

# **CONTROL SYSTEM LAB**

**(EE-324-F)**

**VI SEMESTER**

**Electrical and Electronics Engineering**



**DRONACHARYA**  
College of Engineering

**DEPARTMENT OF ELECTRICAL & ELECTRONICS  
DRONACHARYA COLLEGE OF ENGINEERING  
KHENTAWAS, GURGAON-123506**

## CONTROL SYSTEM LAB (EE-324-F)

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### CONTROL SYSTEM

### LIST OF EXPERIMENTS

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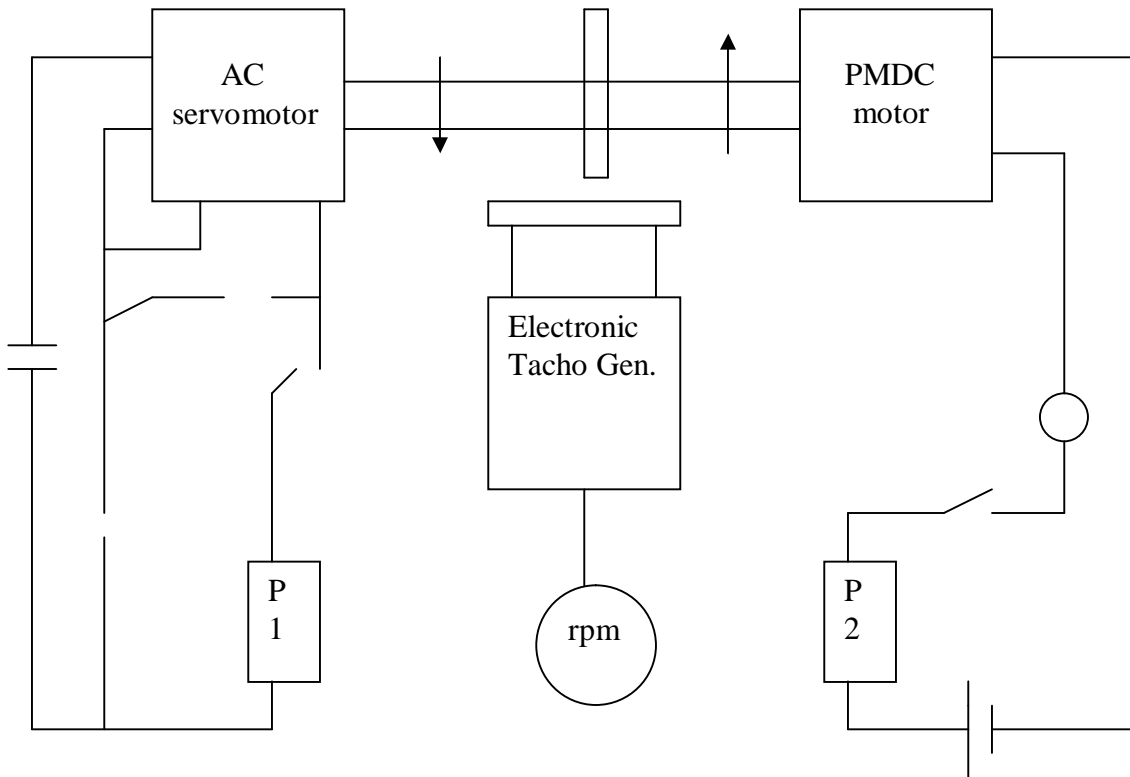
**EXPERIMENT NO: 1(a)**

**AIM:** - To study speed torque characteristics of AC Servo Motor.

**APPARATUS REQUIRED:** - AC Servo Motor Setup, Digital Multimeter and Connecting Leads.

**THEORY:** - AC servomotor has best use for low power control applications. Its important parameters are speed – torque characteristics. An AC servomotor is basically a two phase induction motor which consist of two stator winding oriented 90\* electrically apart. In feedback application phase A is energised with fixed voltage known as “Reference” and phase B is energized with variable voltage called “Control voltage”. In this setup AC servomotor is mounted and mechanically coupled a small PMDC motor loading purpose. When DC supply is fed to DC motor it runs in reverse direction of servomotor direction to impose load on servomotor. The resultant torque developed by DC motor to overcome it increase the current through it which is indicated by panel meter.

**CIRCUIT DIAGRAM:-**



**PROCEDURE: -**

1. Switch ON the power supply, switches ON S1. Slowly increase control P1 so that AC servomotor starts rotating. Connect DVM across DC motor sockets (red & black). Vary the speed of servomotor gradually and note the speed N rpm and corresponding back emf Eb across DC motor.
2. Connect DVM across servo motor control winding socked (yellow) and adjust AC Servomotor voltage to 70V and note speed N rpm in table.
3. Switch On S2 to impose load on the motor due to which the speed of AC motor decreases. Increase the load current by means of P2 slowly and note corresponding speed N rpm and Ia. Calculate  $P=I_a \cdot E_b$  and  $Torque = P \cdot \frac{1.019 \cdot 10^4 \cdot 60}{2.2 \cdot 14} Ngm/cm$

**OBSERVATION TABLE:-**

**TABLE-1**

S.NO	SPEED N rpm	Eb volts
1.		
2.		

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3.		
4.		

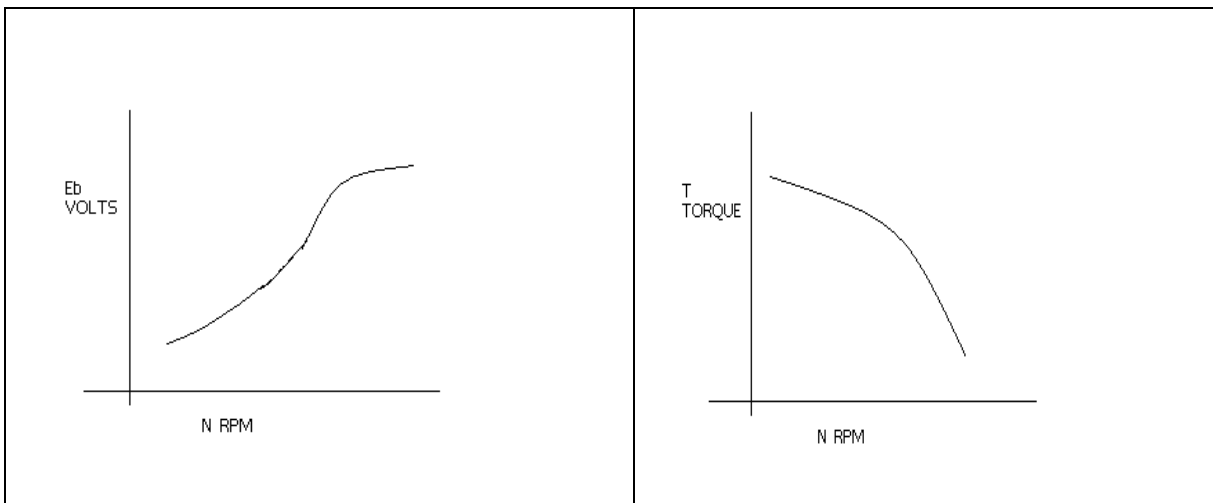
**TABLE-2**

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

### **PRECAUTIONS:** -

1. Apply voltage to servomotor slowly to avoid errors.
2. Impose load by DC motor slowly.
3. Take the reading accurately as the meter fluctuates.
4. Switch OFF the setup when note in use.

### **GRAPH:-**



### **DISCUSSION:-**

The graph is plotted between speed and torque. As we reduce the speed of the motor the torque goes on increasing therefore the graph starts with a low value and rises to a high value approximately linearly. This rise in the graph is due to the rising speed-torque characteristics of AC servo motor.

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### QUIZ:-

- Que 1. What is AC servo motor?  
Ans. An AC servo motor is basically a two phase induction motor except for some Design feature.
- Que.2 What is the use of AC servo motor?  
Ans. AC servo motor has best use for low power control application.
- Que.3 What are the advantages of AC servo motor?  
Ans. It is rugged, light weighted, and has no brush contact as in DC servo motor.
- Que4. What is the important parameter of AC servo motor?  
Ans. The important parameter of AC servo motor is its speed – torque Characteristics.
- Que.5 On what factor does the direction of rotation of AC servo motor Depend.  
Ans. The direction of rotation of AC servo motor depends on the phase relationship of Input voltage V1 and V2 .
- Que 6. What is the drawback of AC servo motor ?  
Ans. The main drawback of AC servo motor is its positive slope which causes Negative damping to lead instability in control system .
- Que.7 How the drawback of positive in AC servo motor is overcome ?  
Ans. The drawback of positive in AC servo motor is overcome by designing the rotor With very high resistance .
- Que.8 What is the input of AC servo motor in feedback control application?  
Ans. In feedback control application phase A is given a fixed rated voltage called Reference voltage and phase B is given a variable voltage called control Voltage.
- Que.9 What is the phase relationship between reference voltage and control Voltage?  
Ans. The reference voltage and control voltage are 90 degrees out of phase with each other.
- Que.10 What are the types of AC servo motor ?  
Ans. AC servo motors are of various type as squirrel cage rotor motor ,drag cup Rotor and solid iron rotor motor.

## EXPERIMENT NO: 1(b)

**AIM:-** To study speed torque characteristics of DC Servo Motor.

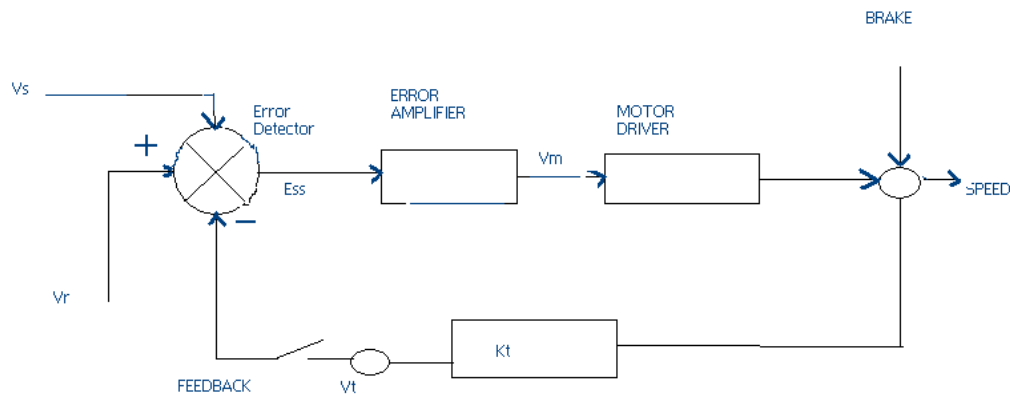
**APPARATUS:-** DC SERVO MOTOR KIT AND DVM.

**THEORY:-** The experiment is carried out in two steps.

1. Open loop performance
2. Close loop performance.

In first case the motor is run without feedback. The amplifier gain factor is kept at minimum gain = 3. motor is connected with main unit by 9 pin D Type socket. Step signal is kept off.

**CIRCUIT DIAGRAM:-**



**PROCEDURE:-**

**OPEN LOOP PERFORMANCE:-** Connect the main unit to the supply. Keep the gain switch off. Set  $V_r = 0.7$  or  $0.8$ . connect DVM with feedback signal socket  $V_t$ . Note the speed  $N$  rpm from display and tacho output  $V_t$  in volts from DVM. Record  $N$  rpm and  $V_t$

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volts for successive gain 4-10 in observation table. Calculate  $V_m = V_r * K_a$ . Where  $K_a$  is the gain set from control 3 – 10.

$$V_r = 0.7 \text{ V.}$$

$$\begin{aligned} V_m \text{ at gain 3} &= 0.7 * 3 \\ &= 2.1 \text{ V.} \end{aligned}$$

**Plot N vs  $V_t$  and N Vs  $V_m$  graph.**

**CLOSED LOOP PERFORMANCE:-** In this case the gain switch is kept in on position thus feedback voltage gets subtracted from reference voltage. This is observed by decreased motor speed. Record the result between gain factor  $K_a$  and speed N. draw the graph between techo voltage  $V_t$  and speed N.

### OBSERVATION TABLE:-

S.NO.	GAIN( $K_a$ )	$V_t$ (volts)	N(rpm)	$V_m = V_r \times K_a$

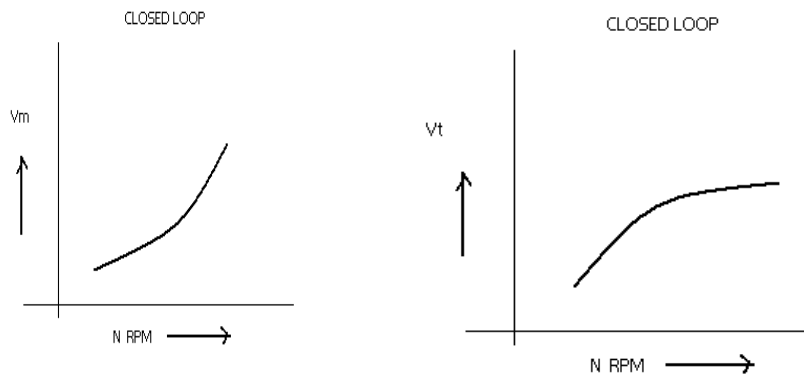
- PRECAUTIONS:-**
1. Apply the voltage slowly to start the motor
  2. Take the reading properly.
  3. Do not apply breaks for long time as the coil may get heated up.
  4. Switch OFF the main power when not in use.

### GRAPH:-

For open loop:







## **DISCUSSION:-**

The graph is plotted between  $N$  (RPM) and  $V_t$  (tachometer voltage) and  $N$  (rpm) &  $V_m$  (motor voltage). The tachometer voltage increases linearly as the RPM of DC servo motor increases. Similarly, the motor voltage increases with RPM in open loop. The slope is less but in closed loop the slope is sharp and this is due to the feedback gain.

## **QUIZ:-**

- Que.1 What are the uses of DC servo motor?  
Ans. DC servo motor is widely used in radars, computers, robots, tracking systems and process controllers etc.
- Que.2. What are the types of DC servo motors?  
Ans. DC servo motors are separately excited or permanent magnet type.
- Que.3. How the speed of DC servo motor is controlled?  
Ans. The speed of DC servo motor is controlled by varying the armature voltage.
- Que.4. What is the relation between torque and speed of DC servo motor?  
Ans. The torque of DC servo motor decreases with increase in speed.
- Que.5. Why the speed torque characteristics of DC servo motor has large Negative Slope?  
Ans. The speed – torque characteristics of DC SERVO MOTOR has a large Negative Slope due to large armature resistance.
- Que.6. What is the effect of negative slope?  
Ans. The negative slope provides viscous damping for the servo drive system.
- Que.7. In which wattage the DC servo motors are available?  
Ans. DC servo motors are available in fraction of a watt to a few hundred watts.
- Que.8. What are the special features of DC SERVO MOTORS?  
Ans. High torque to inertia ratio, High torque to value ratio, Low inductance of Winding and efficient heat dissipation is the special features of DC servomotor

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Que.9. How the direction of rotation of DC servo motor can be changed?

Ans. The direction of rotation of DC servo motor can be changed by reversing the Phase difference from leading to lagging and vice versa between control voltages and reference voltage.

Que.10. What is transfer function of DC SERVO MOTOR?

Ans. The ratio of Laplace transform of output to the laplace transform of input.

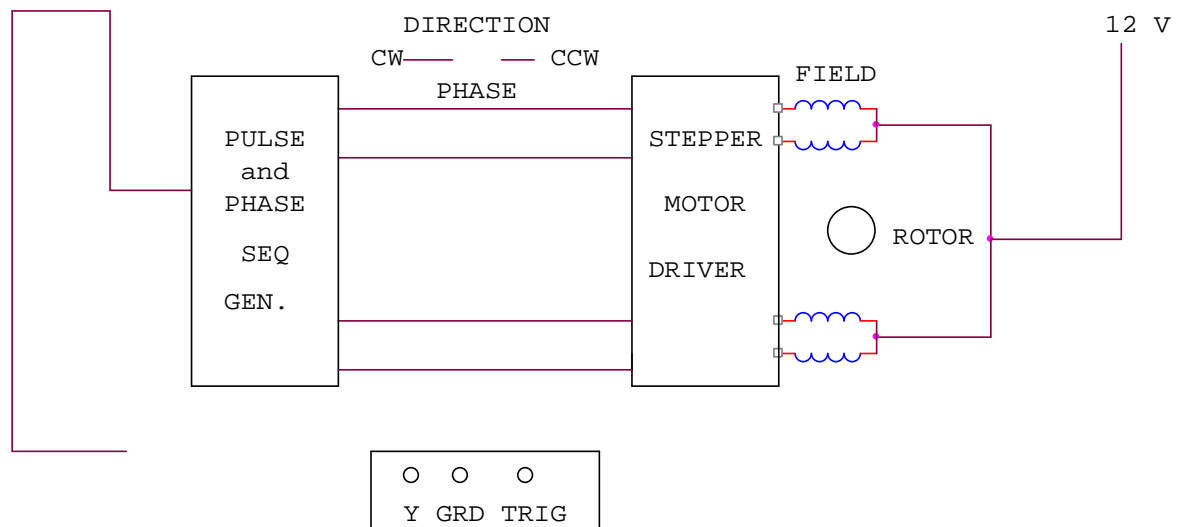
## EXPERIMENT – 2

**AIM: -** To study the stepper motor and to execute microprocessor computer based control of the same by changing number of steps, the direction of rotation and speed.

**APPARATUS USED: -** Stepper Motor Kit,  $\mu$ P Kit, Interface Cord and Connecting Leads.

**THEORY:-** The stepper motor is a special type of motor which is designed to rotate through a specific angle called step for each electrical pulse received from its control unit. It is used in digitally controlled position control system in open loop mode. The input command is in form of a train of pulses to turn the shaft through a specified angle. The main unit is designed to interface with  $\mu$ P 8085 kit. The stepper motor controller card remains active while the pulse sequence generator disabled as given plug is connected with  $\mu$ p interface socket. The following programme enables the stepper motor to run with  $\mu$ p 8085 kit. For two phases four winding stepper motor only four LSB signals are required.

### CIRCUIT DIAGRAM:-



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### **PROCEDURE:-**

Connect the stepper motor with  $\mu$ p 8085 kit as shown in fig. press EXMEM key to enter the address as given then press NEXT to enter the data .

### **ADDRESS DATA**

2000	3E 80 MVI A, 80	Initialize port A as output port.
2002	D3 03 OUT 03	OB
2004	3E F9 Start MVI AFA	
2006	D3 00 OUT 00	Output code for step o.
2008	CD 3020 call delay	delay between two steps.
200B	3E F5 MVI A, F6	Location reserve for current Delay.
200d	D3 00 OUT 00	Output code for step 1.
200F	CD 3020 Call delay	delay between two steps.
2012	3E F6 MVI A, F5	
2014	D3 00 OUT 00	Output code for step 2.
2016	CD 3020 calls delay	between two steps.
2019	3E FA MVI A, F9.	
201B	D3 00 OUT 00	Output code for step 3.
201D	CD 3020 call delay	delay between two steps.
2020	C3 04 20 JMP START	Start.

Press FILL key to store data in memory area. This will complete the pulse sequence generation. To delay programme route, first press EXMEM to start, a dot sign will appear in address field then enter the start address. Press NEXT to enter data.

### **ADDRESS DATA**

2030	11 00 00 LXI D 00 00	Generates a delay.
2033	CD BC 03 CALL DELAY	
2036	11 00 00 LXI D 00 00	Generates a delay.
2039	CD BC 03 CALL DELAY	
203C	C9 RET	

Press FILL to save data to execute the programmed press the key GO .The above programme is to rotate the motor at a particular as defined by the given address. Changing the following contents will change the motor speed.

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<u>ADDRESS</u>	<u>DATA</u>
2030	11 00 20 AND 2036 TO SIMILAR 11 00 20
CHANGE	11 00 10 TO 11 00 10
CHANGE	11 00 05 TO 11 00 05
CHANGE	11 00 03 TO 11 00 03.

The motor direction depends upon codes FA, F6 ,F5 AND F9.Change in following codes will change the motor direction.

<u>ADDRESS</u>	<u>DATA</u>
2005	3E F9 TO 3E FA
200C	3E F5 TO 3E F6
2012	3E F6 TO 3E F5
2019	3E FA TO 3E F9.

### OBSERVATION TABLE:-

Sr No.	No. of Pulses	Displacement	Step Angle

**RESULT:-** The stepper motor runs as per fed programme.

### **PRECAUTION:-**

1. Make the connection of motor with  $\mu$ p kit properly.
2. Feed the programme carefully and correctly.
3. Do not change the motor direction at high speed.

### **QUIZ:-**

Que.1.Why the application of stepper motor is increasing?

Ans. The use of stepper motor is increasing due to availability in large power rating and reducing cost.

Que.2. What is stable condition of rotor in stepper motor ?

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Ans. It is that angle at which torque is zero and is positive for smaller angle and negative for larger angle.

Que.3. What are the modes of operation of stepper motor?

Ans. There are two modes of operation of stepper motor, open loop and close loop mode.

Que.4. What are the types of stepper motor?

Ans. There are three types of stepper motors, VR stepper motor, P stepper motor and hybrid stepper motor.

Que.5. How the windings of stepper motor are wound?

Ans. The windings of stepper motor are wound in such a way that there are only two phases.

Que.6. How many logics are there in each sequence?

Ans. There are two logics in each sequence, 0 and 1.

Que.7. In how many phases does the motor run?

Ans. The stepper motor runs in four phases, A, AB, B and AB.

Que.8. Why the stepper motor is run in four phases?

Ans. The stepper motor is run in four phases to avoid over stepping and to improve the response

Que.9. On what factor does the settling time of stepper motor depend?

Ans. The settling time of stepper motor depends upon loading and input sequence.

Que.10. What is use of  $\mu\text{p}$  kit?

Ans. The  $\mu\text{p}$  kit is used to run the stepper motor as per the fed programme.

## EXPERIMENT NO. 3

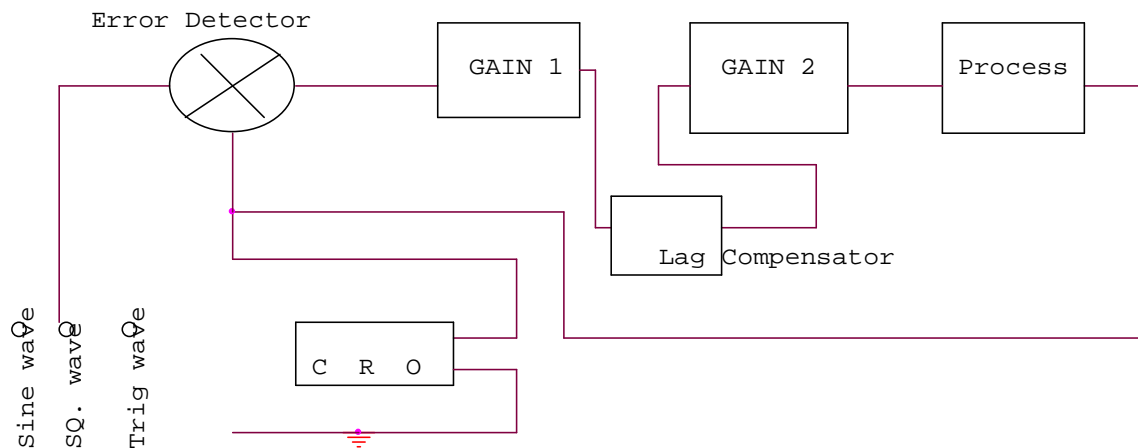
**AIM:** To study LEAD LAG compensator and to draw magnitude and phase plots.

**APPARATUS REQUIRED:** lead lag compensator kit, CRO, and connecting leads.

### THEORY:

Compensation network are often used to make improvement in transient response and small change in steady state accuracy. The set up is divided in to three parts. Signal source: It has sine wave of 10-1200 Hz. Of 0-8 Vpp, Square wave of 20, 40 and 80 Hz of 0-2 Vpp. Trigger is available for trigger of CRO in external trigger mode. The amplitude is 1.2 Vpp. There are three compensation circuits as lag, Lead and Lag-Lead with transfer function. The set up has two DC regulated power supply for signal source and systems.

### CIRCUIT DIAGRAM



**PROCEDURE:** The experiment is divided in two parts.

1. Open Loop Response: Connect square wave to gain and CRO across input and output. Select frequency to 80 Hz at 0.2 Vpp. Measure input amplitude Vpp as A and output as amplitude as B. Calculate gain factor= $B/A$ . Connect sine wave with process input, CRO across input and output. Set input voltage =8Vpp. From low frequency end 10Hz note output voltage Vpp as B. Note the phase difference for each test frequency. Connect the sine wave with lag input .connect CRO across input and output. Note the output voltage, phase difference for each test

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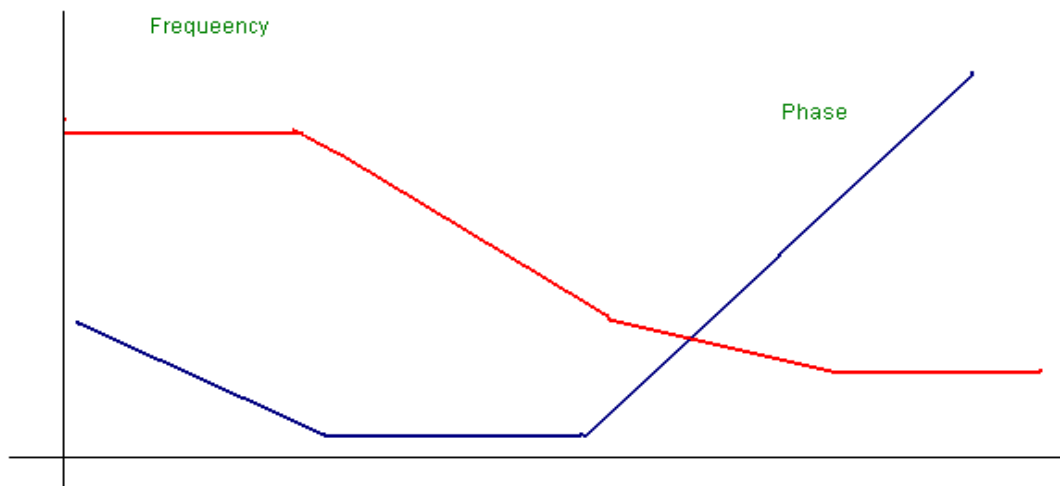
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- frequency. Prepare a table between input/output voltage, gain magnitude in db and phase angle in degrees. Plot a graph accordingly.
2. Close loop response: connect the square wave signal of 20Hz, 1Vpp at input of error detector. Adjust gain to the value found from plot for required shape of response and sketch it on the paper. From the transient response measure maximum overshoot  $M_p$ , steady state error  $E_{ss}$  and peak time  $T_p$ . Select wave frequency to 40Hz, 1Vpp and adjust gain control to 60%. Note gain control setting. Trace wave form on paper with record of  $E_{ss}$ ,  $M_p$ , and  $T_p$ . Select frequency to 80Hz and adjust gain control for minimum  $E_{ss}$ . Trace wave form with  $M_p$  and  $T_p$ . connect process with lag compensator and gain 2. Set square wave frequency to 20Hz, 1Vpp at error detector input. Adjust gain control to for similar  $E_{ss}$ . Note gain to from dial setting. Trace the wave form on paper with record of  $M_p$ ,  $T_p$  and  $E_{ss}$ .

### OBSERVATION TABLE :

S.NO.	A Vpp	B Vpp	GAIN dB	PHASE ANGLE

### **GRAPH:**





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### QUIZ:

- Que.1. What is the use of adder at the input of PID controller?  
Ans. Adder is used to sum up the reference signal and feed Back signal.
- Que.2. What is the use of time delay?  
Ans. Time delay generates a delay of 1.3 seconds between input And output.
- Que.3. What is uncommitted amplifier?  
Ans. It is an operational amplifier configured as phase inverter.  
Its gain constant is= -1.
- Que.4. What is the range of frequency and amplitude of square wave Source?  
Ans. The range of frequency is from 10 to 40 hz and amplitude is From 0 to 2 Vpp.
- Que.5. What is range of voltage source?  
Ans. The range of voltage source is from -2 to +2 v.
- Que.6. What is equation of PID controller?  
Ans. The equation of PID controller is  
$$m(t) = K_p e(t) + K_i \int e(t) dt + K_d de(t)/dt.$$
- Que.7. What is the transfer function of PID controller?  
Ans. The transfer function of PID is  $G(\text{PID}) = m(s)/E(S).$
- Que.8. What are the methods of tuning PID?  
Ans. There are two methods of tuning PID, process reaction curve method and continuous cycling method.
- Que.9. What is the main advantage of derivative error compensation?  
Ans. Main advantage of this compensation is that as the damping increases due to compensation , system settling time reduces.
- Que.10. How derivative output compensation is obtained?  
Ans. Derivative output compensation is obtained by means of a Tachometer feedback.

## EXPERIMENT NO:4

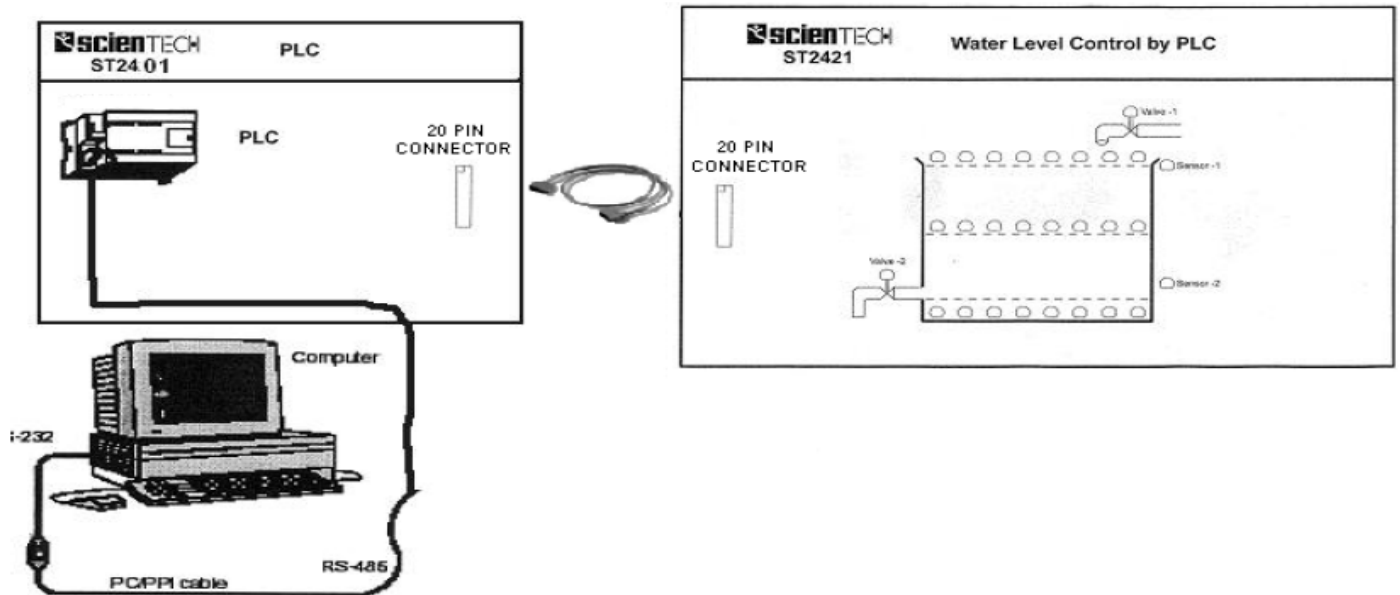
**AIM:** To study water level control using industrial PLC

**APPARATUS REQUIRED:** -Trainer kit ST2421 PLC trainer ST2401, ST2402 and connector.

### **THEORY:**

Water level controlling is shown with the help of LEDs. The apparatus is connected with output of PLC. Two valves for filling and draining water are shown, for indicating ON\OFF condition of valve LED is used. Filling of tank indicated by two sensors, positioned to sense maximum and minimum water levels of tank.

### **CONNECTION DIAGRAM:-**



### **PIN CONFIGURATION OF CONNECTOR:-**

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I/P - 0.0	<input type="radio"/>	<input type="radio"/>	M (GND)
I/P - 0.1	<input type="radio"/>	<input type="radio"/>	O/P - 0.0
I/P - 0.2	<input type="radio"/>	<input type="radio"/>	O/P - 0.1
I/P - 0.3	<input type="radio"/>	<input type="radio"/>	O/P - 0.2
I/P - 0.4	<input type="radio"/>	<input type="radio"/>	O/P - 0.3
I/P - 0.5	<input type="radio"/>	<input type="radio"/>	O/P - 0.4
I/P - 0.6	<input type="radio"/>	<input type="radio"/>	O/P - 0.5
I/P - 0.7	<input type="radio"/>	<input type="radio"/>	O/P - 0.6
I/P - 1.0	<input type="radio"/>	<input type="radio"/>	O/P - 0.7
+L (V)	<input type="radio"/>	<input type="radio"/>	O/P - 1.0

---

### **PROCEDURE:**

1. First the valve-1 will open (LED is ON), then water level will increase (row of LEDs will glow)
2. As level reaches above sensor-1, sensor LED will glow. As water level reaches above sensor-2 valve-1 gets closed.
3. After some delay valve-2 will get ON, which will drain water. As soon as water level goes below sensor-1, valve-2 will close. And same process will go on.

### **Truth Table**

Sensor-1	Sensor-2	Valve-1	Valve-2
OFF	OFF	ON	OFF
ON	OFF	ON	OFF
ON	ON	OFF	ON

### **PRECAUTIONS:-**

1. Use only the mains cord designed for this instrument
2. To avoid fire or shock hazards, observe all ratings and marks on the instrument.
3. Use the fuse type and rating specified for this instrument.
4. Do not operate in wet / damp conditions.
5. Do not operate in an explosive atmosphere.
6. Keep the product dust free, clean and dry.

### **QUIZ:-**

Q.1 What is PLC?

Ans. A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assemble lines, amusement rides, or light fixtures.

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Q.2 What is full form of PLC?

Ans. The full form of PLC is Programmable Logic controller.

Q.3 What are the applications of PLC ?

Ans. Manufacturing Industry, Travel Industry, Textile Industry etc.

Q.4 Which is the famous programming language is used in PLC?

Ans. Ladder logic is mainly used in PLC.

Que5. What are the advantages of PLC.

Ans. Flexible, Correcting Errors, Space Efficient, low cost.

Que6. What are the most popular PLC's used on the packing industry?

Ans: Packaging industry PLC's, most notably cosmetic and pharmaceutical packaging machinery

Q.7 Why PLC is different from other Computers?

Ans. The main difference from other computers is that PLCs are armored for severe conditions (such as dust, moisture, heat, cold) and have the facility for extensive input/output (I/O) arrangements.

Que8. What is DCS?

Ans. DCS is Distributed Control Systems which is used to control very big plants by using simple GUI screens. PLCs are interfaced with DCS for interlocking.

Que9. What is SCADA?

Ans. SCADA is Supervisory Control and Data Acquisition which is used to control and Monitor small number of Equipments in a field.

Que10. What is the difference between PLC and Relay?

Ans. PLC is the much less complex than large relay based system. Also PLC is the very flexible due to network architecture compare to relay panel.

## EXPERIMENT NO. 5

**AIM:** - To study motion control of a conveyor belt using a industrial PLC

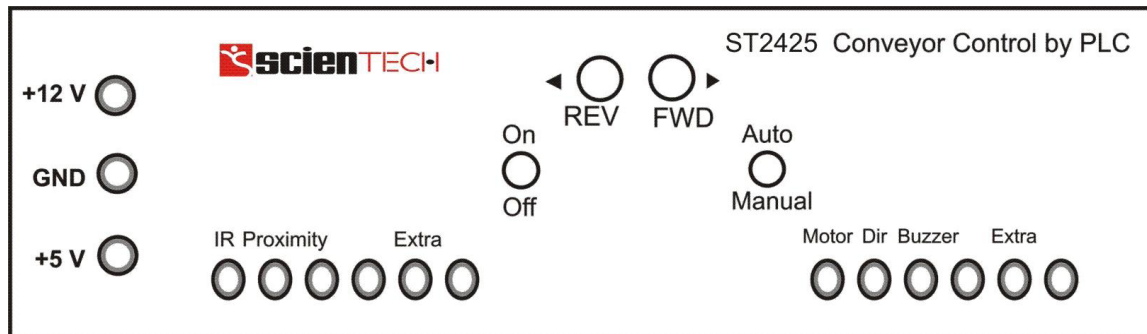
**APPARATUS REQUIRED:** - Trainer kit ST2425, Connecting wires.

### THEORY:-

Conveyors are basically material handling equipments. Conveyors used for moving materials over a fixed path. There is a broad range of types of conveyor systems. Wheel conveyor, roller conveyor, chain conveyor, Magnetic conveyor, pneumatic conveyor are the major types.

ST2425 Conveyor Control by PLC is a *Flat Belt Conveyor* system. It consists of two sensors one is IR sensor and other is proximity sensor. Belt is driven by a DC motor. Output of proximity sensor, output of IR sensor are the inputs of PLC and motor, motor direction, buzzer are the outputs of PLC. Some additional I/Os also given for users.

### PANEL DIAGRAM:-



### PROCEDURE:-

There are two modes of operation of ST2425 one is “Auto Mode” and other is “Manual Mode”.

Auto Mode:

1. Switch on the Trainer
2. The switch indicated by arrow should be placed in Auto mode
3. Connect +24 V & +5 V supplies
4. Connect inputs and outputs to PLC
5. Set the total count
6. Place containers on the belt randomly

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Manual Mode:

1. Switch on the Trainer
2. The switch indicated by arrow should be placed in Manual mode
3. You can change the direction of motor by using push buttons

### **PRECAUTIONS:-**

1. Make sure that connections are tight.
2. Properly connect inputs and outputs to PLC
3. Switch off the set when not in use.

### **QUIZ:**

Q.1 What is control system?

Ans It is combination of elements intended to act together to accomplish an objective.

Q.2 What is full form of PLC?

Ans. The full form of PLC is Programmable Logic controller.

Q.3 What are Conveyors?

Ans. Conveyors are basically material handling equipments. Conveyors used for moving materials over a fixed path.

Q.4 Why PLC is different from other Computers?

Ans. The main difference from other computers is that PLCs are armored for severe conditions (such as dust, moisture, heat, cold) and have the facility for extensive input/output (I/O) arrangements.

Q.5 What are is proximity sensor.

Ans. A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.

Q.6 Where are the conveyors used?

Ans. The conveyors are used:When material is to be moved frequently between specific points, to move materials over a fixed path and When there is a sufficient flow volume to justify the fixed conveyor investment.

Que7.What is the difference between PLC and Relay?

Ans. PLC is the much less complex than large relay based system.Also PLC is the very flexible due to network architecture compare to relay panel.

Que8.What is the full form of PLC

Ans. The full form of PLC is Programmable Logic controller.

Que.9 What are the applications of PLC ?

Ans. Manufacturing Industry, Travel Industry, Textile Industry etc.

Que10 What is the difference between the PLC and other computers.

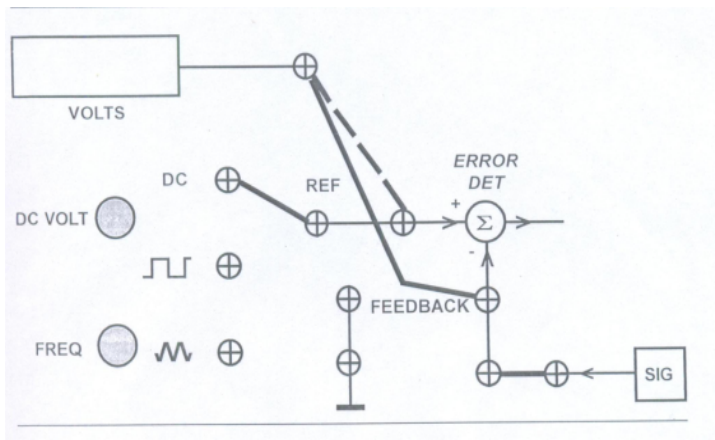
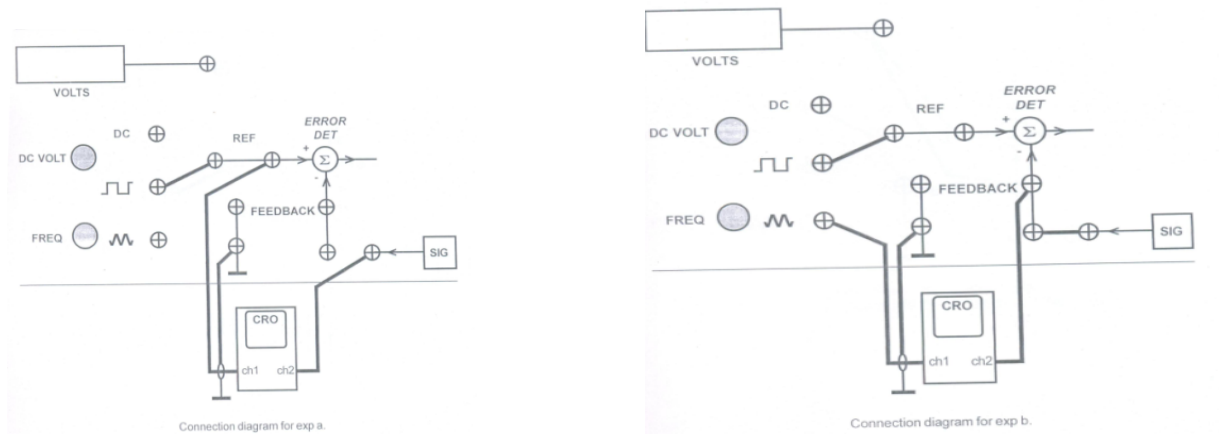
Ans.The main difference from other computer is that PLCs operate in industrial environments(dust,moisture,heat,cold)and have multiple input/output terminals.

**EXPERIMENT NO. 6**

**AIM:** To study control action of light control device/system (e.g.lamp response)

**APPARATUS REQUIRED:** Dual trace CRO, DVM

**CIRCUIT DIAGRAM:**



**PROCEDURE:**

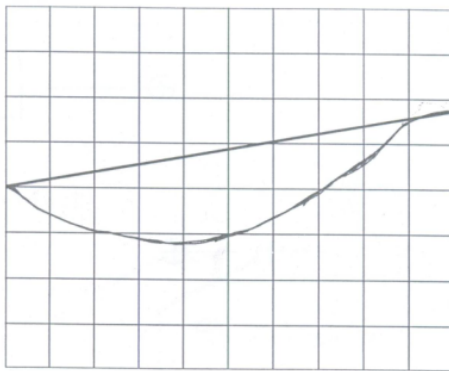
To study the dynamic response of lamp:

1. A square wave signal of 5-20 Hz, is given with the main unit

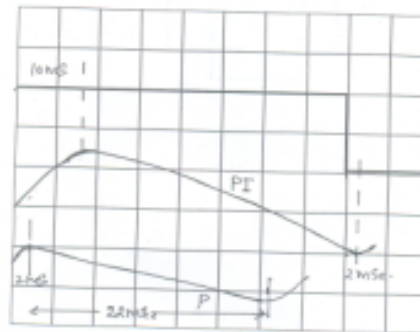
## CONTROL SYSTEM LAB (EE-324-F)

2. Connect the CRO one channel with the reference input socket of error detector block. Connect the 15.9Hz (60mSec) square wave signal with the same input of error detector
3. Connect the other channel of CRO with the signal conditioner output socket. Select the amplifier mode from the selector switch and keep the disturbance switches in off condition.
4. Switch on the power supply and adjust the amplifier gain select to number 6, means the amplifier is selected to amplifying factor 6.
5. Adjust the CRO time base and amplitude controls to obtain the steady waveform pattern showing the input and output signal. Note the output signal is taken from the sensor signal conditioner which is negative in polarity thus its inverted form is applied as the lamp response signal .
6. Observe and trace the response curve of both the actuating signal and the lamp output. Note the +ve lead signal of square wave is 60 mSec duration.
7. Decrease the amplifier gain to 4 and observe its effect upon the lamp output response. It is observed that the amplitude of lamp intensity is decreased, since the sensor output is directly in proportion of lamp intensity.

### WAVEFORMS



Dynamic response in X - Y mode. X with triangular and Y with square wave excited. Freq = 15.9 Hz.



P and P - I controller dynamic response.  $f = 15.9$  Hz.

### PRECAUTIONS:

1. Use only the main cord designed for this instrument
2. To avoid fire or shock hazards, observe all the ratings.
3. Use the fuze type and the rating specified for this instrument
4. Don't operate in wet /damp conditions
5. Do not operate in an explosive atmosphere
6. Keep the product dust free, clean and dry



## CONTROL SYSTEM LAB (EE-324-F)

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### QUIZ:-

Que.1. What is full form of PID?

Ans. P stands for proportional, I stand for integrated and D stands for Derivative gain.

Que.2. What is derivative error compensation?

Ans. A system is said to have derivative error compensation when the generation of its output depends in some way on its rate of change of actuating signal .

Que.3. What is integral error compensation?

Ans. A system is said to have integral error compensation if its output Response depends in some way upon the integral of its actuating Signal.

Que.4. What is effect of integral error compensation on the system ?

Ans. Integral error compensation changes a second order system to a Third order system.

Que.5. How derivative error compensation is obtained ?

Ans. Derivative error compensation is obtained by using an amplifier Which provides a signal having two terms, one proportional to To derivative of actuating signal and other proportional to the actuating Signal itself.

Que.6. How integrating error compensation is obtained?

Aue. Integrating error compensation is obtained by introducing a controller Which contains two terms, one is proportional to the integration of Actuating- signal and other proportional to actuating signal itself.

Que.7. Where PID is used?

Ans. PID is used in process industries for feedback gain.

Que.8. If dynamic model is not known then PID is tuned experimentally by Simulation.

Que.9. How PID is tuned if dynamic model is known?

Ans. If dynamic model is known then PID is tuned by Ziegler-Nicholas Method.

Que.10. What time response specifications are required to be met by the control System?

Ans. Three time response specifications are to be met by the control system, Steady- state accuracy, damping factor and settling time.

**EXPERIMENT NO:-7**

**EXPERIMENT:** To study behavior of 1 order, 2 order, type 0, type 1 system.

**APPARATUS REQUIRED:** Linear system simulator kit & CRO

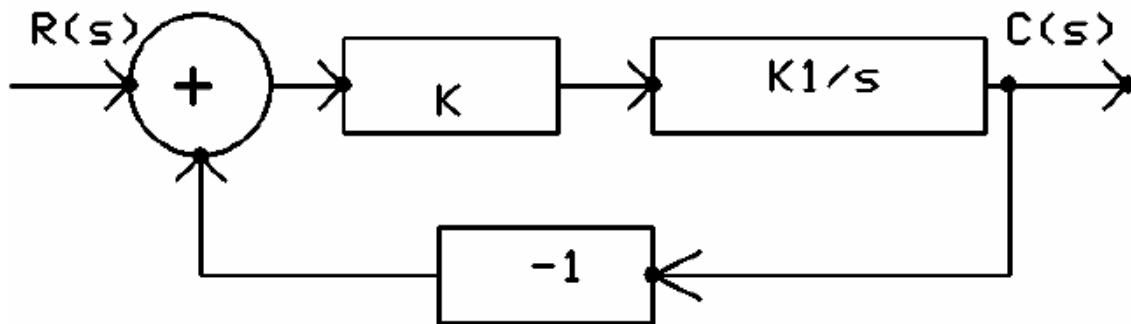
**THEORY :** The type number of the system is obtained from the number of poles located at origin in a given system. Type – 0 system means there is no pole at origin. Type – 1 system means there is one pole located at the origin.

The order of the system is obtained from the highest power of s in the denominator of closed loop transfer function of the system.

The first order system is characterized by one pole or a zero. Examples of first order systems are a pure integrator and a single time constant having transfer function of the form  $K/s$  and  $K/(sT+1)$ . The second order system is characterized by two poles and upto two zeros. The standard form of a second order system is  $G(s) = \omega_{n2} / (s^2 + 2 \xi \omega_n s + \omega_{n2})$  where  $\xi$  is damping ratio and  $\omega_n$  is undamped natural frequency.

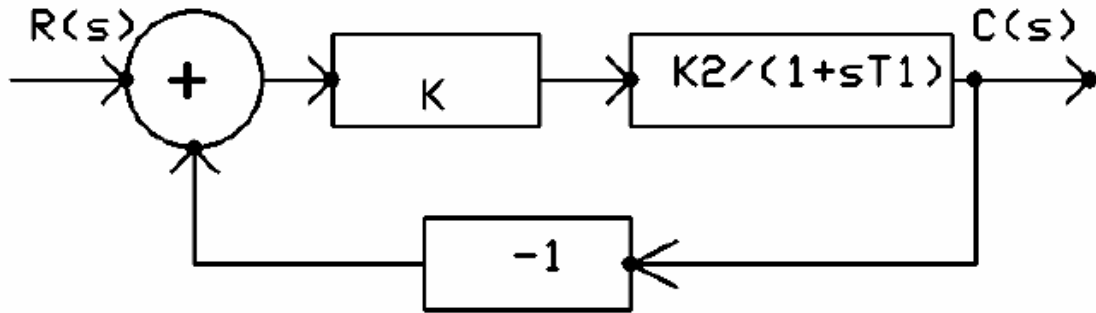
**BLOCK DIAGRAM:**

**1.Type- 1 First order system**

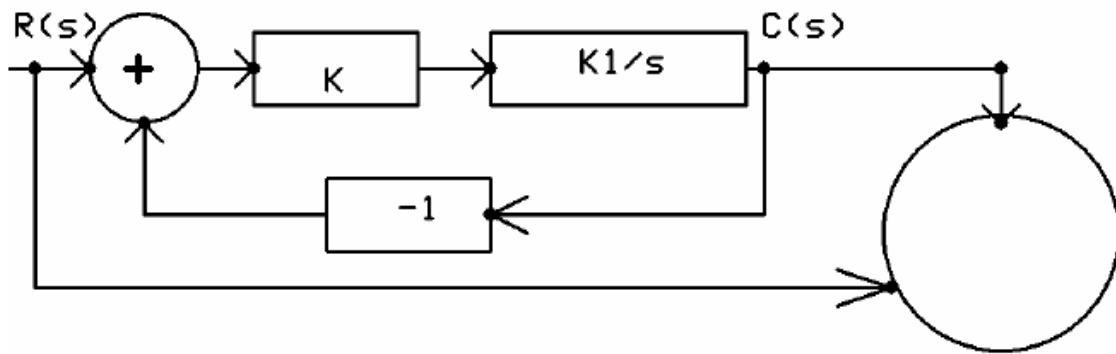


**2.Type-0 first order system**

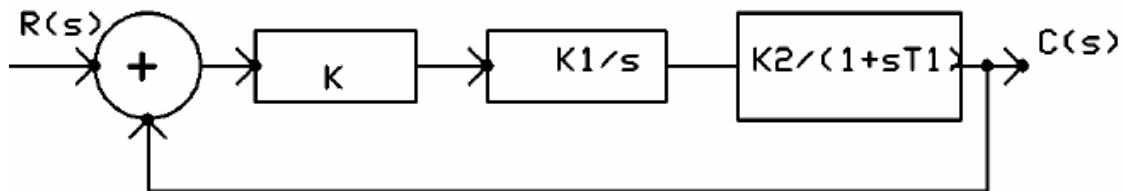
CONTROL SYSTEM LAB (EE-324-F)



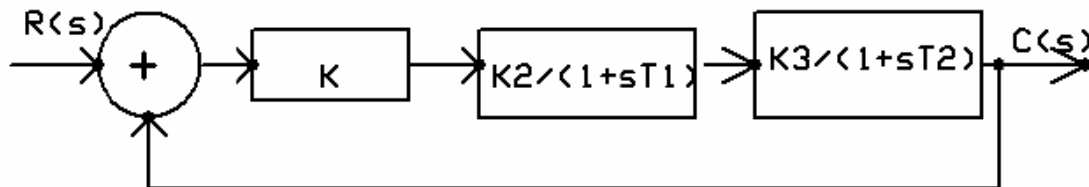
To find steady state error of type- 1 system



Type-1 second order system



Type-1 second order system



## CONTROL SYSTEM LAB (EE-324-F)

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### FORMULAE USED:

1. Steady state error  $e_{ss}(V) = R_e/K K_1$

where  $R_e = 2R$

where R is the slope.

K is the gain

K<sub>1</sub> is the gain of integrator block

From the waveform

2. Damping ratio,  $\xi = \sqrt{(\ln M_p)^2 / (\pi^2 + (\ln M_p)^2)}$

Where  $M_p$  is peak percent overshoot obtained from the waveform

3. Undamped natural frequency,  $\omega_n = \pi / t_p \sqrt{1 - \xi^2}$

Theoretical Values of  $\omega_n$  and  $\xi$  can be obtained by comparing the co-efficients of the denominator of the closed loop transfer function of the second order system with the standard format of the second order system

Closed loop transfer function of the type – 1-second order system is

$$G(s) = K K_1 K_2 / s (1 + sT_1)$$

K is the gain

K<sub>1</sub> is the gain of Integrator = 9.6

K<sub>2</sub> is the gain of the time constant – 1 block = 10

T<sub>1</sub> is the time constant of time constant – 1 block = 1 ms

Closed loop transfer function of the type – 0 second order system is

$$G(s) = K K_2 K_3 / (1+sT_1) (1 + sT_2)$$

K is the gain

K<sub>2</sub> is the gain of the time constant – 1 block = 10

K<sub>3</sub> is the gain of the time constant – 2 block = 10

T<sub>1</sub> is the time constant time constant – 1 block = 1 ms

T<sub>2</sub> is the time constant time constant – 2 block = 1 ms

### PROCEDURE:

#### 1. To find the steady state error of type – 1 first order system

1. The blocks are Connected using the patch chords in the simulator kit.

2. The input triangular wave is set to 1 V peak to peak in the CRO and this applied to the REF terminal of error detector block. The input is also connected to the Xchannel of CRO.

3. The output from the system is connected to the Y- channel of CRO.

4. The experiment should be conducted at the lowest frequency to allow enough time for the step response to reach near steady state.

5. The CRO is kept in X-Y mode and the steady state error is obtained as the vertical displacement between the two curves.

6. The gain K is varied and different values of steady state errors are noted.

7. The steady state error is also calculated theoretically and the two values are compared.

#### 2. To find the steady state error of type – 0 first order system

1. The blocks are connected using the patch chords in the simulator kit.

2. The input square wave is set to 1 V peak to peak in the CRO and this applied

## CONTROL SYSTEM LAB (EE-324-F)

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to the REF terminal of error detector block. The input is also connected to the Xchannel of CRO.

3.The output from the system is connected to the Y- channel of CRO.

4.The CRO is kept in X-Y mode and the steady state error is obtained as the vertical displacement between the two curves.

5.The gain K is varied and different values of steady state errors are noted.

### **3.To find the closed loop response of type – 0 and type- 1 second order system**

1.The blocks are connected using the patch chords in the simulator kit.

2.The input square wave is set to 1 V peak to peak in the CRO and this applied to the REF terminal of error detector block. The input is also connected to the Xchannel of CRO.

3.The output from the system is connected to the Y- channel of CRO.

4.The output waveform is obtained in the CRO and it is traced on a graph sheet. From the waveform the peak percent overshoot, settling time, rise time, peak time are measured. Using these values  $\omega_n$  and  $\xi$  are calculated.

5.The above procedure is repeated for different values of gain K and the values are compared with the theoretical values.

### **TABULAR COLUMN:**

#### **1.To find the steady state error of type – 1 first order system**

S.No.	K	R (V/sec)	$e_{ss}^*$ (V)	$e_{ss}^\#$ (V)

#### **2.To find the steady state error of type – 0 first order system**

S.No.	K	$e_{ss}$ (V)

#### **3. To find the closed loop response of type – 0 & type – 1 second order system**

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Page

## CONTROL SYSTEM LAB (EE-324-F)

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S.No.	K	%M <sub>P</sub>	t <sub>r</sub> (sec)	t <sub>p</sub> (sec)	t <sub>s</sub> (sec)	$\xi^*$	$\omega_n^*$ (rad/sec)	$\xi^\#$	$\omega_n^\#$ (rad/sec)

**CALCULATION:**

**RESULT:**

Thus the time response of first and second order type- 0 and type- 1 systems are studied.

## **EXPERIMENT NO:-8**

**EXPERIMENT:** To study the different control systems toolboxes in MATLAB.

**APPARATUS REQUIRED:** MATLAB software

**THEORY :** Control System Toolbox is a package for Matlab consisting of tools specifically developed for control applications. The package offers data structures to describe common system representations such as state space models and transfer functions, as well as tools for analysis and design of control systems. There are also tools for simulation of systems.

In this exercise you will get to know the basic commands of Control System Toolbox. When you have completed this exercise, you should be able to understand and use Control Systems Toolbox to create and analyze linear systems. Extensive use of the Matlab help command is recommended. It is also recommended that you create a script file (e.g. myscript.m) in which you write your commands. By running a script file instead of typing the commands directly at the Matlab prompt, it is easier to correct mistakes, and also, your work will be saved for later use.

To enter a matrix in Matlab, for example matrix A, do

## CONTROL SYSTEM LAB (EE-324-F)

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$$A = [0 \ 1; -1 \ -1]$$

Creation and conversion of systems Control System Toolbox supports several system representations of linear time invariant systems. In this exercise we will use two of the most common representations; state space models and transfer functions. Define the system matrices A, B, C and D given above. (What is the value of D in the model?) Create a state space description of the system using ss, and name it sys\_ss. Find out how to use ss by using the help function (help ss). At this stage, you should have obtained a state space description of the system. Let us now create an equivalent transfer function model of the system above.

This could, as you know, be done by using the formula  $G(s) = C(sI-A)^{-1}B+D$ . However, Matlab may also be used for the task. Use the command tf to convert the state space model to a transfer function and name it sys\_tf. Notice that tf may be used for creation of transfer functions as well as conversion.

### **Time domain analysis**

Use the command step to plot the step response of the system. Relate the characteristics of the step response to the location of the poles. If there is time, use initial and lsim to study the system response.

Some useful Matlab commands



## CONTROL SYSTEM LAB (EE-324-F)

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plot	Linear plot.
subplot	Breaks the Figure window into small axes.
axis	Control axis and scaling appearance.
hold	Hold current graph.
grid	Grid lines.
title	Graph title.
xlabel, ylabel	Axes labels.
tf	Create a transfer function model.
tfdata	Extract numerator and denominator.
ss	Create a state-space model.
ssdata	Extract state-space matrices.
zpk	Create a zero/pole/gain/model.
step	Step response.
initial	Response of state-space model with given initial state.
pole	System poles.
zero	System zeros.
roots	Find polynomial roots.
pzmap	Pole-zero map.
eig	Compute eigenvalues and eigenvectors.
bode	Draw a bode frequency response.
lsim	Simulate time response of LTI models to arbitrary inputs.
simulink	Open the simulink browser.
sim	Use a Simulink model from a Matlab script
simset	Set options for the sim command
ictools	Interactive tools for control
pplane6	Phase plane analysis, download from our webside
linmod	Obtain the state-space linear model of the system of ordinary differential equations described in a simulink model, note that the model must contain a simulink block <i>out</i> from sinks and a simulink block <i>in</i> from sources

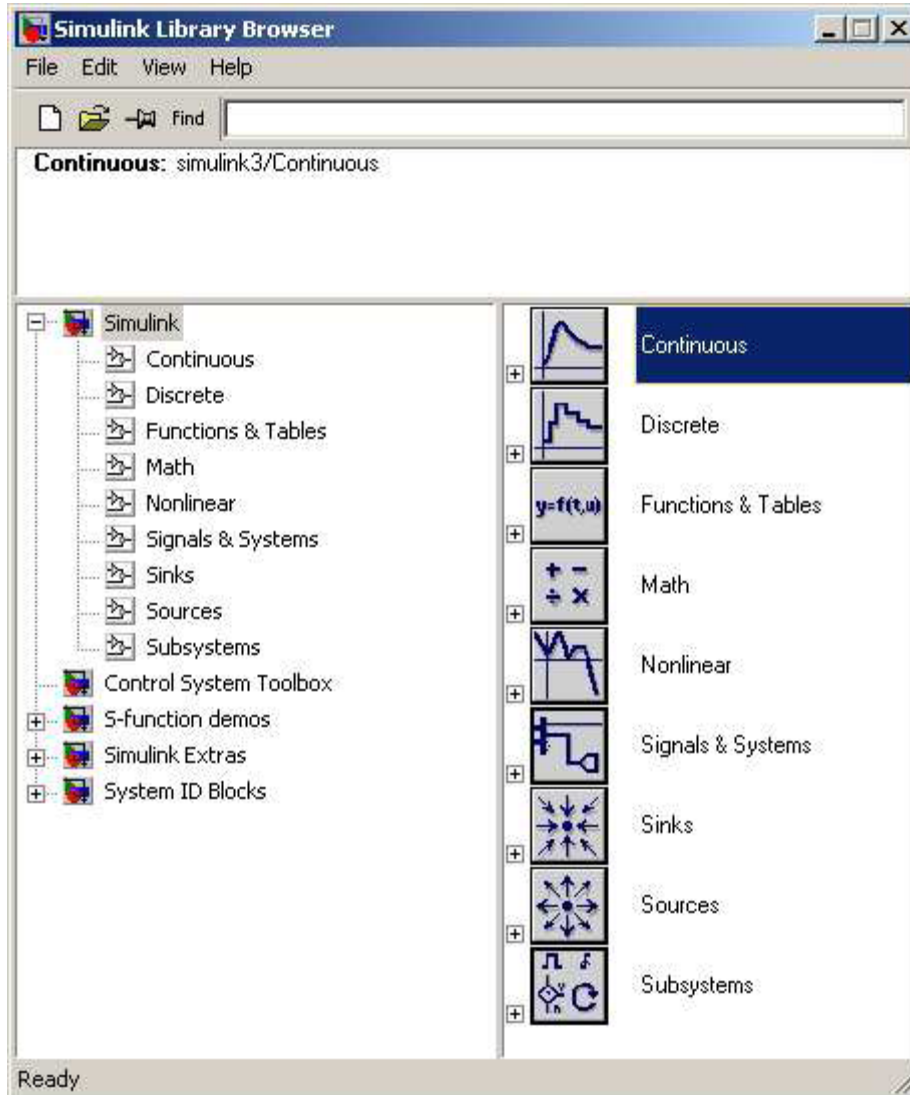
### Introduction to Simulink

Simulink is a simulation program based upon Matlab. There are several ways to define a model. One can work graphically and connect block diagrams with predefined blocks. Alternatively one can give the mathematical description in forms of differential equations in an mfile (the format for programs written in the Matlab programming language). Matlab/Simulink supports both these representations as well as combinations. Furthermore one can use descriptions that include a hierarchy of connected subsystems. To understand how models are described and simulated using block diagrams, it is best to run small examples on a computer.

#### **How to Start Simulink**

StartMatlab6.

Then give the command simulink in Matlab. This gives a window with blocks as shown in fig.



## Using Simulink Models in Matlab Scripts

Often, it is convenient to work with Matlab scripts (mfiles), in order to save a sequence of commands. It is possible to use Simulink models from within a Matlab script, using the command `sim`. By using the command `simset` options for the `sim` command may be specified. Use the model from the previous example. Save the model, and name it "mymodel.mdl". Create a Matlab script named "mysim.m", and enter the following commands:

```
tfinal = 300;
```

## CONTROL SYSTEM LAB (EE-324-F)

---

```
options = simset('reltol',1e-5,'refine',10,'solver','ode45');
sim('mymodel',tfinal,options);
%plot results
figure(1)
clf
subplot(211)
plot(t,u);
ylabel('u')
subplot(212)
plot(t,y)
ylabel('y')
```

When you run the script, you should see a plot showing the input and the output of the transfer function. Use the help command to learn more about how to use the simset and sim commands.

### **EXPERIMENT NO:-9**

**EXPERIMENT**: Determine transpose, inverse values of given matrix.

**APPARATUS REQUIRED**: Computer with MATLAB software.

**THEORY**: Open M-files and start performing the following:

## CONTROL SYSTEM LAB (EE-324-F)

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Entering matrices into MATLAB is the same as entering a vector, except each row of elements is separated by a semicolon (;) or a return:

```
B = [1 2 3 4;5 6 7 8;9 10 11 12]
```

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

```
B = [ 1  2  3  4  
     5  6  7  8  
     9 10 11 12]
```

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

Matrices in Matlab can be manipulated in many ways. For one, you can find the transpose of a matrix using the apostrophe key:

```
C = B'
```

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

To find the inverse  
Let us take

```
E = [1 2;3 4]
```

The inverse of a matrix:

```
X = inv(E)
```

```
X =  
 -2.0000    1.0000  
  1.5000   -0.5000
```

### QUIZ:

Que1: What is MATLAB?

Ans: MATLAB is the name used to refer to the class of matrix calculator environments derived from the first, called MATLAB

## CONTROL SYSTEM LAB (EE-324-F)

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Que2:What can we use MATLAB for?

Ans: Matlab is to be utilized for data extraction,data analysis and data processing,it is further utilized for some statistical task to analyze the behavior of the system by plotting.it is used to generate stimulus for verification of the system.

Que3: Explain The MATLAB mathematical function library?

Ans. This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms

Que4.What is transpose of matrix

Ans: Let A be an  $m * n$  matrix. Then  $A^t$ , the transpose of A, is the matrix obtained by interchanging the rows and columns of A.

Que5 What is inverse of matrix?

Ans: It is defined as Let  $I = [e_1 e_2 \dots e_n]$  be the  $n \times n$  identity matrix. Let A be an  $n \times n$  matrix. A  $n \times n$  matrix, B, is called an *inverse of A* if and only if  $AB = I$  and  $BA = I$ . B is often written as  $A^{-1}$ .

Que 6: On what machines Matlab should be run?

Ans : Run it from sthelens, and only if sthelens is down, from cher, orsay or tiree. It works on other machines too, but some of the other machines have older versions of the OS and core dump upon exiting from matlab. Some other local machines with new setups work fine. Try your local machine. Matlab is blocked from running on the servers.

Que 7: Can we run Matlab without graphics?

Ans.Sometimes you may want to run scripts which contain plotting commands without displaying the plots and without going into the script to comment out the commands.

Que8. Explain The MATLAB working environment?

Ans. This is the set of tools and facilities that you work with as the MATLAB user or programmer. It includes facilities for managing the variables in your workspace and importing and exporting data. It also includes tools for developing, managing, debugging, and profiling M-files, MATLAB's applications.

Que9. How to add noise to an image in Matlab?

Ans. The function noise.m, now installed on ashland too, adds Gaussian, uniform, salt and pepper, additive or multiplicative noise to an image.

Que10. Explain The MATLAB mathematical function library?

Ans. This is a vast collection of computational algorithms ranging from elementary functions like sum, sine, cosine, and complex arithmetic, to more sophisticated functions like matrix inverse, matrix eigenvalues, Bessel functions, and fast Fourier transforms.

### **EXPERIMENT NO:-10**

## CONTROL SYSTEM LAB (EE-324-F)

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**EXPERIMENT:** Plot the pole-zero configurations in s-plane for the given transfer function

**APPARATUS REQUIRED:** Computer with MATLAB

**PROCEDURE:** Plot s-plane grid lines on the root locus for the following system.

$$H(s) = \frac{2s^2 + 5s + 1}{s^2 + 2s + 3}$$

You can do this by typing in MATLAB

```
H = tf([2 5 1],[1 2 3])
```

```
Transfer function:
```

```
2 s^2 + 5 s + 1
```

```
-----
```

```
s^2 + 2 s + 3
```

### **QUIZ:**

Que1: What do you understand by MATLAB software?

Ans: MATLAB is a high level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming language.

Que2. What does MATLAB stands for?

Ans: matrix laborartory

Que3. Where can we use MATLAB?

Ans: It is widely used in academic and research institutions as well as industrial enterprises.

Que4. Name some tool boxes?

Ans: Control tool boxes, fuzzy logic tool boxes.

Que5. What is system requirement for MATLAB?

Ans: 1 GB for MATLAB only, 3-4 GB for a typical in typical Installation 1024 MB.

Que6. What is transfer function?

Ans. Transfer function is defined as ratio of laplace of output to the laplace of input.

Que7. What are zeros and poles in control system?

Ans: zeroes are determined by equating the numerator of the transfer function to zero  
poles are determined by equating the denominator of the transfer function to zero  
zeroes means the o/p at those frequencies is zero while pole means that o/p at that frequency is infinite(or very large)

Que8: What is Root Locus?

## CONTROL SYSTEM LAB (EE-324-F)

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Ans; Root-Locus allows to graph the locations of the poles and zeros for every value of gain, by several simple rules.

Que9: What is the stability in control system?

Ans: The stability of a system relates to its response to inputs or disturbances. A system which remains in a constant state unless affected by an external action and which returns to a constant state when the external action is removed can be considered to be stable.

Que10. Name some tool boxes in matlab?

Ans: Control tool boxes, fuzzy logic tool boxes.



## EXPERIMENT NO:-11

**EXPERIMENT:** Plot unit step response of given transfer function and find peak overshoot, peak time.

**APPARATUS REQUIRED:** Computer with MATLAB

**THEORY:** Consider a higher-order system defined using MATLAB, plot the unit-step response curve of this system. Using MATLAB, obtain the rise time, peak time, maximum overshoot, and settling time.

$$\frac{C(s)}{R(s)} = \frac{6.3223s^2 + 18s + 12.811}{s^4 + 6s^3 + 11.3223s^2 + 18s + 12.811}$$

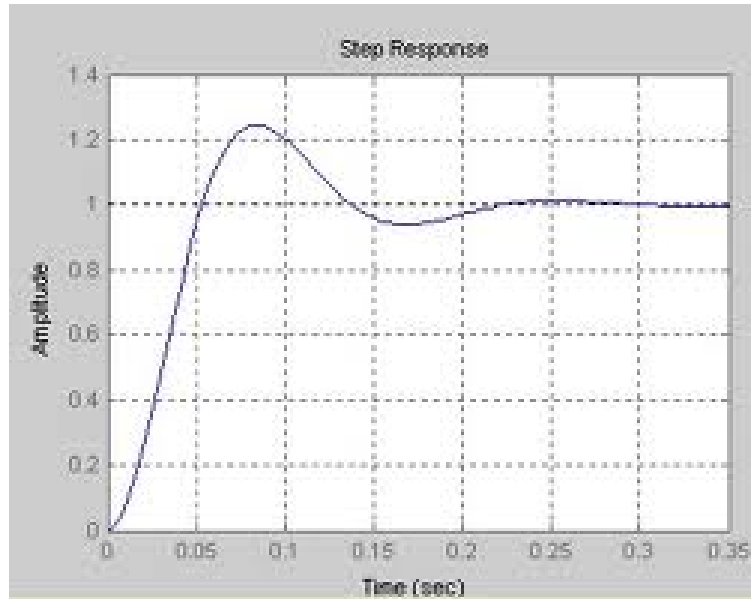
% ----- This program is to plot the unit-step response curve, as well as to find the rise time, peak time, maximum overshoot, and settling time.  
% In this program the rise time is calculated as the time required for the %'' response to rise from 10% to 90% of its final value. -----

```
num = [0 0 6.3223 18 12.811 1];
den = [1 6 11.3223 18 12.8111];
t = 0:0.02:20;
[y,x,t] = step(num,den,t);
plot(t,y)
grid
title('Unit-Step Response')
xlabel('t (set)')
ylabel('Output y(t)')
r1 = 1; while y(r1) < 0.1, r1 = r1 + 1; end;
r2 = 1; while y(r2) < 0.9, r2 = r2 + 1; end;
rise-time = (r2-r1)*0.02
rise-time =
0.5800
[ymax,tp] = max(y);
peak-time = (tp-1)*0.02
peak-time =
max-overshoot = ymax-1
max_overshoot =
0.6182
```

## CONTROL SYSTEM LAB (EE-324-F)

---

```
s = 1001; while y(s) > 0.98 & ( y(s) < 1.02; s = s-1; end;  
settlingtime = (s-1)*0.02  
settling-time =  
10.0200
```



### QUIZ:

Que1: What do you understand by MATLAB software?

Ans: MATLAB is a high level language and interactive environment that enables you to perform computationally intensive tasks faster than with traditional programming language.

Que2. What does MATLAB stands for?

Ans: matrix laboratory

Que3. What is transfer function.

Ans. Transfer function is defined as ratio of laplace of output to the laplace of input.

Que4. What is peak overshoot.

Percent overshoot, - The percent overshoot is defined as the amount that the waveform at the peak time overshoots the steady-state value, which is expressed as a percentage of the steady-state value.

Que 5. What is Peak time?

Ans. The peak time is the time required for the response to reach the first peak.

Que6. What is settling time

Ans. The settling time is the time required for the amplitude of the sinusoid to decay to 2% of the steady-state value.

## CONTROL SYSTEM LAB (EE-324-F)

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Que7.What is rise time

Ans. Time the response takes to rise from 0 to 100%

Que8. What is transient response?

Ans: Transient response mean the response(temporary output voltage change)of the converter due to load transient.

Que9What is damping ratio?

Ans: The damping ratio is a dimensionless measure describing how oscillations in a system decay after a disturbance. Many systems exhibit oscillatory behavior when they are disturbed from their position of static equilibrium.

Que10.What is steady state system?

Ans:The manner in which the system output behaves as  $t$  approaches infinity – the error after the transient response has decayed, leaving only the continuous response.

## **EXPERIMENT NO:-12**

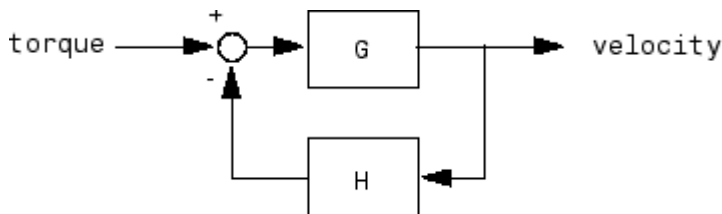
**EXPERIMENT:** Write a program to find the transfer function of a given closed loop control system.

**APPARATUS REQUIRED:** Computer with MATLAB

**THEORY:**The Transfer Function of any electrical or electronic control system is the mathematical relationship between the systems input and its output, and hence describes the behaviour of the system. Note also that the ratio of the output of a particular device to its input represents its gain. Then we can correctly say that the output is always the transfer function of the system times the input.

The Transfer Fcn block models a linear system by a transfer function of the Laplace-domain variable  $s$ . The block can model single-input single-output (SISO) and single-input multiple output (SIMO) systems.

Let us take an example:



to connect the plant

$$G(s) = \frac{2s^2 + 5s + 1}{s^2 + 2s + 3}$$

## CONTROL SYSTEM LAB (EE-324-F)

---

with the controller

$$H(s) = \frac{5(s+2)}{s+10}$$

using negative feedback, type

```
G = tf([2 5 1],[1 2 3], 'inputname', 'torque', ...  
      'outputname', 'velocity');  
H = zpk(-2,-10,5)  
Cloop = feedback(G,H)
```

These commands produce the following result.

```
Zero/pole/gain from input "torque" to output "velocity":  
0.18182 (s+10) (s+2.281) (s+0.2192)  
-----  
(s+3.419) (s^2 + 1.763s + 1.064)
```

The result is a zero-pole-gain model as expected from the precedence rules.