The root locus technique in control system was first introduced in the year 1948 by Evans. We can find poles and zeros from G(s). The location of poles and zeros are crucial keeping view stability, relative stability, transient response and error analysis. When the system put to service stray inductance and capacitance get into the system, thus changes the location of poles and zeros. In root locus technique in control system we will evaluate the position of the roots, their locus of movement and associated information. These information will be used to know about the system performance.

II BODE PLOTS

Bode plots were first introduced by H.W. Bode, when he was working at Bell labs in the United States. Bode plots are the most widely used means of displaying and communicating frequency response information. There are many reasons for that. Bode' plots are really log-log plots, so they collapse a wide range of frequencies (on the horizontal axis) and a wide range of gains (on the vertical axis) into a viewable whole.In Bode' plots, commonly encountered frequency responses have a shape that is simple. That simple shape means that laboratory measurements can easily be discerned to have the common factors that lead to those shapes. For example, first order systems have two straight line asymptotes and if you take data and plot a Bode' plot from the data, you can pick out first order factors in a transfer function from the straight line asymptotes.

III NYQUIST PLOT

The stability analysis of a feedback control system is based on identifying the location of the roots of the characteristic equation on s-plane. The system is stable if the roots lie on left hand side of s- plane. Relative stability of a system can be determined by using frequency response methods like Nyquist plot and Bode plot. Nyquist criterion is used to identify the presence of roots of a characteristic equation in a specified region of s-plane

9.6 Procedure

(a) Click on MATLAB icon.
(b) From FILE menu click on NEW button and select SCRIPT to open Untitled window
(c) Enter the following program in untitled window
(d) Save the above program by clicking on SAVE button from FILE menu (or) Ctrl+S
(e) Run the program by clicking RUN button (or) F5 and clear the errors (ifany).
(f) Observe the output on the MATLAB Command Window and plots from figure window.

9.7 Program

I ROOT LOCUS

```
clc;
disp('Transfer Function of given system is : ');
num = input ('Enter Numerator of the Transfer Function: n');
den = input ('Enter Denominator of the Transfer Function : n');
G = tf(num,den);
figure(1);
rlocus(G);
```

II BODE PLOTS

```
clc;
disp('Transfer Function of given system is : ');
```

```
num = input ('Enter Numerator of the Transfer Function :  n');
den = input ('Enter Denominator of the Transfer Function :  n');
G = tf(num,den);
figure(2);
bode(G);
[Gm,Pm,Wpc,Wgc] = margin(G);
disp('Phase Cross Over frequency is : ');

Wpc
disp ('Gain Cross Over frequency is : ');

Wgc

disp('Phase Margin in degrees is : ');

Pm

disp('Gain Margin in db is : ');

Gm = 20*log(Gm)

Gm

if (Wgc ¡ Wpc)

disp('Closed loop system is stable')

else

if (Wgc ¿ Wpc)

disp('Closed loop system is unstable')

else

disp('Closed loop system is Marginally stable')

end
```

III NYQUIST PLOT

```
clc;
disp(' Transfer function of given system is ');
num = input (' enter numerator of Transfer function: ');
den = input (' enter denominator of Transfer function: ');
G= tf (num, den)
```

```
figure(1);
nyquist (G);
[gm, pm, wpc, wgc] = margin (G)
Disp (‘ gain margin in degrees is: ’)
end
```

9.8 Results and Discussions

9.8.1 Theoretical Calculation

I Phase Margin

(a) For a given Transfer Function G(s), get G(j) by placing s= j
(b) Separate Magnitude and Phase terms from G(j).
(c) Equate magnitude of G(j) to ONE and get value, this is called Gain Cross Over Frequency (Wgc)
(d) Substitute Wgc in place of G(j), get the phase angle ().
(e) Now Phase margin (PM) = 180 +

II Gain Margin

(a) For a given Transfer Function G(s), get G(j) by placing s= j
(b) Separate Magnitude and Phase terms from G(j).
(c) Equate magnitude of G(j) to ONE and get value, this is called Gain Cross Over Frequency (Wgc)
(d) Substitute Wgc in place of G(j), get the phase angle ().
(e) Now Gain Margin (GM) = 20 log10 (1/K)

III Maximum Allowable Gain

(a) For a given Transfer Function G(s), place K in the numerator and get the characteristic equation Q(s) = 1 + G(s).
(b) Separate imaginary and real terms from Q(j).
(c) Equate magnitude of G(j) to ONE and get value, these values called Imaginary Cross Over points.
(d) Substitute Wgc in place of G(j)and equate real part of G(j) to ZERO and get the corresponding gain (K).
(e) This gain is called maximum Allowable Gain (Kmax) or Limiting value of the Gain for stability.

Specification	**Gain Margin (GM) and Gain Cross Over Frequency (Wgc)**	Phase Margin (PM) and Phase Cross Over Frequency (Wpc)	Maximum allowable gain (Kmax)
From MATLAB			
Theoretical			

9.9 Viva Questions

1. What is gain margin and phase margin?

2. What is gain cross over frequency and phase crossover frequency?

3. What are the different types of stability conditions?

4. What are the advantages and disadvantages of root locus, bode nyquist plot?

5. What are the advantages of frequency response analysis?

9.10 Further Probing Experiments

1. For the considered transfer function, if a pole is removed added, how the stability will be effected for all the plots using MATLAB LABVIEW

2. For the considered transfer function, if a zero is removed added, how the stability will be effected for all the plots using MATLAB LABVIEW

LAB-10 STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING MATLAB

10.1 Introduction

A state-space model is commonly used for representing a linear time-invariant (LTI) system. It describes a system with a set of first-order differential or difference equations using inputs, outputs, and state variables. In the absence of these equations, a model of a desired order (or number of states) can be estimated from measured input-output data. The models are widely used in modern control applications for designing controllers and analysing system performance in the time domain and frequency domain. The models can be applied to non-linear systems or systems with non-zero initial conditions. They also provide a convenient way to represent, analyse, and control multi-input/multi-output (MIMO) systems.

10.2 Objective

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

10.3 Prelab Preparation:

students should known the concept of State Space Model

10.4 Equipment needed

S.No.	**Equipment**	Quantity
1	MATLAB 16a Software	1
2	Personal Computer	1

10.5 Background

State-space models are models that use state variables to describe a system by a set of first-order differential or difference equations, rather than by one or more nth-order differential or difference equations. State variables x(t) can be reconstructed from the measured input-output data, but are not themselves measured during an experiment. The state-space model structure is a good choice for quick estimation because it requires you to specify only one input, the model order, n. The model order is an integer equal to the dimension of x(t) and relates to, but is not necessarily equal to, the number of delayed inputs and outputs used in the corresponding linear difference equation.

10.6 Procedure

(a) Click on MATLAB icon.

(b) From FILE menu click on NEW button and select SCRIPT to open Untitled window

(c) Enter the following program in untitled window

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

(e) Run the program by clicking RUN button (or) F5 and clear the errors (ifany).

(f) Observe the output on the MATLAB Command Window and plots from figure window.

10.7 Program

For Transfer Function to State Space Model:

```
clc;

disp(' Transfer Function of given system is : ');
Num = [2 3 2];
Den = [2 1 1 2 0];
sys = tf(num,den);
Disp('Corresponding State Space Model A,B,C,D are: ');
[A,B,C,D] = tf2ss(num,den)
A

B

C

D
```

For State Space Model to Transfer Function:

```
clc;
disp('A,B,C,D Matrices of given State Space Model are :: ');
A = [1 2;3 4 ]
B = [1;1]
C = [1 0]
D = [0]
[num,den] = ss2tf(A,B,C,D);
Disp(('And corresponding Transfer Function is : ');
Sys = tf(num,den);
Sys
```

10.8 Results and Discussions

Transfer Function of given system is Transfer Function:

$2s^2 + 3s + 2/2s^4 + s^3 + s^2 + 2s$

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

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

B = 1
0
0
0

C = 0 1.0000 1.5000 1.000

D = 0

State Space Model to Transfer Function

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

A = 1 2
3 4
B = 1
1
C = 1 0
D = 0

and corresponding Transfer Function is: $s2/s^2 – 5s - 2$

10.9 Viva Questions

1. What are the advantages disadvantages of state space analysis?

2. What is workspace and command window?

3. Explain the following commands: Acker, Bode, Ctrl, Dstep, Feedback, Impulse, Margin, Place, Rlocus, stairs

4. What are the disadvantages of transfer function?

5. What are the different functions in MATLAB?

10.10 Further Probing Experiments

1. For the considered transfer function, if a pole is removed added, how the stability will be effected for all the plots using MATLAB LABVIEW

2. For the considered transfer function, if a zero is removed added, how the stability will be effected for all the plots using MATLAB LABVIEW

LAB-11 CONTROL SYSTEM DESIGN TOOLS USING LAB-VIEW

11.1 Introduction

LabVIEW Control Design and Simulation Module is an add-on to LabVIEW where you can do simulations and create control systems within the LabVIEW environment.Control design is a process that involves developing mathematical models that describe a physical system, analysing the models to learn about their dynamic characteristics, and creating a controller to achieve certain dynamic characteristics. Control systems contain components that direct, command, and regulate the physical system, also known as the plant. In this manual, the control system refers to the sensors, the controller, and the actuators.

11.2 Objective

By the end of this experiment, the student should be able to learn model-based control design and describes how you can use the LabVIEW Control Design Toolkit to design a controller.

11.3 Prelab Preparation:

Read the material from google internet that describes about LabVIEW software and its related terminology like VI, front panel and block diagram.

11.4 Equipment needed

S.No.	**Equipment**	Quantity
1	LABVIEW 18.0 Software	1
2	Personal Computer	1

11.5 Background

This experiment focuses on the Virtual Instruments using LABVIEW. LabVIEW programs are called virtual instruments, or VIs, because their appearance and operation imitate physical instruments, such as oscilloscopes and multimeters. Lab VIEW contains a comprehensive set of tools for acquiring, analyzing, displaying, and storing data, as well as tools to help you troubleshoot code you write. In LabVIEW, you build a user interface, or front panel, with controls and indicators. Controls are knobs, push buttons, dials, and other input mechanisms. Indicators are graphs, LEDs, and other output displays. After you build the front panel, you add code using VIs and structures to control the front panel objects. The block diagram contains this code. You can use Lab VIEW to communicate with hardware such as data acquisition, vision, and motion control devices, as well as GPIB, PXI, VXI, RS232, and RS485 instruments. Virtual Instrument: A virtual instrument (VI) is a program in the graphical programming language G. Virtual instrument front panels often have a user interface similar to physical instruments. G also has built-in functions that are similar to VIs, but do not have front panels or block diagrams as VIs do.

LabVIEW can be used to analyze systems described by transfer functions. Since the transfer function is a ratio of polynomials, we begin by investigating how LabVIEW handles polynomials, remembering that working with transfer functions means that both a numerator polynomial and a denominator polynomial must be specified. In LabVIEW, polynomials are represented by row vectors containing the polynomial coefficients. We can use LabVIEW functions to carry out the block diagram transformations. A simple open-loop control system can be obtained by interconnecting a plant and a controller

We can utilize the CD Feedback function to aid in the block diagram reduction process to compute closed-loop transfer functions for single- and multiple-loop control systems. When the closed-loop control system has unity feedback, we can use the CD Unit Feedback function to compute the closed-loop transfer function.

Given a transfer function, we can obtain an equivalent state-space representation and vice versa. The function CD Convert to State-Space Model is used to convert a transfer-function representation to a state-space representation; the function CD Convert to Transfer Function Model is used to convert a state-space representation to a transfer function

11.6 Procedure

(a) Open new VI by selecting File New, select New VI from the Lab VIEW dialog box. Then you can see block diagram panel and front panel.

(b) Then right click on the block diagram panel and select a separate tool box Control Simulation.

(c) In Control Simulation select control design, from control design select CD design

(d) first select CD construct transfer function,right click on the block select single input and single output

(e) The parameters are numerator, denominator and delay. Then create control for numerator and denominator

(f) Then add a block of CD Step Response to CD construct transfer function

(g) Then create a indicator of step response

(h) Observe in detail in front panel and give the required data and see the response

Figure 11.1: The block diagram of CD Step Response function

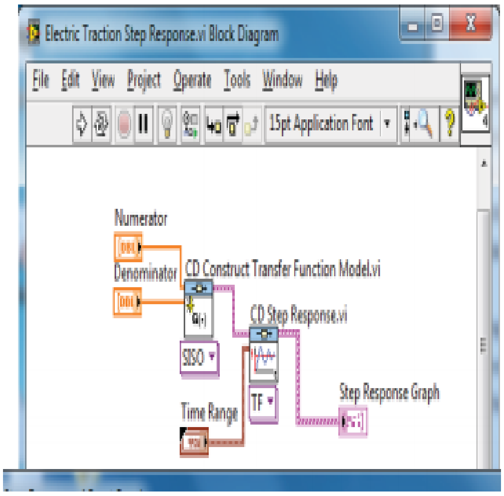
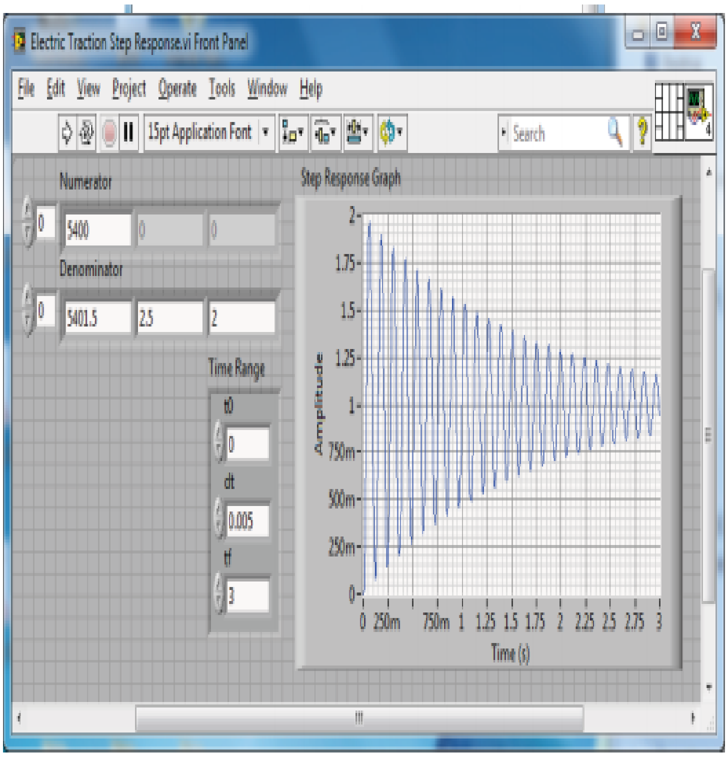


Figure 11.3: The CD Step Response function



11.7 Results and Discussions

11.8 viva Questions

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

2. Define Peak overshoot and write formula?

3. Classify the system depending on the value of damping?

4. Explain about various test signals used in control systems?

5. Derive the expression for time domain specification of a under damped second order system to a step input?

11.9 Further Probing Experiments

1. Analyse the Response of a system for various standard inputs using MATLAB LABVIEW
2. Develop the circuit for converting given transfer function to state model using LABVIEW

LAB-12 LINEAR SYSTEM ANALYSIS (TIME DOMAIN ANALYSIS USING MATLAB)

12.1 Introduction

In this experiment the time domain analysis of a given system is analysed through Digital simulation(MATLAB)

12.2 Objective

To write a program and simulate dynamical system of I/O model.

12.3 Prelab Preparation:

students should known the concept of time domain analysis

12.4 Equipment needed

MATLAB Software

12.5 Background

The time response has utmost importance for the design and analysis of control systems because these are inherently time domain systems where time is independent variable. During the analysis of response, the variation of output with respect to time can be studied and it is known as time response. To obtain satisfactory performance of the system with respect to time must be within the specified limits. From time response analysis and corresponding results, the stability of system, accuracy of system and complete evaluation can be studied easily. Due to the application of an excitation to a system, the response of the system is known as time response and it is a function of time. The two parts of response of any system: (i) Transient response (ii)Steady-state response. Transient response: The part of the time response which goes to zero after large interval of time is known as transient response.

Steady state response: The part of response that means even after the transients have died out is said to be steady state response.

The total response of a system is sum of transient response and steady state response: C(t)=Ctr(t)+Css(t)

12.6 Procedure

(a) Click on MATLAB icon.
(b) From FILE menu click on NEW button and select SCRIPT to open Untitled window
(c) Enter the following program in untitled window
(d) Save the above program by clicking on SAVE button from FILE menu (or) Ctrl+S
(e) Run the program by clicking RUN button (or) F5 and clear the errors (ifany).
(f) Observe the output on the MATLAB Command Window and plots from figure window.

12.7 Program

num=input('enter the numerator of transfer function:')
den=input('enter the denominator of transfer function:')
s=tf(num,den)
step(s)
title('the response of second order system is:')
Xlabel('t in secs')
Ylabel('v in volts')
[nt,dt]=tfdata(s,'v')
wn=sqrt(dt(3))
z=dt(2)/(2*wn)
disp('the rise time is:')
tr=pi-(atan$^{-}1(sqrt(1-z^2)/z)/(wn*sqrt(1-z^2)))$
$disp('thepeaktimeis:')$
$tp = pi/(wn*sqrt(1-z^2))$
$disp('thesettlingtimeis:')$
$ts = 4/(z*wn)$
$disp('thepeakovershootis:')$
$pos = exp((-z*pi)/sqrt(1-z^2))*100$
end

12.8 Results and Discussions

enter the numerator of transfer function:100
num =
100
enter the denominator of transfer function:[1 5 100]
den =
1 5 100
Transfer function:

$$\frac{100}{s^2+5s+100}$$

nt =
0 0 100
dt =

1 5 100
wn =
10
z =
0.2500
the rise time is:
tr =
2.8238
the peak time is:
tp =
0.3245
the settling time is:
ts =
1.6000
the peak over shoot is:
pos =
44.4344

12.9 viva Questions

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

2. Define Peak overshoot and write formula?

3. Classify the system depending on the value of damping?

4. Explain about various test signals used in control systems?

5. Derive the expression for time domain specification of a under damped second order system to a step input?

12.10 Further Probing Experiments

1. Perform the linear system circuit for second order for ramp input.

2. Design the linear system simulator for first and second order using LABVIEW.

Figure 12.1: Response of second order system

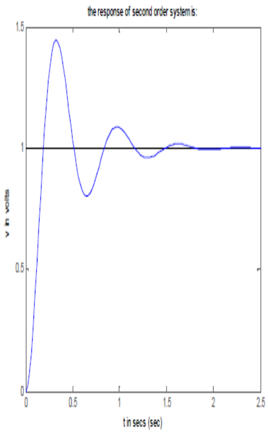


Figure 12.2: Response of second order system

LAB-13 DC MOTOR SPEED CONTROL AND POSITION CONTROL

13.1 Introduction

The DC motor system on the Quanser Controls Board was designed to make that experience even easier by: A) tuning the dynamics of the motor to match a theoretical linear model accurately, and B) creating an interface to the hardware that makes sending commands to the amplifier system and reading the sensors quick and easy.

13.2 Objective

By the end of the la students will be able to complete the following activities.

1. Tune PI control parameters for speed control of a DC motor.
2. Design PI control parameters to meet speed control specifications.
3. Assess the steady-state error of a position controller
4. Design PD control parameters to meet position control specifications

13.3 Prelab Preparation:

students should known the concept of DC Motor characteristics

13.4 Equipment needed

1. Hardware: Quanser Controls Board

2. Software: LabVIEW Version 18.0 or Later

13.5 Background

One of the most common tasks that automation, robotics, and industrial engineers are called upon to perform when creating industrial systems is to control the speed of a DC motor. From automation in manufacturing, to automotive systems, autonomous systems and even aerospace, DC motors are used to actuate critical systems, and their speed needs to be controlled to perform within specific design criteria. As an introduction to control systems, the control of a DC motor serves as an excellent starting point because DC motors are relatively easy to model and control. The DC motor system on the Quanser Controls Board was designed to make that experience even easier by: A) tuning the dynamics of the motor to match a theoretical linear model accurately, and B) creating an interface to the hardware that makes sending commands to the amplifier system and reading the sensors quick and easy. Despite the ease of use, the skills gained in these exercises are directly applicable to a multitude of exciting emerging application areas in engineering. The speed of the Quanser Controls Board DC motor is controlled using proportional-integral (PI)control system.PI control combines a measure of the current instantaneous error of the system with the accumulated error over time.

The transfer function representing the DC motor speed-voltage relation with steady-state gain K and time constant is

$$\frac{Y(s)}{U(s)} = \frac{K}{s+1}$$

and will be used to design the PI controller.

13.6 Procedure

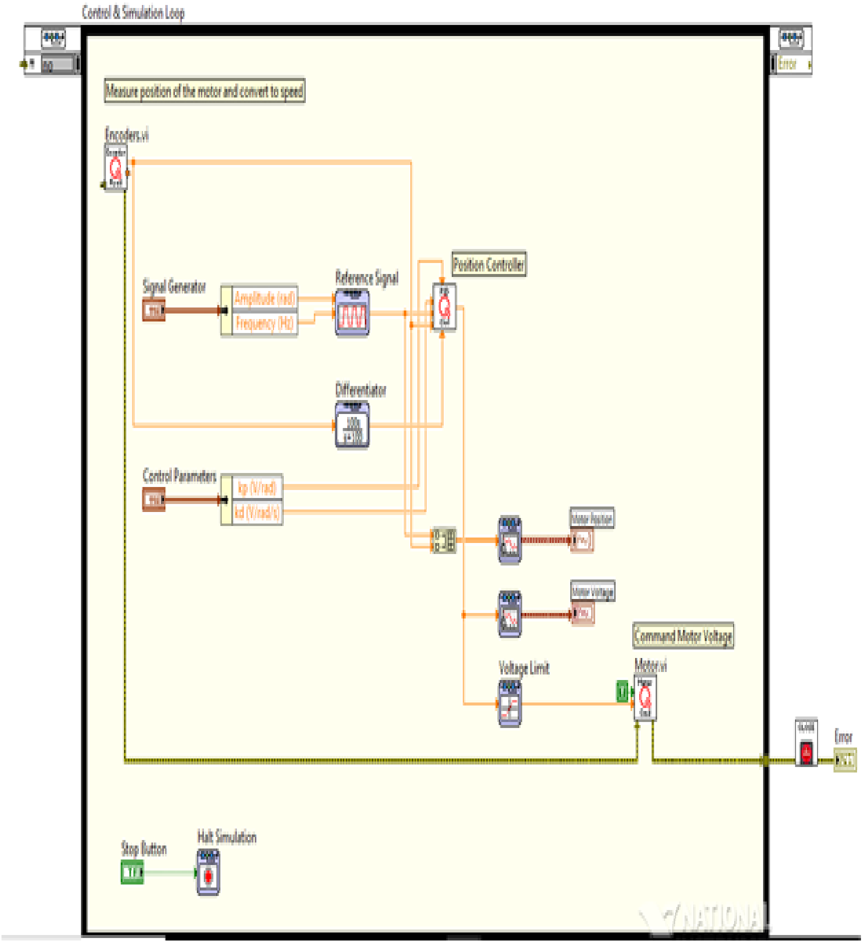
I DC MOTOR SPEED CONTROL

(a) 1.Open the project Quanser Controls Board.lv proj, and then open DC Motor Speed Control.vi listed under the NI ELVIS III.
(b) Run the VI. The DC motor should begin rotating and the scopes should look similar to Fig 13.2
(c) In the Signal Generator section of the front panel set:- Amplitude (rad/s) to 10, Frequency (Hz) to 0.2, Offset (rad/s) to 80
(d) In the Control Parameters section set: kp (V s/rad) to 0.050, ki (V/rad) to 1.00, bsp to 0.00
(e) Examine the behavior of the measured speed, shown in red, with respect to the reference speed, shown in blue, in the Speed (rad/s) scope.
(f) Increment and decrement kp in steps of 0.005 V s/rad.
(g) Observe the changes in the measured signal with respect to the reference signal in response to the updated proportional gains.
(h) Set kp to 0 V s/rad and ki to 0 V/rad. The motor should stop spinning.
(i) Increment the integral gain ki insteps of 0.10 V/rad, between 0.1 V/rad and 2.00 V/rad.
(j) Examine the response of the measured speed in the Speed (rad/s) scope.
(k) Click on the Stop button to stop the VI.

II DC MOTOR POSITION CONTROL

(a) Open the project Quanser ControlsBoard.lvproj, and then open DC Motor Position Control.vi listed under the NI ELVIS III
(b) Run the VI. The DC motor should begin rotating back and forth fig13.4
(c) In the Signal Generator section of the front panel set:Amplitude (rad) to 0.50, Frequency (Hz) to 0.40
(d) In the Control Parameters section set: kp (V s/rad) to 0.050, ki (V/rad) to 1.00, bsp to 0.00

Figure 13.1: DC Motor Speed Control block diagram



(e) Capture the position response found in the Motor Position scope and control signal used in the Motor Voltagescope

(f) Measure the peak time and percentage overshoot of the measured position response.

(g) If your response does not match the above overshoot and peak time specifications, try tuningyour control gains until they are satisfied. Save the resulting response.

(h) Stop the VI by clicking on the Stop button

13.7 Results and Discussions

13.8 Viva Questions

1. Explain the effect of PI Controller

2. State the working characteristics of DC Motor

3. Determine the pole and zero of the lead compensator

4. Explain Bode plot analysis to lead compensator

5. The locations of the pole and zero of the lead compensator

13.9 Further Probing Experiments

1. Explain the behaviour of the measured speed with respect to the reference speed

2. What is the expected peak time and overshoot

Figure 13.3: DC Motor Position Control block diagram

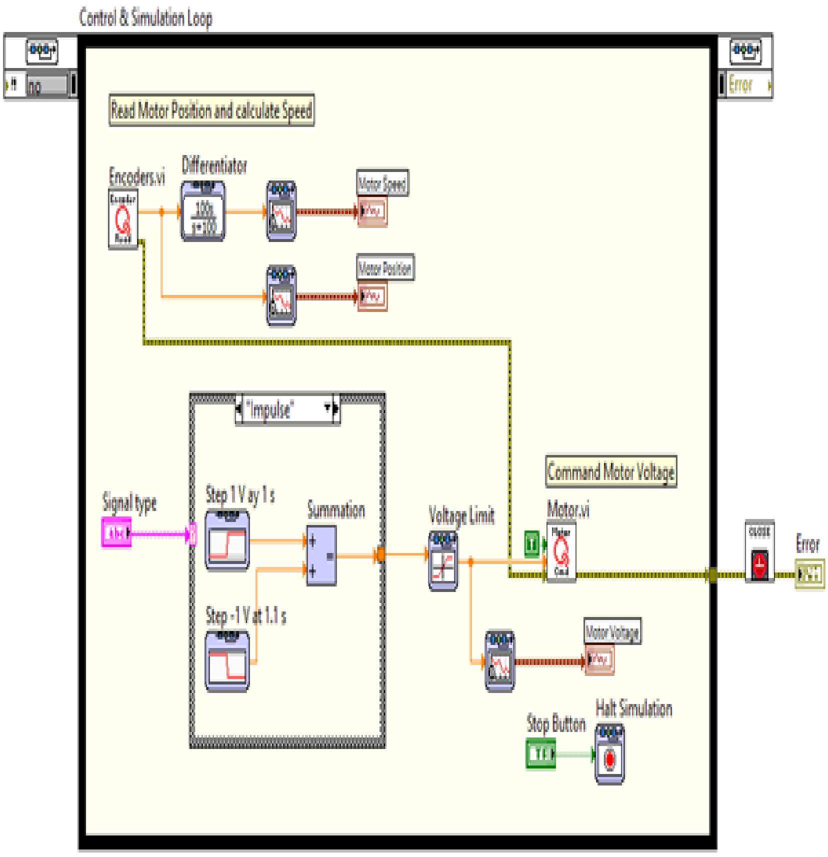


Figure 13.5: response of the PI control application

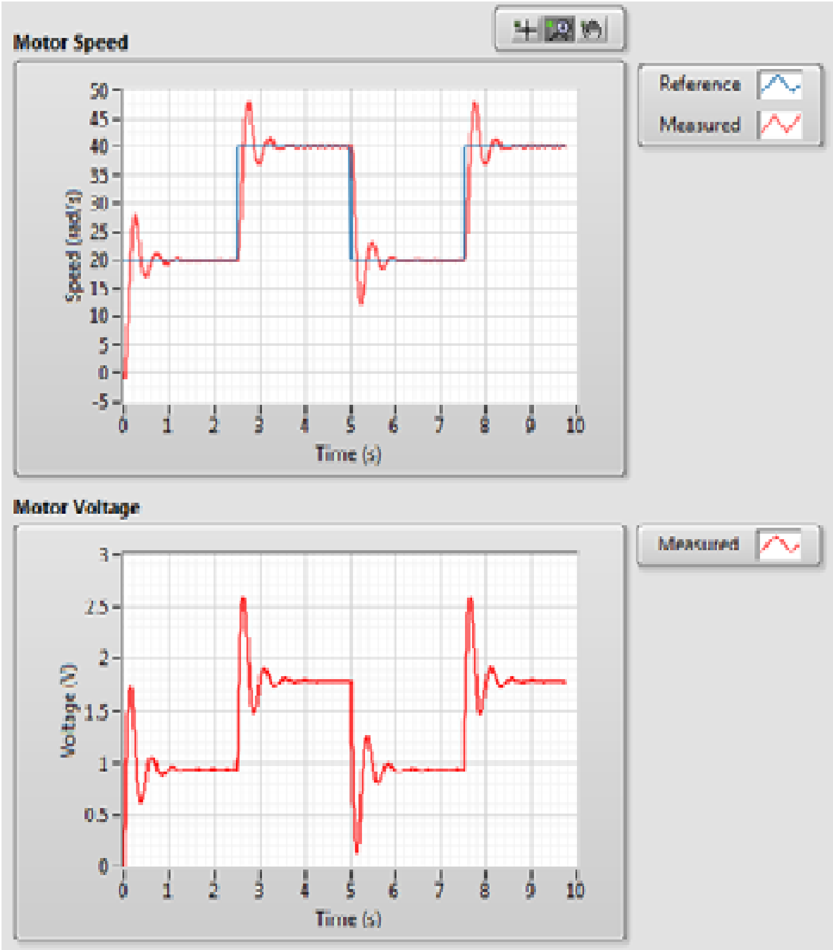
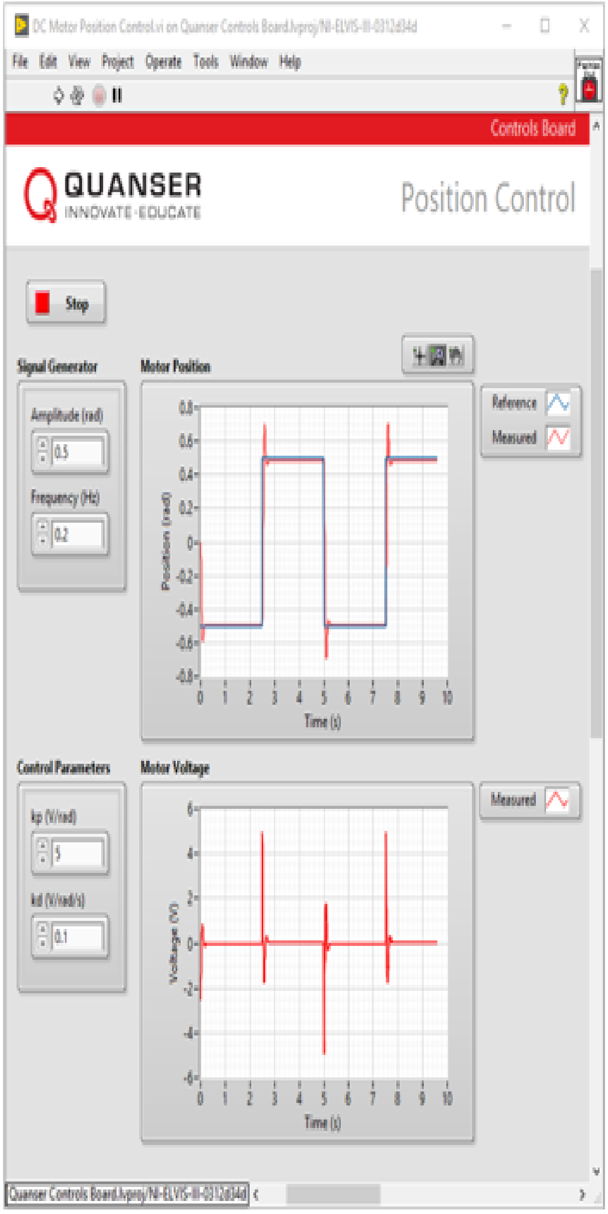


Figure 13.7: PDposition control



LAB-14 STABILITY ANALYSIS

14.1 Introduction

In this experiment the time and frequency domain of a given system's stability is analysed through Digital simulation(LABVIEW)

14.2 Objective

By the end of the la students will be able to complete the following activities.

1. Determine BIBO stability of a first- and second-order system
2. Use Nyquist plots to examine the stability of a third-order system
3. Examine stability using the Routh-Hurwitz criterion

14.3 Prelab Preparation:

students should known the concept of stability and also parameters like poles, zeros, gain margin, phase margin

14.4 Equipment needed

1. Hardware: Quanser Controls Board

2. Software: LabVIEW Version 18.0 or Later

14.5 Background

I **BIBO Stability**

A BIBO (bounded-input bounded-output) stable system is a system for which the outputs will remain bounded for all time, for any finite initial condition and input. A continuous-time linear time-invariant system is BIBO stable if and only if all the poles of the system have real parts less than 0. Definition for Bounded-Input Bounded-Output (BIBO) stability is:

1. A system is stable if every bounded input yields a bounded output.
2. A system is unstable if any bounded input yields an unbounded output

The stability of a system can be determined from its poles:

• Stable systems have poles only in the left-hand plane.
• Unstable systems have at least one pole in the right-hand plane and/or poles of multiplicity greater than 1 on the imaginary axis.
• Marginally stable systems have one pole on the imaginary axis and the other poles in the left-hand plane.

The voltage-to-speed transfer function of the Controls board is given as follows

P(s)= $\frac{K}{ts+1}$

where K = 22.6 rad/s/V is the model steady-state gain, t = 0.12 s is the model time

II **Nyquist Stability Analysis**

The gain and phase margins of a system can be used to assess the stability of a closed-loop system. The gain margin indicates how much open-loop gain is required before the system goes unstable. The phase margin indicates how much phase shift is needed in order to make the system go unstable. These are key indicators used to assess the stability of a system. The Nyquist plot can be used to find these stability margins.This will be used to control the angular rate of the Quanser Controls Board.
The gain margin (g$_m)isformallydefinedastheincreaseinthesystemgainwhenthephaseis180^0thatwillresultina$
$180^0.ThegainmarginequalsonedividedbythemagnitudeofthelooptransferfunctionL(s)atthegainmarginfreq$

III **Routh-Hurwitz Stability Analysis**

The Routh-Hurwitz Criterion is a two-step process to determine the system's stability without having to obtain exact pole locations. In the first step, a Routh table is created, which is then interpreted in the second step to find out how many poles are in the left half plane, on the imaginary axis, or in the right half plane. The major benefit of the Routh-Hurwitz Criterion is its inherent capability to determine the range for which unknown system parameters result in a stable closed-loop system response. To determine the stability we are only interested in the pole locations of the closed-loop system. If and only if all poles are strictly in the left half plane, the system is stable. To create a Routh table, we add a row for each coefficient of D(s) and add, starting from the highest coefficient, every other coefficient in decreasing order in the first line. Next, repeat the procedure for the second line, starting with the second highest coefficient and add every other coefficient in decreasing order similar to the first line.
Once the Routh table is found, the number of sign changes in the first column is equal to the number of right half plane (unstable) system poles. If a whole row in the Routh table is zero, the denominator polynomial has a factor that is an even polynomial. To complete the Routh table for this instance, move up one row, write out the corresponding polynomial of that row using the entries of the row as the coefficients. Then differentiate this polynomial and use the coefficients of the differentiated polynomial instead of the zeroes previously obtained.

14.6 Procedure

I **BIBO Stability**

(a) Open the project Quanser ControlsBoard.lvproj, and open BIBO Stability Analysis.vi.
(b) From the Signal type dropdown combo box select Step, and run the VI.
(c) The VI will run for 3 seconds, applying a step input of 1 V to the DC motor. Position and speed responses will be displayed similar to fig14.2
(d) Observe the behavior of the system and take a screenshot of your results
(e) Examine the behavior of the measured speed, shown in red, with respect to the reference speed, shown in blue, in the Speed (rad/s) scope.
(f) Examine the response of the measured speed in the Speed (rad/s) scope.
(g) Click on the Stop button to stop the VI.

II **Nyquist Stability Analysis**

(a) Open the project Quanser ControlsBoard.lvproj, and open Nyquist Plot.vi.
(b) Use the Transfer Function numeric control to enter the nominator and denominator coefficients of L(s) as well as the control loop rate h.
(c) Determine the forward loop transfer function L(s). Assume kp = 0.1, ki = 1, K = 22.6, t = 0.12, and h = 0.01. Alternatively, you can use the gain (K) and time constant (t) parameters that you have previously determined for your board.
(d) Run the VI.
(e) Use the Forward Loop Transfer Function display to verify that you have entered the correct transfer function coefficients.
(f) Upon execution, the VI will generate a Nyquist plot of the forward loop transfer function L(s) similar to fig14.4
(g) The VI also uses the CD Gain and Phase Margin VI to calculate and display the theoretical gain and phase margins. Take a screen shot of your results.
(h) Click on the Stop button to stop the VI.

III **Routh-Hurwitz Stability Analysis**

(a) Open the project Quanser ControlsBoard.lvproj, and open Routh-HurwitzStability Analysis.vi.
(b) Create a Routh table for the closed-loop transfer function and record your results
(c) Calculate the range of values of kpfor which the system is stable
(d) Use the steady-state gain K = 22.6 V/rad and the time constant t = 0.12 s
(e) Run the VI.
(f) Set the Set point (rad) numeric control to 0 Set the kp numerical control to 1.
(g) Further increase the proportional gain until you reach the value for kp for which the system is theoretically only marginally stable. Manually perturb the system and observe its response and stability. Approximate any steady-state error that you may observe. Take a screen shot of your results
(h) Click on the Stop button to stop the VI.

14.7 Results Discussions

14.8 Viva Questions

1. What is gain cross over frequency and phase crossover frequency?

2. How can you analyze the stability of system with bode and nyquist

3. What are the advantages of frequency response analysis?

4. What are the different types of stability conditions?

5. What is gain margin and phase margin?

14.9 Further Probing Experiments

1. Based on the speed response to the step input and the BIBO stability principle, determine the stability of the system.

2. Describe the behaviour and stability of the system when perturbed while using kp = 5

Figure 14.1: Closed-loop implementation used to find stability margins experimentally

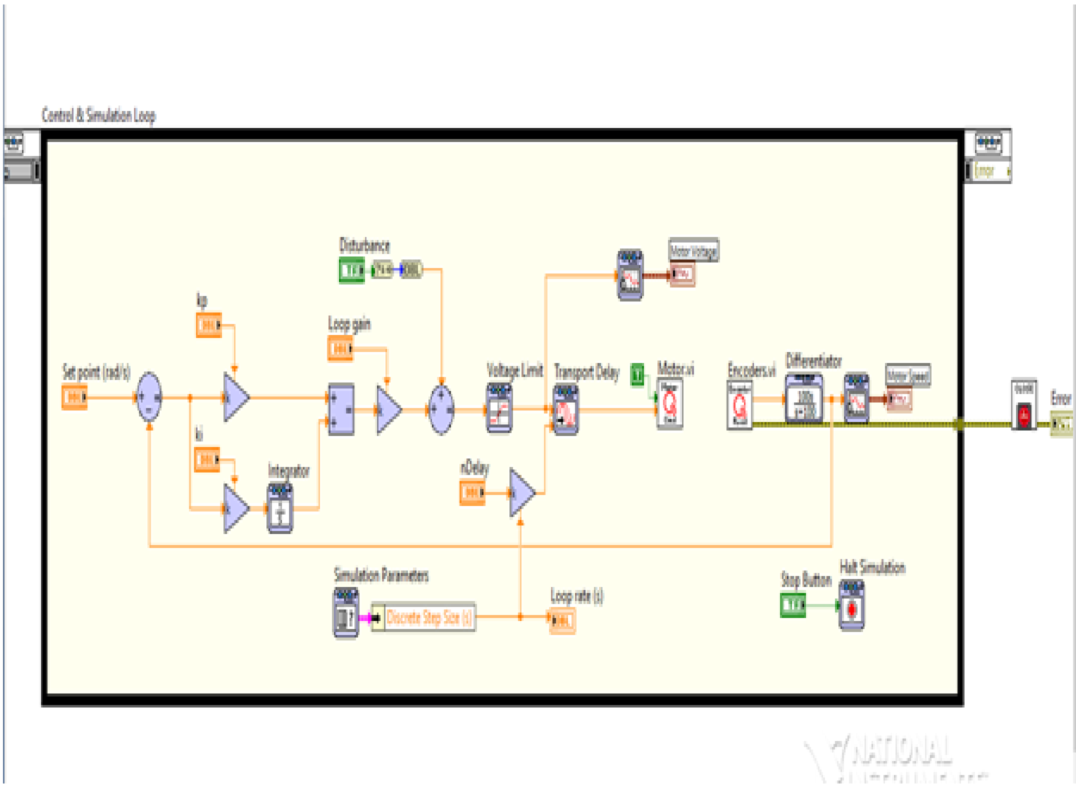


Figure 14.3: Routh-Hurwitz Criterion block diagram

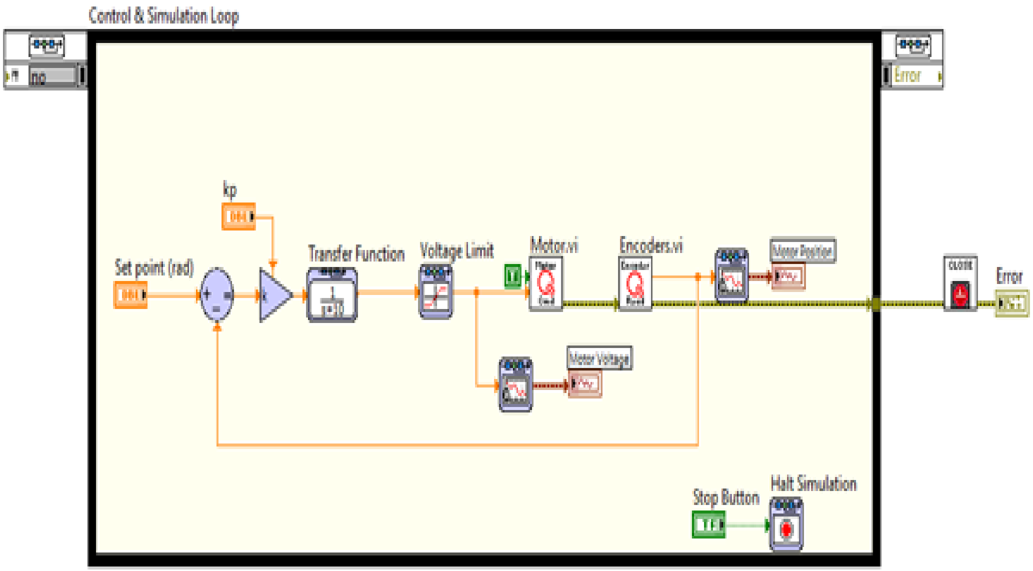


Figure 14.5: Response to a step input

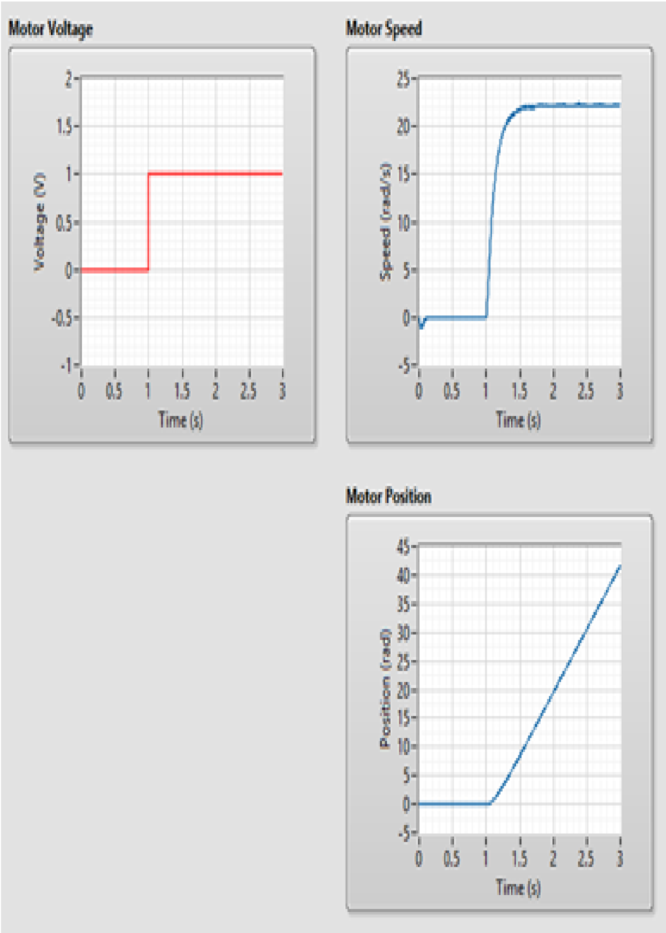


Figure 14.7: Nyquist plot