B.Tech.(IV Sem) **23EE56-Control Systems Lab**

L	T	P	Cr.
0	0	3	1.5

Course Objectives: The objective of this course is to impart hands on experience to understand the performance of basic control system components such as magnetic amplifiers, D.C. servo motors. It also provides knowledge on time and frequency responses of control system with and without controllers and compensators and on different logic gates and Boolean expressions using PLC.

Course Outcomes: At the end of the course, the student will be able to:

CO1: Analyze the performance of servo motors and dc motors. **(Apply-L3)**
CO2: Design PID controllers and compensators for various applications. **(Apply-L3)**
CO3: Analyze the stability, controllability and observability using simulation tools. **(Apply-L3)**

List of Experiments

Any 10 of the following experiments are to be conducted:

1. Analysis of Second order system in time domain
2. Characteristics of Synchros
3. Effect of P, PD, PI, PID Controller on a second order systems
4. Design of Lag and lead compensation – Magnitude and phase plot
5. Transfer function of DC motor
6. Root locus, Bode Plot and Nyquist Plot for the transfer function of systems up to 5^{th} orderusing MATLAB.
7. Kalman's test of Controllability and Observability using MAT LAB.
8. Temperature controller using PID
9. Characteristics of magnetic amplifiers
10. Characteristics of AC servo motor
11. Characteristics of DC servo motor
12. Study and verify the truth table of logic gates and simple Boolean expressions using PLC.

1. Analysis of Second order system in time domain

AIM:

To determine the time domain specifications and steady state error for Second Order under damped System.

APPARATUS:

S.No	Name of Equipment
1	Linear Simulator Kit.
2	CRO and Connecting Probes.

THEORY: Specifications of second order system:

1. **Delay Time (T_d):** It is the time required for the response to reach 50% of the final value in the first attempt.
2. **Rise time:** It is the time required for the response to rise from 10% to 90% of the final value for over damped systems and 0 to 100% of the final value for under damped systems.
3. **Peak time:** It is the time required for the response to reach the peak of the time response or the peak over shoot.
4. **Peak over shoot (M_P):** It indicates the normalized difference between the time response peak and the steady output and is defined as

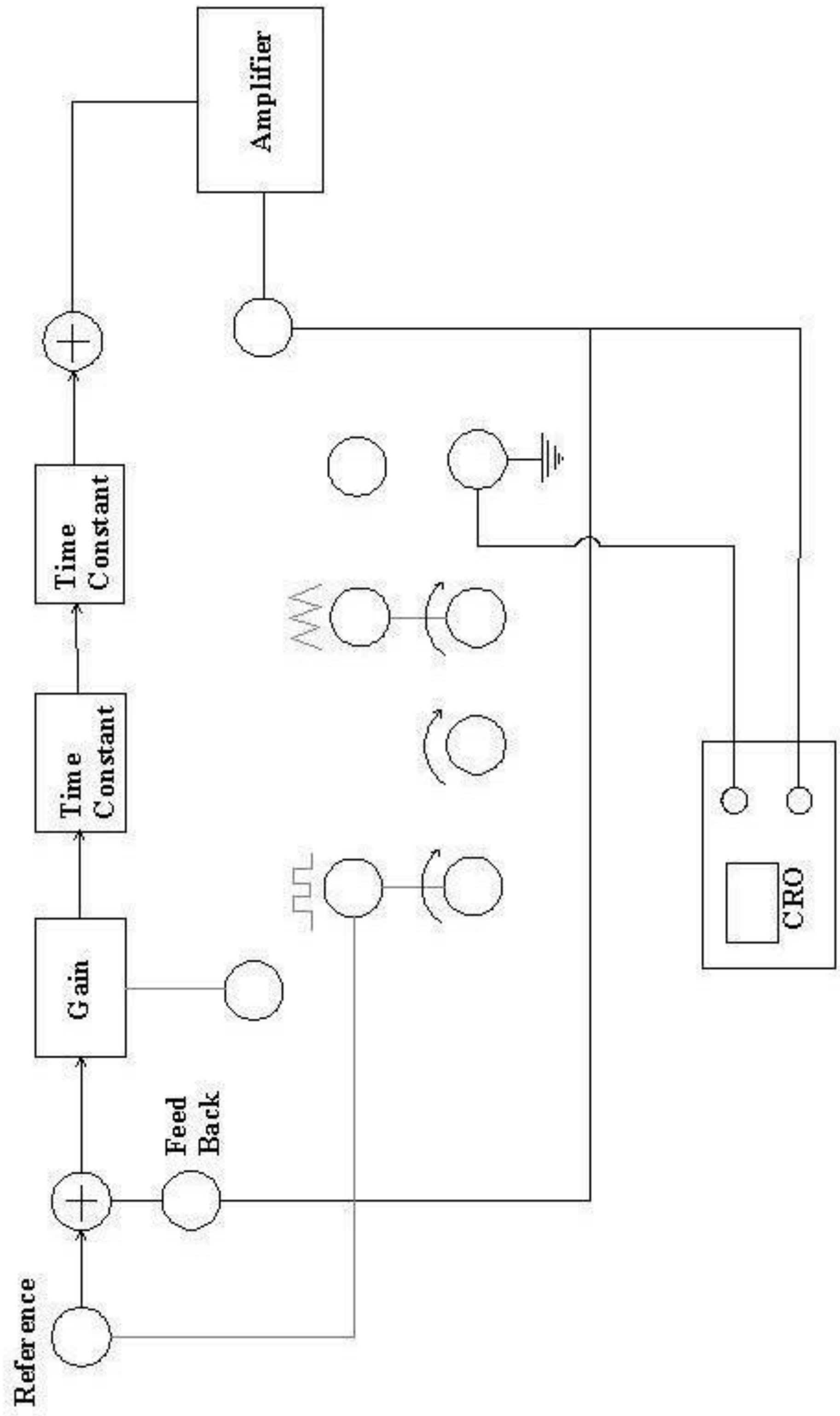
$$\text{Peak percent over shot } = \frac{c(T_P) - c(\infty)}{c(\infty)} \times 100$$

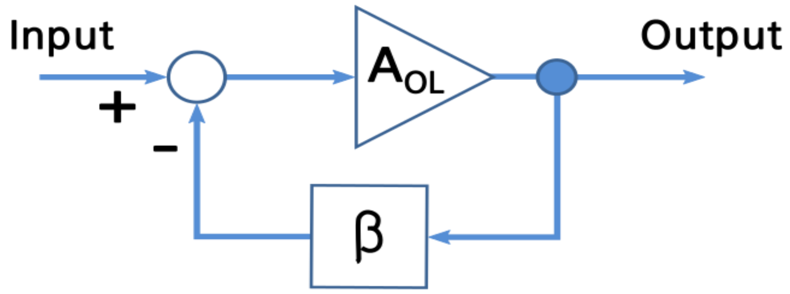
5. **Settling time (t_s):** It is the time required for the response to reach and stay with in a specified tolerance band (usually 2% or 5%) of its final value.

PROCEDURE:

1. Construct the second order system by considering the first block diagram.
2. Apply a 1 volt P-P square wave input.
3. Trace the output wave form on trace paper for deferent values of K.
4. Obtain percentage peak overshoot, settling time, rise time and steady state error.
5. Repeat the steps for different values of K and tabulate.

BLOCK DIAGRAM:





Ideal negative feedback model; open loop gain is A_{OL} and feedback factor is β

OBSERVATIONS:

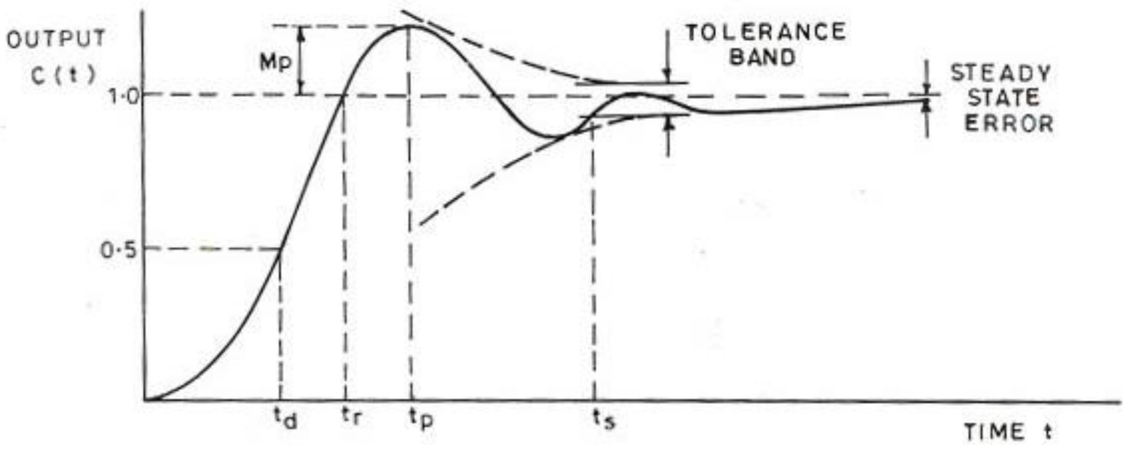
K	t_r	t_p	t_s	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

PRECAUTIONS:

1. Avoid loose connections.
2. Note down the readings with out any parallax error

Model graph:-

Second order system



Result:

Viva-Voce questions

1.What is Time response?

2.What is t_r, t_p, $\%M_p$, t_s , e_{ss}?

3.What is the Damping Ratio?

4.What is the effect of K on $\%M_p$

5. What is the effect of K on damping ratio?

6. Explain the pole locus diagram of second order system with respect to damping ratio

7. What is natural undamped frequency?

8. what is damping frequency?

9.What is Critically damped system?

10.What is Undamped system and what its nature of step response?

11.What is the general operating range of damping factor of a system?

2. CHARACTERISTICS OF SYNCHROS

AIM: To obtain the characteristics of synchro transmitter and receiver pair

APPARATUS:

1. Patch cards
2. Multimeter
3. Synchro pair kit

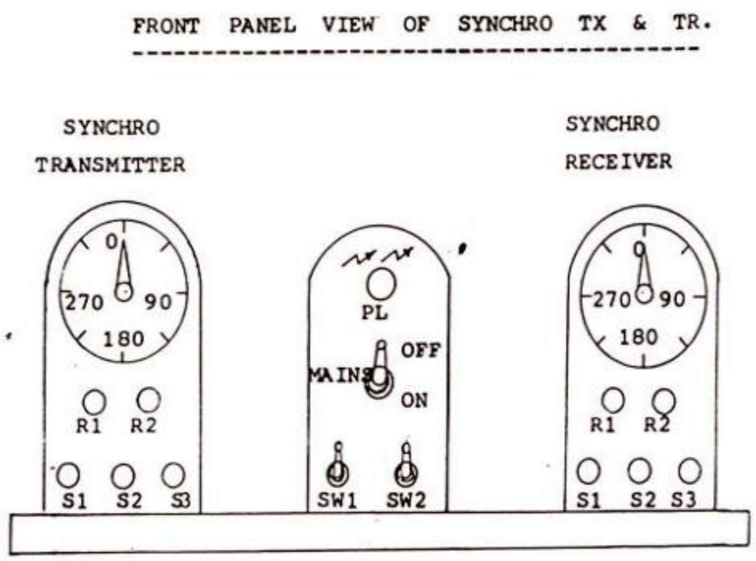


Fig – 1.Front panel view of synchro

THEORY:

A Synchro is an electromagnetic transducer commonly used to converter an angular position of a shaft into an electric signal. The basic synchro is usually called a synchro transmitter. Its construction is similar to that of a three phase alternator. The stator (stationary member) is of laminated silicon steel and is slotted to accommodate a balanced three phase winding which is usually of concentric coil type (three identical coils are placed in the stator with their axis 120 degree apart) and is star connected. The rotor is a dumb bell construction and wound with a concentric coil. AC voltage is applied to the rotor winding through slip rings.

Let an a.c. voltage Vr (t) = Vr sin (ω_ct) be supplied to the rotor of the synchro transmitter. This voltage causes a flow of magnetizing current in the rotor coil which produces a sinusoidally time varying flux directed along its axis and distributed nearly sinusoidally in the air gap alongstator periphery. Because of transformer action, voltages are induced in each of the stator coils. As the air gap flux is sinusoidally distributed, the flux linking any stator coil is proportional to the cosine of the angle between rotor and stator coil axis and so is the voltage induced in each stator coil.

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

Let Vs1 N, Vs2 N and Vs3 N respectively be the voltages induced in the stator coils S1, S2and S3 with respect to the neutral. Then for the rotor position of the synchro transmitter showed in figure, where the rotor axis makes an angle 0 with the axis of the stator coil S2. Let

V_{s1N} = KVr

sin (ω_ct)cos

(θ+120)V_{s2N}

= KVr sin(

ω_ct) cos (θ)

V_{s3N} = KVr sin (ω_ct) cos (θ+240)

The three terminal

voltages of the stator

areV_{s1s2} = V_{s1N} – V_{s2N}

= 3 KVr

sin (θ+240) sin

(ω_ct)Vs_{2s3} =

V_{s2N} – V_{s3N}

= 3 KVr

sin (θ+124) sin

(ω_ct)Vs3s1 =

Vs3N – Vs1N

= 3 KVr sin (θ) sin (ω_ct)

Where θ is zero, it is seen that maximum voltage is induced in the stator coil s2 while it follows that the terminal voltage V_{s3s1} is zero. This position of rotor is defined as the electricalzero of the Tx and is used as a reference for specifying the angular position of the rotor.

Thus it is seen that the synchro transmitter is the angular position of its rotor shaft and the output is a set of three single phase voltages. The magnitude of these voltages are functions of a shaft position.

The classical synchro system consists of two units:

1. Synchro Transmitter.
2. Synchro Receiver.

The Synchro Receiver is having almost the same constructional features. The two units are connected as shown in figure. Initially the winding S2 of the stator of transmitter is positionedfor maximum coupling with rotor winding. Suppose its voltage is V, the coupling between S1and S2 of the stator and primary (ROTOR) winding is a cosine function. Therefore the effective voltages in these winding are proportional to 60 degrees or they are V/2 each. So long as the rotors of the transmitters and receivers remain in this position, no current will flow between windings because of voltage balance. When the rotor of transmitter is moved to a new position, the voltage balance is distributed. Assume that the rotor of transmitter is moved through 30 degrees, the stator winding voltageswill be changed to zero, 0.866V and 0.866V respectively. Thus there is a voltage imbalance between the windings causes currents to flow through the close circuit producing torque that tends to rotate the rotor of the receiver to a new position.

where the voltage balance is again restored. This balance is restored only if the receiver turns through the same angle as the transmitter and also the direction of the rotation is the same as that of transmitter.

The transmitter & receiver pair thus serves to transmit information regarding angular positionat one point to a remote point..

PROCEDURE-SYNCHRO TRANSMITTER CHARACTERISTICS

1. Connect the main supply to the system with the help of cable provided. Do not connect any patchcards to terminals marked S1,S2 and S3.
2. Switch on main supply for the unit.
3. Starting from zero position noted down the voltage between stator winding terminals i.e. V_{s1s2}, V_{s2s3},V_{s3s1} in a sequential manner. Enter readings in a tabular form and plot a graph of angular position of rotor voltages for all three phases.
4. Note down that zero position of the stator rotor considers with Vs3s1 voltage equal to zero voltage. Donot disturb this condition.

CIRCUIT DIAGRAM

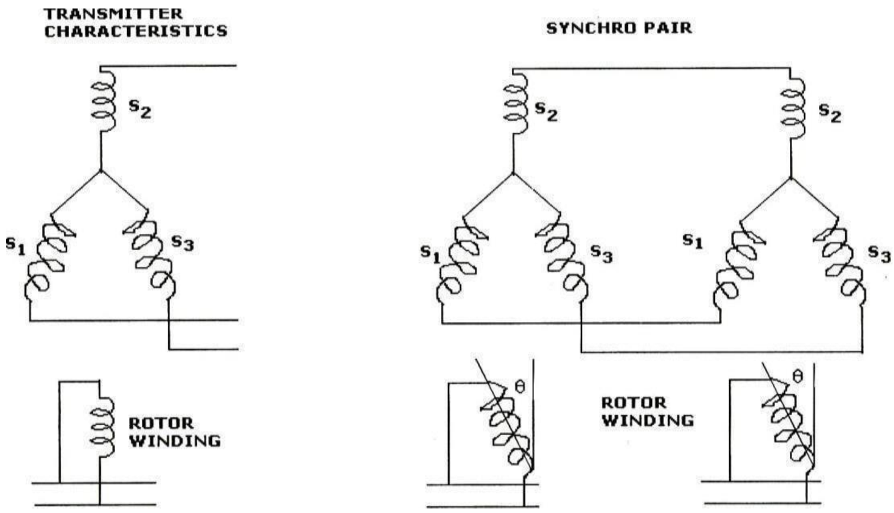


Fig – 2.2 Circuit Diagram of Synchro-Transmitter Receiver

PROCEDURE:-Characteristics of Synchro Transmitter –Receiver Pair

1. Connect main supply cable.
2. Connect s1, s2 &s3 terminals of transmitter to s1, s2&s3 of synchro receiver by patch cardsprovided.
3. Switch on sw1 &sw2 and also switch on main supply.
4. Move the pointer i.e. rotor position of synchrotransmitter (TX) in Steps of 30 degrees andobserve the new rotor position. Observe that whenever rotor (TX) is rotated, the Tr rotor follows it for both the directions of rotations and their positions are in good agreement.
5. Enter the input angular position and output angular position in the tabular form and plot agraph.

PRECAUTIONS:

1. Handle the pointer for both the rotor s in a gentle manner.
2. Do not attempt to pullout the pointer.
3. Do not start rotor or stator terminals.

OBSERVATION TABLE:

SYNCHRO TRANSMITTER

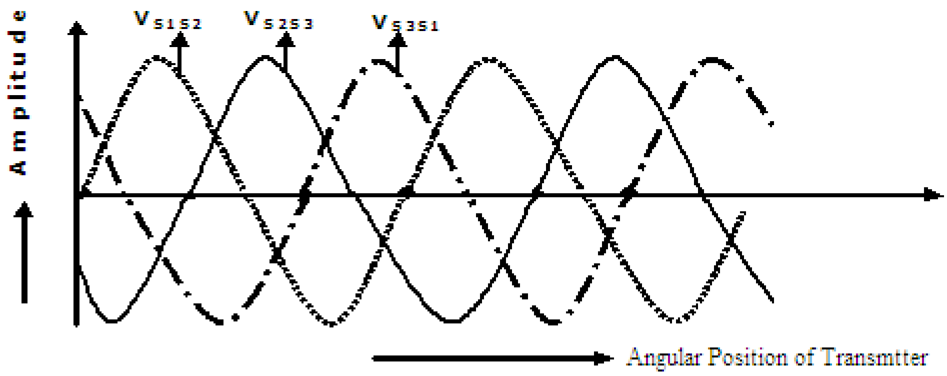
S.no.	Rotor position in degrees	RMS voltage of stator V_{s1s3}(V)	RMS voltage of stator V_{s1s2}(V)	RMS voltage of stator V_{s2s3}(V)

SYNCHROTRANSMITTER AND RECEIVER PAIR:

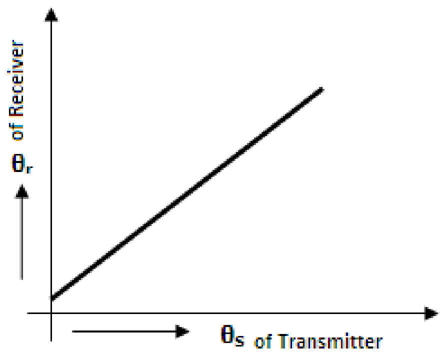
S.no.	Angular position of syn. Transmitter in degrees	Angular position of syn. receiver in degrees

MODEL GRAPHS:

Synchro Transmitter Characteristics



Synchro Transmitters - Receiver Characteristics



RESULT:

VIVA QUESTIONS:

1. Define the term "synchro".
2. Name the two general classifications of Synchros.
3. List the different synchro characteristics and give a brief explanation of each.
4. Explain the operation of a basic synchro transmitter and receiver.
5. Mention the application of synchro.

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

AIM:

To observe the effect of P, PI, PID Controller on a Second Order System and to calculate error constants giving sweep input.

APPARATUS:

S.No	Name of Equipment
1	Function Generator
2	CRO
3	Experimental Kit

THEORY: The PID controller can be designed both in the frequency domain and in the S-plane through the classical or trail and error design procedure. The method needs the pole-zero locations or frequency- phase responses of the plant, for its implementation. A large number of process control systems are however characterized by

* Incomplete or inaccurate plant equations
* Extremely slow response
* Presence of time delays
* High order transfer function
* Limited possibility of experimentation for identification of the plant
* Need for fine trimming the compensator at site.

In such a situation alternative simpler techniques of setting the controller parameters (K_c, T_i, T_d) or tuning, are of great importance.

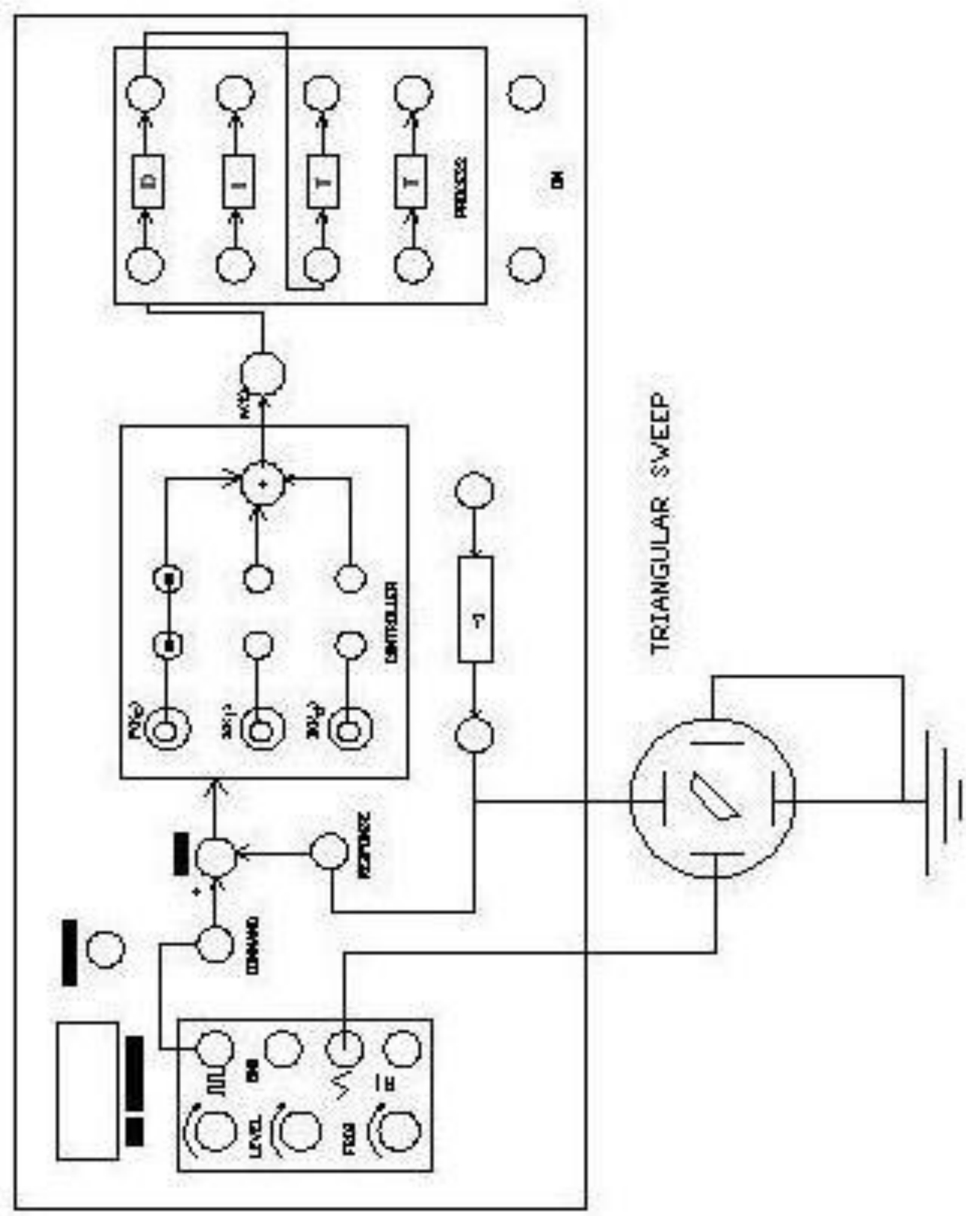
PROCEDURE:

a) Proportional Control:

1. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
2. Connect P Controller and Disconnect I and D controllers
3. Apply a 1 volt P-P square wave input.
4. Observe the output of the system on CRO.
5. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
6. Repeat the steps for different values of K_p and tabulate.

K_p	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

BLOCK DIAGRAM:



(b). Proportional +Integral (PI)Control:

1. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
2. Connect P Controller, Integral Controller Disconnect D controllers
3. Apply a 1 volt P-P square wave input.
4. Set K_p=----- .
5. Observe the output of the system on CRO.
6. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
7. Repeat the steps for different values of K_i and tabulate.

K_i	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

c) Proportional +Derivative(PD)Control:

1. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
2. Connect P Controller, Derivative controllers Disconnect Integral Controller
3. Apply a 1 volt P-P square wave input.
4. Set K_p=----- .
5. Observe the output of the system on CRO.
6. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
7. Repeat the steps for different values of K_d and tabulate.

K_d	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

d) Proportional +Derivative+Integral(PID)Control:

1. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
2. Connect P Controller, Derivative controllers and Integral Controller
3. Apply a 1 volt P-P square wave input.
4. Set K_p=----- and K_d=------.
5. Observe the output of the system on CRO.
6. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
7. Repeat the steps for different values of K_i and tabulate.

K_i	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

e). Proportional +Derivative+Integral(PID)Control:

1. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
2. Connect P Controller, Derivative controllers and Integral Controller
3. Apply a 1 volt P-P square wave input.
4. Set K_p=----- and K_i=------.
5. Observe the output of the system on CRO.
6. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
7. Repeat the steps for different values of K_d and tabulate.

K_d	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

Result :

Viva-Voce Questions:

1. Define second order system?
2. Where shall we apply PID controller?
3. What is the Effect of Proportional Controller?
4. What is the Effect of PI Controller?
5. What is the Effect of PD Controller?
6. What is the Effect of PID Controller?
7. Why steady state error is non zero incase of PI controller?
8. What are draw backs of PD Controller?
9. PI Controller is what type of compensator and Filter?
10. PD Controller is what type of compensator and Filter?

4.LAG AND LEAD COMPENSATION NETWORK.

AIM:

To obtain the frequency response of Phase lag and Lead Networks and their phase plots.

APPARATUS:

S.No	Name of Equipment	Type	Range	Quantity
1	Lag and Lead Network Kit			1
2	CRO			1
3	Connecting Probes			
4	R1		**10K**	
5	R2		**330 Ω**	
6	C1		1 μf	

PROCEDURE:

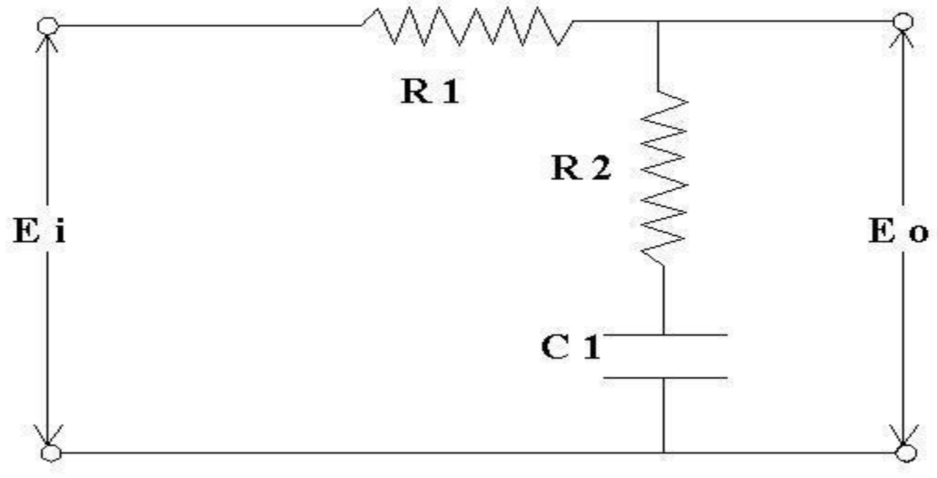
1. Connect the circuit diagrams for Lag and Lead networks as shown in the fig.
2. With the help of function generator apply the sinusoidal voltage as input and set the voltage as 5V p-p in the CRO.
3. Now by changing the frequencies using function generators observe the o/p waveforms by comparing with the input using CRO.
4. Calculate the o/p voltage, phase angle and magnitude.
5. Calculate Phase angle and magnitude at different frequencies theoretically.
6. Plot the graph between frequency Vs Phase angle and frequency *Vs* Gain

OBSERVATIONS:

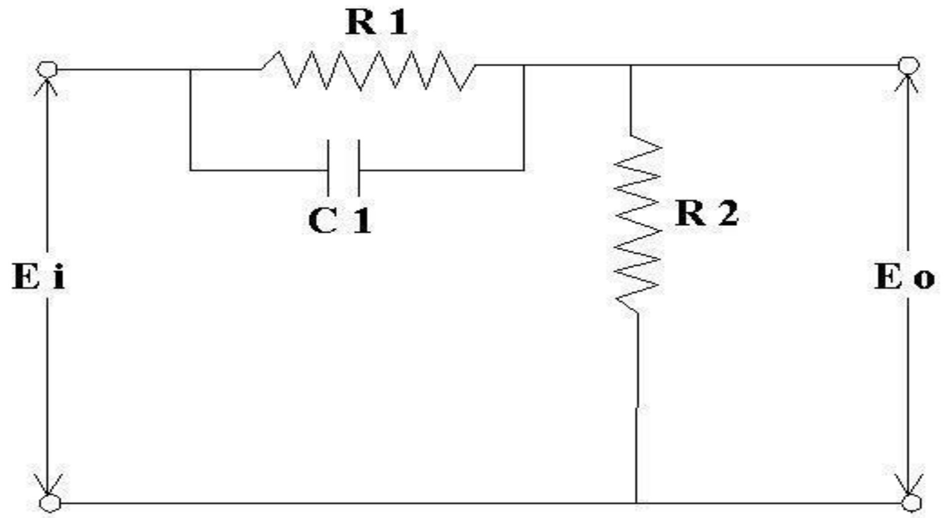
Lag Network:

S.NO	Frequency HZ	T=1/f (Sec)	t(Time difference b/w V_i and V_o)	V_i (Volts)	Vo (Volts)	Gain in db $20\log V_o/V_i$	$\Phi = t*F*360$

CIRCUIT DIAGRAM:

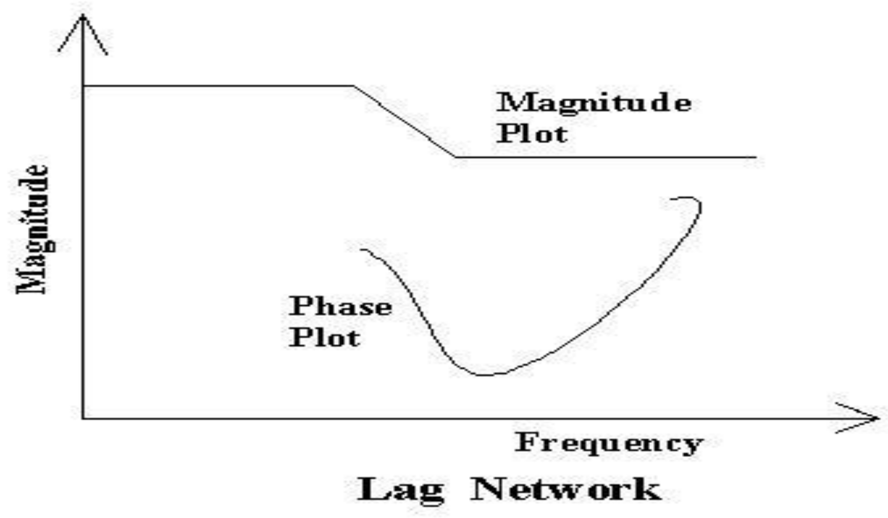


CIRCUIT DIAGRAM FOR LAG NETWORK.



CIRCUIT DIAGRAM FOR LEAD NETWORK.

MODEL GRAPHS:

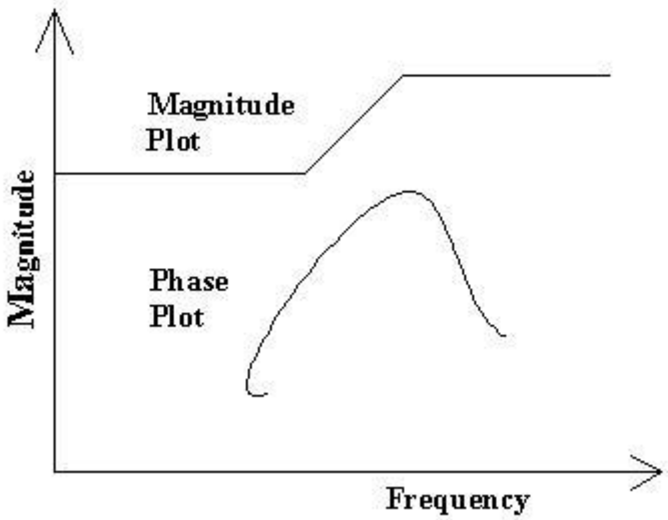


OBSERVATIONS:

Lead Network:

S.NO	Frequency HZ	T=1/f (Sec)	t(Time difference b/w V_i and V_o)	V_i (Volts)	Vo (Volts)	Gain in db $20\log V_o/V_i$	Φ=t*F*360

MODEL GRAPHS:



Lead Network

PRECAUTIONS:

1. Avoid lose connections.
2. Observe the response with out any parallax errors

RESULT:

Viva-Voce Questions

1. What is the Compensator?
2. What is Lag Compensator?
3. What is Lead Compensator?
4. What is the effect of Lag compensator?
5. What is the effect of Lead compensator?
6. Draw the bode plot of Lead Compensator
7. Draw the bode plot of Lag Compensator
8. Draw the pole zero diagram of lag compensator
9. Draw the pole zero diagram of lead compensator
10. At what frequency maximum phase lag occur in lag compensator and what is the gain of compensator at this frequency?

5.TRANSFER FUNTION OF D.C MOTOR

AIM: To obtain transfer function of a D.C motor and study the Effect of feedback on D. C. Servo motor .

Apparatus: D.C speed control motor kit, CRO.

Theory: Transfer function of DC Servo motor can be calculated by writing the system dynamical equations in S-domain by applying KCL, KVL and D'Alemberds principle to the equivalent circuit representation of DC Servo Motor as Shown in circuit diagram.

R_a= Resistance of armature (ohms)

L_a= Inductance of armature winding (henrys)

I_a = Armature current (amperes)

I_f = Field current (amperes)

V(e)= applied armature voltage (volts)

E_b= Back emf (volts)

T_m= Torque developed by motor

θ= Angular displacement of motor-shaft (rad)

J = Equivalent moment of inertia of motor and load referred to motor shaft

f_0 = Equivalent viscous friction coefficient of motor and load referred to motor shaft (newton-meter /rad/sec)

In servo applications the D.C motors are generally used in the liner range of magnetization curve. The air gap flux Φ is proportional to the field current i.e. $\Phi = K_f i_f$

$$T_M = K_1 K_{f,} i_a i_f$$

$$= K_{T,} i_a$$

The motor back EMF being proportional to speed is

$$e_b = \left(K_b \frac{d\theta}{dt} \right)$$

$$L_a \frac{di_a}{dt} + R_a I_a + e_b = e$$

$$J \frac{d^2\theta}{dt^2} + f_0 \frac{d\theta}{dt} = T_M = K_T I_a$$

Taking the Laplace transform of the equations assuming zero initial conditions.

$E_b (S) = K_b S \theta (S)$

$\{(L_a S + R_a) I_a (S)= E(S) -- E_b (S)\}$

$\{(JS^2 + F_o S) \theta(S) = T_M (S) = K_T I_a (S)\}$

$$\frac{\theta(S)}{E(S)} = \frac{\theta(S)}{V(S)} = \frac{K_T}{S[(R_a + SL_a)(JS + f_o) + K_T K_b]}$$

$$\frac{\theta(S)}{E(S)} = \frac{\theta(S)}{V(S)} = \frac{K_T}{S[R_a(JS + f_0) + K_T K_b]} \qquad \frac{\theta(S)}{E(S)} = \frac{K_T / R_a}{JS^2 + S\left(f_0 + \frac{K_T K_b}{R_a}\right)}$$

$$\frac{\theta(S)}{E(S)} = \frac{K_T / R_a}{S[JS + f]} = \frac{K_M}{S(ST_m + 1)}$$

Where $f = f_0 + \frac{K_T K_b}{R_a}$

K_M= Motor gain constant $K_m = \frac{K_T}{R_a f}$

T_M=Mechanical time constant. $T_m = \frac{J}{f}$

$$G(S) = K_A \frac{K_M}{(ST + 1)} = \frac{\omega(S)}{V_E(S)} = \frac{K}{ST + 1} \qquad (1)$$

Where K_A=Gain of amplifier

The Tacho generator transfer function may be written as

$$H(S) = \frac{V_T(S)}{\omega(S)} = K_T$$

Closed loop transfer function of the complete system is

$$\frac{\omega(S)}{V_R(S)} = \frac{K_A K_M}{ST + K_A K_M T + 1} = \frac{\frac{K_A K_M}{K_A K_M K_T + 1}}{S\left[\frac{T}{K_A K_M T_T + 1}\right] + 1}$$

Time constant of Dc Servo Motor can be calculated by approximating the dc servo motor to first order system. Consider a general first order type zero transfer function of the from

$$\frac{C(S)}{R(S)} = \frac{K}{S\tau + 1}$$

$$C(t) = R.K(1 - e^{-t/\tau})$$
$$= R.K(1 - e^{-t/\tau})$$
$$1 - \frac{C(p-p)}{R(p-p)}\left[\frac{1}{K}\right] = e^{-t/\tau}$$
$$\ell n\left[1 - \frac{C(p-p)}{R(p-p)}\frac{1}{K}\right] = \frac{-t}{\tau}$$

$$\tau = \frac{1}{2f\left\{\ell n\left[1 - \frac{C(p-p)}{R(p-p)}\frac{1}{K}\right]\right\}}$$

Since the are measuring the shaft speed using Tacho generator $\omega(p-p)$ = $V_{T\,(p\text{-}p)}$ /K_T, and $V_{M(p\text{-}p)}$ the motor input is easily monitored,

$$T = \frac{-1}{2f}\frac{1}{\ell n\left[1 - \frac{V_T(p-p)}{V_M(p-p)}\frac{1}{K_M K_T}\right]} \qquad (2)$$

Speed control is very common requirement in many industrial applications such of rolling mills, spinning mills, paper factory etc. The present unit is a low power D. C motor speed control system designed as for laboratory experiments. The various components and subsystems have been carefully integrated to illustrate the performance characteristics in a simple way. Performance of the closed loop system is evaluated in terms of Steady state error and disturbance rejection as functions of forward gain.

Speed measurement: -

The slotted disk attached to the rotor shaft generator produces 12 pulses for every revolution of the shaft through optical interruption. After passing through single conditioning and frequency scaling circuits. Then pulses are fed to a built in frequency counter to display the shaft speed directly in rpm.

Tacho Generator: -

A D. C signal proportional to the shaft speed is obtained from an electrostatic tachogenerator. A frequency to voltage counter circuit the signal is brought to a suitable speed level by single conditioning to field a tachogenerator constant of about 0.5 V/ 1000 rpm.

Steady state error: -

Defining positioned error coefficient, K_P.

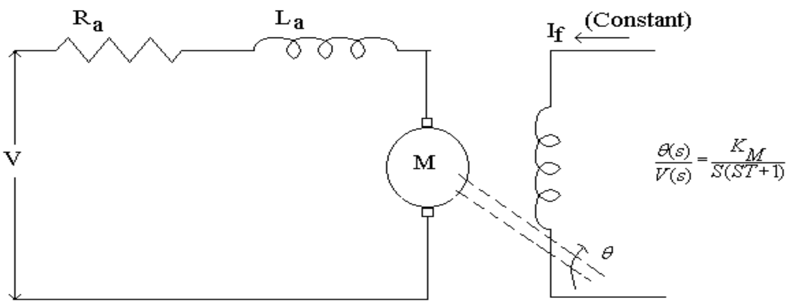
$$K_P = Lt_{s\to\infty} G(s)H(S) = K_A K_M K_T$$

The steady state error, e_{SS} to step input Ru (t) is given by

$$\underset{s\to\infty}{Lt}(V_R - V_T) = \frac{1}{1+K_P} \quad \Rightarrow \frac{R}{1+K_A K_M K_T}$$

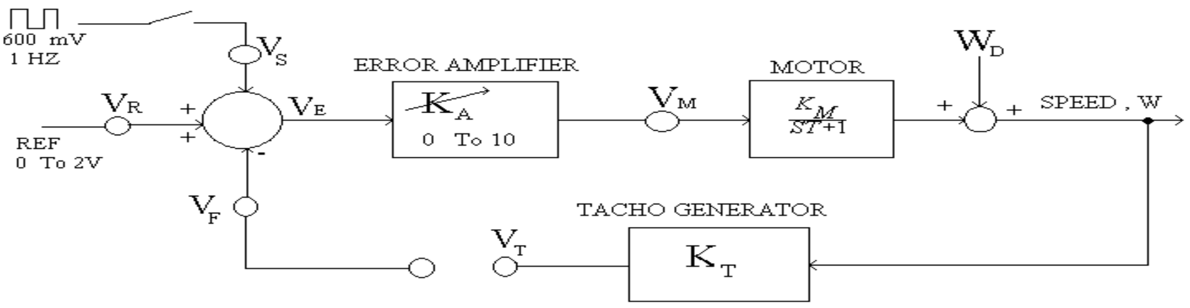
The steady state error may be determined from a measurement of V_R and V_F. e_{ss} decreases as K_P increases.

Circuit Diagram:



Armature Controlled DC Servo Motor

Block Diagram



Procedure For Obtaining Transfer Function

1. To calculate K_M , K_T .

a) Signal and references

Set K_A = 0. Connect DVM to measure the range of variation of reference voltage V_R.

b) Motor and Tachogenerator

1. Set V_R=1V and K_A=3. The motor may be running at as low speed. Record speed N in *rpm*, and the Tachogenerator output V_T.
2. Repeat with V_R=1 and K_A=4,5,-----------,10. and Tabulate measured motor voltage

V_M=V_RK_A), steady state motor speed n in *rpm* (or ω_{ss}=N*2π/60 in *rps*) and Tachogenerator output V_T.

3. Plot N *vs* V_M, and V_T *vs* N. Obtain K_M and K_T from the linear region of the curves

Motor Gain Constant, $K_M = \frac{\omega_{ss}}{V_M}$ (rpm/V)

Tacho Generator Constant, $K_T = \frac{V_T}{\omega_{ss}}$ (V/rpm)

Observations:

S.L No	**K_A Setting**	**N in rpm**	**V_T volts**	**V_M volts**	**$K_A = V_M / V_R$**

2. To calculate f :-

Set K_A =0 Connect DVM (Multimeter) to measure the range of variation of reference voltage V_R.. Switch on the square wave signal Vs and measure it's amplitude and frequency using calibrated CRO [The frequency of this signal is about 1 Hz, which makes the CRO display very inconvenient for measurements. It is suggested that the amplitude may be measured with time-base switched off, and for frequency simply count the number of pulses (as seen on CRO), in say 60 seconds, using watch.].

3. To calculate motor time constant:

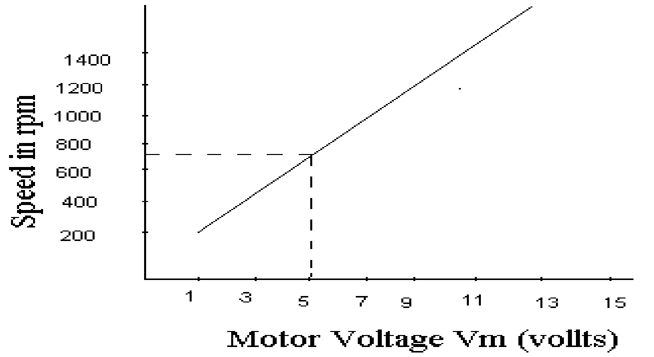
a). Switch on squire wave signal and set V_R and K_A so that the peak to peak variation of V_M lies between 3-8 volts. This would ensure a reasonably linear operation of the motor.

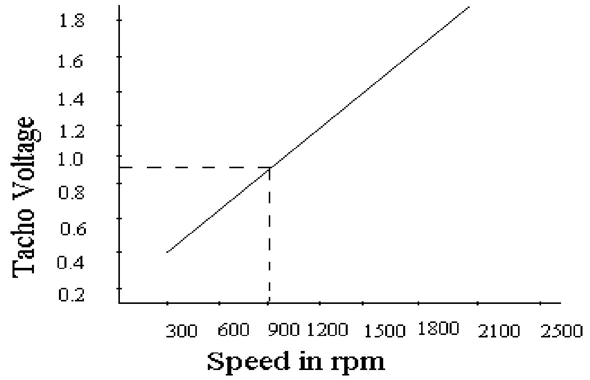
b). Measure the $V_{M(Peak-Peak)}$ and $V_{T(Peak-Peak)}$ by using CRO.

c). Calculate time constant of DC Servo Motor by using the Equation (2)

4. Write the transfer function of DC Servo Motor as shown in the Equation (1)

<u>Model Graphs:</u>





Motor Characteristics **Tacho Characteristics**

II. Closed loop Performance (Effect of feed Back):

a) Steady state error:

1. Set V_R=1V and K_A=5. the motor may be running at a low speed. Measure and record speed N in rpm, Tachogenerator voltage V_T , and the steady state error $e_{ss}=V_R-V_T$.
2. Repeat above for K_A=5, 10,-------,100.
3. Compare in each case the value of steady state error computed by using

$$e_{ss} = \frac{1}{1 + K_A K_M K_T}$$

S.No	K_A	N (rpm)	V_T (Volts)	$e_{ss} = (V_R - V_T)$ Experimentally	$e_{ss} = 1/1 + K_A K_M K_T$

b) **Disturbance rejection: -**

1. With k_A=5, Feedback terminals shorted and the break setting at the zero, adjust reference V_R to get a speed close to 1200rpm.
2. Record and tabulate the variation in speed in speed for different settings of the eddy current break. Calculate percentage decrease in speed at each setting of the break.
3. Repeat above for K_A=---,------,----.
4. Compare the percentage decrease in speed at various break settings for open loop, Closed loop with K_A=5, and closed loop with K_A=10.

II. Closed Loop Performance

K_A (rpm)	Break Settings	0	1	2	3	4	5
	Open Loop Speed						
	Closed Loop Speed						
	Open Loop Speed						
	Closed Loop Speed						
	Open Loop Speed						
	Closed Loop Speed						

Result:

Viva - Voce Questions:

1. What is Transfer Function?
2. What is the Electrical time constant of DC Servo Motor?
3. What is the Mechanical time constant of DC Servo Motor?
4. What is the difference between the DC motor and DC Servo Motor?
5. How to obtain the Electrical time constant of DC Servo Motor Experimentally?
6. How to obtain the Mechanical time constant of DC Servo Motor Experimentally?
7. What is the Feed back?
8. What are the different speed control methods of DC Servo Motor?
9. What type of the disturbance applied on the DC Servo Motor in the Experiment?
10. What is the effect of the feed back on the parameter sensitivity of the system?

6. Stability Analysis of Linear Systems Using MATLAB(Root Locus, Bode and Nyquist plot).

Aim: To plot Root Locus, Bode Plot, Nyquist Plot By Using MATLAB and stability analysis of the given system.

Apparatus:

PC, MATLAB Software

Theory:

1.Root Locus:

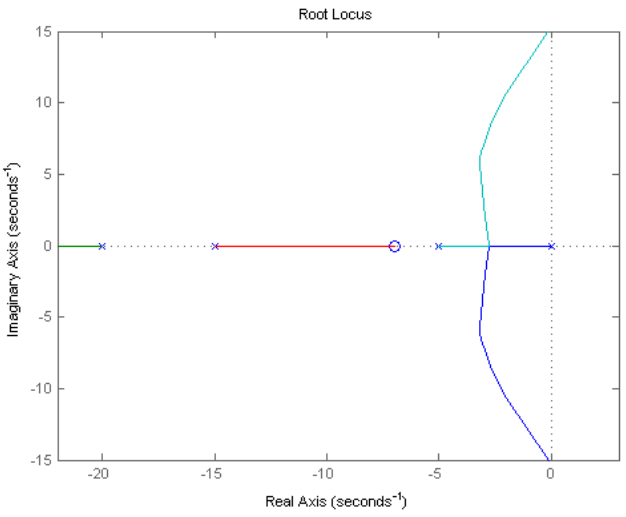
Plotting the Root Locus of a Transfer Function

Consider an open-loop system which has a transfer function of

$$H(s) = \frac{Y(s)}{U(s)} = \frac{s+7}{s(s+5)(s+15)(s+20)} \qquad (4)$$

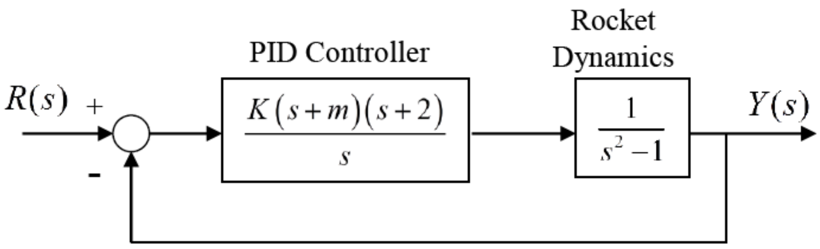
How do we design a feedback controller for the system by using the root locus method? Say our design criteria are 5% overshoot and 1 second rise time. Make a MATLAB file called rl.m. Enter the transfer function, and the command to plot the root locus:

```
s = tf('s');
sys = (s + 7)/(s*(s + 5)*(s + 15)*(s + 20));
rlocus(sys)
axis([-22 3 -15 15])
```



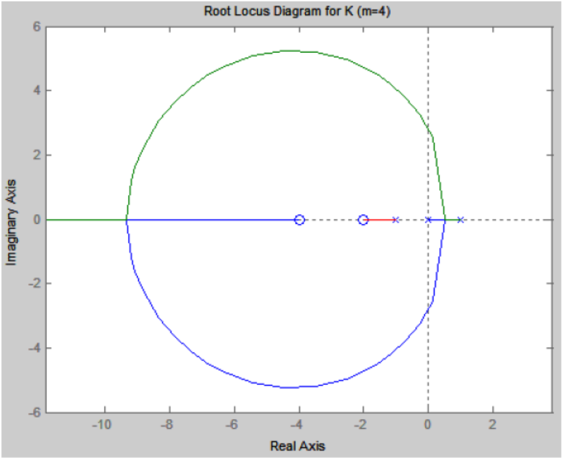
Exercise:

The block diagram of the closed-loop system is shown below. The goal is to use MATLAB to draw a root locus diagram for the parameter K, given the parameter m=4.



The characteristic equation of the closed-loop system is or . Substituting the transfer functions from the block diagram gives 1+GH= 0.

The MATLAB commands that produce the root locus diagram are:

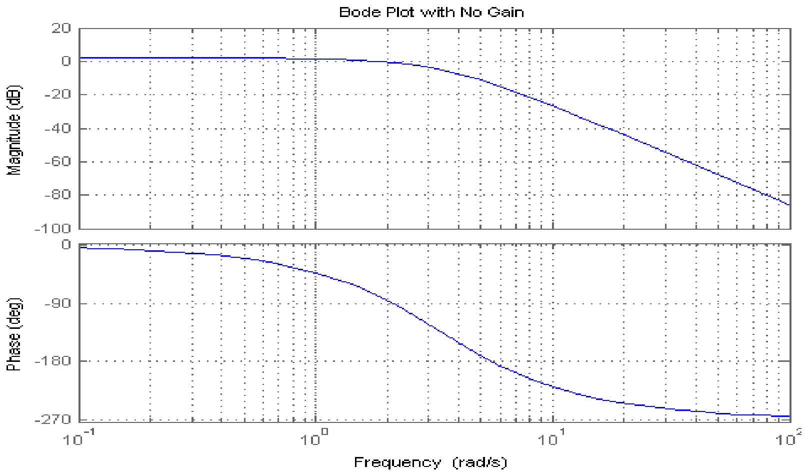



```
>> num=[1,6,8];
>> den=[1,0,-1,0];
>> sys=tf(num,den)
Transfer function:
s^2 + 6 s + 8
-------------
s^3 - s
>> rlocus(sys)
>> axis('equal')
>> title('Root Locus Diagram for K (m=4)')
>> grid
```

Bode Plot:

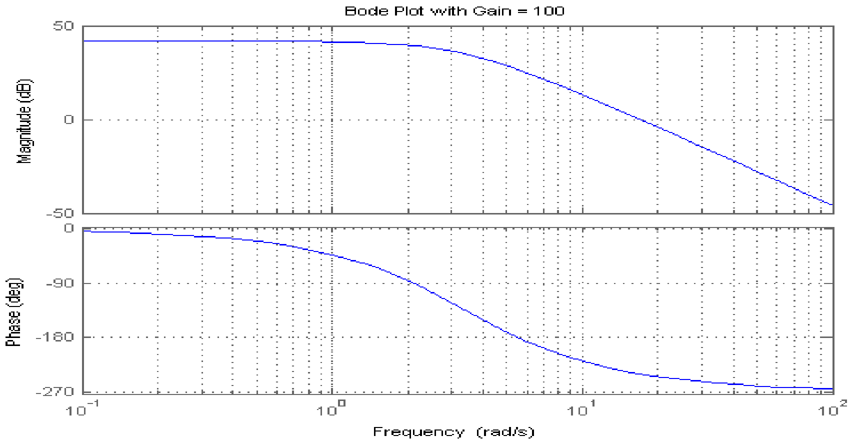
For example, suppose you entered the command bode(sys). You will get the following bode plot:

```
s = tf('s');
sys = 50/(s^3 + 9*s^2 + 30*s +40);
bode(sys)
grid on
title('Bode Plot with No Gain')
```



You should see that the phase margin is about 100 degrees. Now suppose you added a gain of 100, by entering the command bode(100*sys). You should get the following plot:

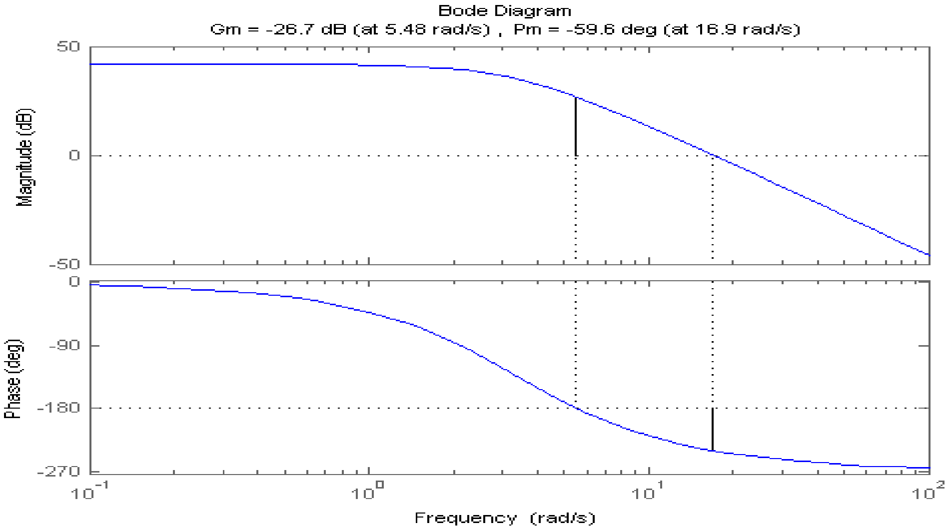
```
bode(100*sys)
grid on
title('Bode Plot with Gain = 100')
```



As you can see the phase plot is exactly the same as before, and the magnitude plot is shifted up by 40 dB (gain of 100). The phase margin is now about -60 degrees. This same result could be achieved if the y-axis of the magnitude plot was shifted down 40 dB. Try this, look at the first Bode plot, find where the curve crosses the -40 dB line, and read off the phase margin. It should be about 90 degrees, the same as the second Bode plot.

We can have MATLAB calculate and display the gain and phase margins using the margin(sys) command. This command returns the gain and phase margins, the gain and phase cross over frequencies, and a graphical representation of these on the Bode plot. Let's check it out:

```
margin(100*sys)
```



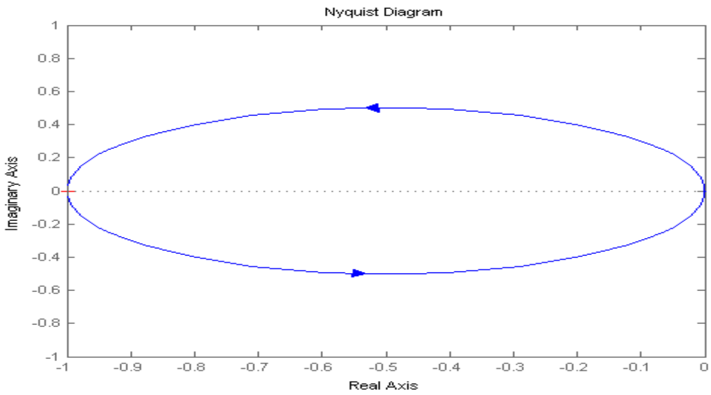
Nyquist Plot:

The Nyquist plot allows us to predict the stability and performance of a closed-loop system by observing its open-loop behavior. The Nyquist criterion can be used for design purposes regardless of open-loop stability (remember that the Bode design methods assume that the system is stable in open-loop). Therefore, we use this criterion to determine closed-loop stability when the Bode plots display confusing information.

To view a simple Nyquist plot using MATLAB, we will define the following transfer function and view the Nyquist plot:

$$\frac{0.5}{s-0.5} \qquad (3)$$

```
s = tf('s');
sys = 0.5/(s - 0.5);
nyquist(sys)
axis([-1 0 -1 1])
```

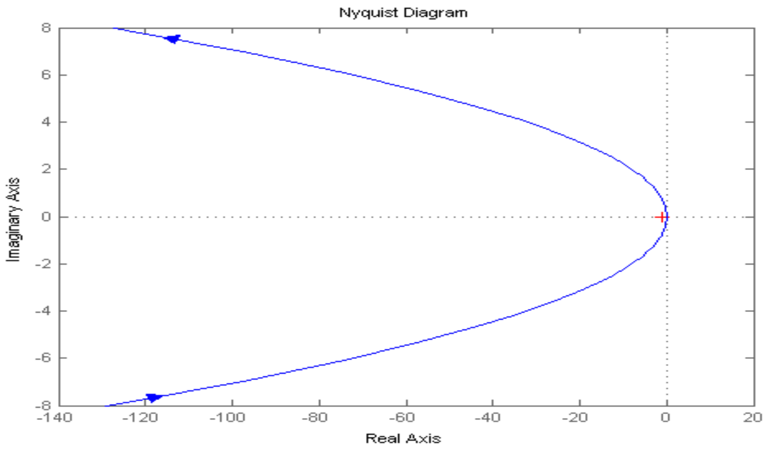


Now we will look at the Nyquist diagram for the following transfer function:

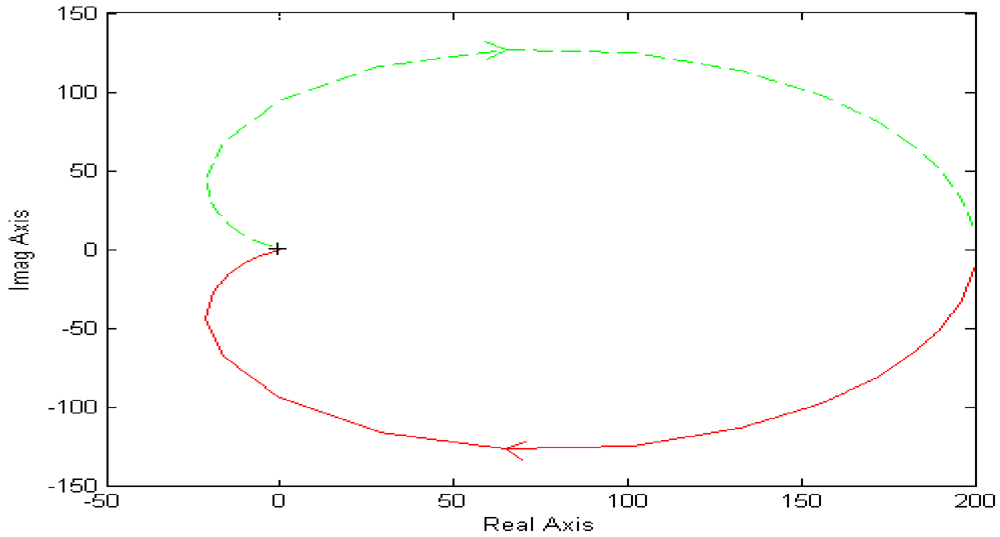
$$\frac{s+2}{s^2} \qquad (4)$$

Note that this function has a pole at the origin. We will see the difference between using the nyquist, nyquist1, and lnyquist commands with this particular function.

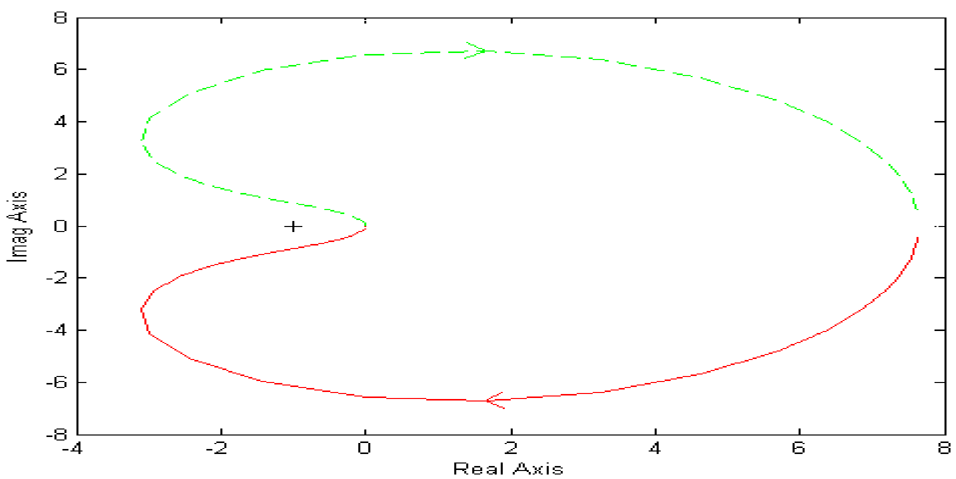
```
sys = (s + 2)/(s^2);
nyquist(sys)
```




```
nyquist1(sys)
```

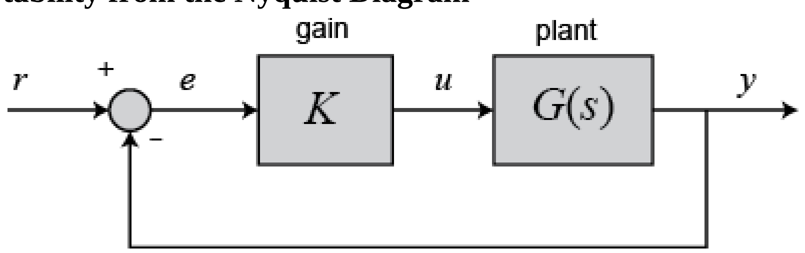


lnyquist(sys)



Note that the nyquist plot is not the correct one, the nyquist1 plot is correct, but it's hard to see what happens close to the -1 point, and the lnyquist plot is correct and has an appropriate scale.

Closed-Loop Stability from the Nyquist Diagram



where G(s) is:

$$\frac{s^2 + 10s + 24}{s^2 - 8s + 15} \quad (8)$$

This system has a gain K which can be varied in order to modify the response of the closed-loop system. However, we will see that we can only vary this gain within certain limits, since we have to make sure that our closed-loop system will be stable. This is what we will be looking for: the range of gains that will make this system stable in the closed-loop.

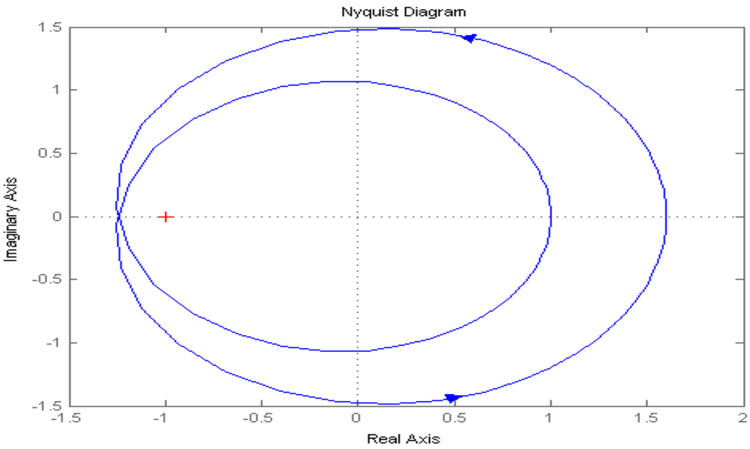
The first thing we need to do is find the number of positive real poles in our open-loop transfer function:

```
roots([1 -8 15])
ans =
    5
    3
```

The poles of the open-loop transfer function are both positive. Therefore, we need two anti-clockwise (N = -2) encirclements of the Nyquist diagram in order to have a stable closed-loop system (Z = P + N). If the number of encirclements is less than two or the encirclements are not anti-clockwise, our system will be unstable.

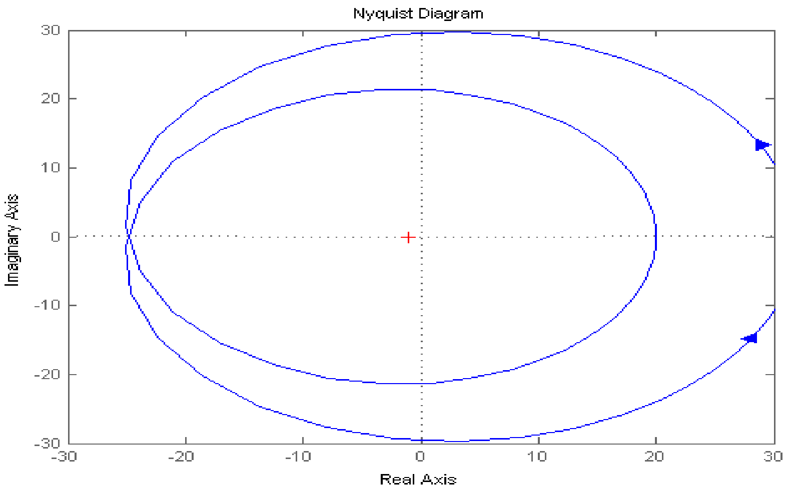
Let's look at our Nyquist diagram for a gain of 1:

```
sys = (s^2 + 10*s + 24)/(s^2 - 8*s + 15);
nyquist(sys)
```

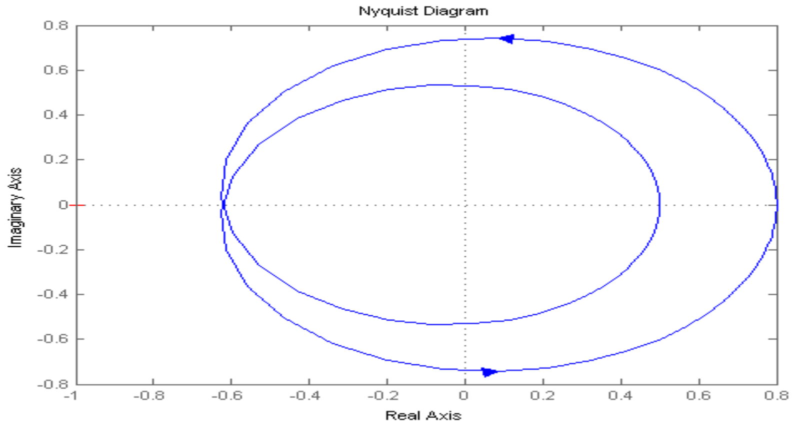


There are two anti-clockwise encirclements of -1. Therefore, the system is stable for a gain of 1. Now we will see how the system behaves if we increase the gain to 20:

```
nyquist(20*sys)
```



The diagram expanded. Therefore, we know that the system will be stable no matter how much we increase the gain. However, if we decrease the gain, the diagram will contract and the system might become unstable. Let's see what happens for a gain of 0.5:
nyquist(0.5*sys)



The system is now unstable. By trial and error we find that this system will become unstable for gains less than 0.80. We can verify our answers by zooming in on the Nyquist plots as well as by looking at the closed-loop steps responses for gains of 0.79, 0.80, and 0.81.

Result:

<u>Viva-Voce questions:</u>

1. What is the bandwidth of the system?
2. What is the cutoff frequencies?
3. What is the cutoff rate?
4. Is the system sensitive to disturbance?
5. What is root locus?
6. What is Bode Plot?
7. What is nyquist plot?
8. What is state space model and what are the advantages of state space model?
9. What is controller?
10. How the system behave in frequency?

7. Kalman's test of Controllability and Observability using MATLAB.

Aim: To obtain the Controllability and Observability for a given state equations using MATLAB.

Apparatus:

MATLAB tool

Theory:

The **state space model** of Linear Time-Invariant (LTI) system can be represented as,

$$\dot{X} = AX + BU$$

$$Y = CX + DU$$

The first and the second equations are known as state equation and output equation respectively.

Where,

- X and $\dot{X}$ are the state vector and the differential state vector respectively of order Nx1
- U and Y are input vector (Px1) and output vector (Qx1) respectively
- A is the system or state matrix of NxN size
- B and C are the input and the output matrices of NxP and QxN respectively
- D is the feed-forward matrix of order QxP.

Controllability:

The system is controllable when the desired output is obtained by applying the specific controlled input. It is the ability to control the state of the system. The controllability of the system can be checked using the Kalman Test.

The given below is the condition for the controllability:

$$Q_C = [B: AB: A^2 B: \ldots\ldots A^{n-1} B]$$

- If the determinant of Q_C is not equal to 0 then the system is controllable.

$$|Q_C| \neq 0 \quad \text{—- (system is controllable)}$$

$$|Q_C| = 0 \text{ —— (system is un-controllable)}$$

- For the system to be controllable, the rank of the composite matrix Q_C must be equal to 'N'

Observability:

It is the system's ability to measure or observe the system state. If the internal state of the system is determined using the input and output signals during a finite interval of time then the system is said to be observable. The observability of the system can be checked using the Kalman Test. The given below is the condition for the observability:

$$Q_O = [C^T \; A^T \; C^T ..... (A^T)^{n-1} C^T]$$

Note: A^T, C^T means transpose of the respective matrix

- If the determinant of Q_O is not equal to 0 then the system is observable.

$$|Q_O| \neq 0 \text{ —- (system is observable)}$$

$$|Q0| = 0 \text{ —— (system is not observable)}$$

- For the observable system, the rank of the composite matrix Q_O must be equal to 'N'

Applications of Controllability and Observability:

1. Controllability and observability find their application in aerospace engineering. Controllability ensures that the aircraft can be moved to different locations when the specific input is given. On the other hand, observability helps in the accurate estimation of state for navigation.
2. It is used in the field of robotics where controllability helps in providing the precise control of the robotic arm motion while observability measures the state estimation for mapping.
3. It is also used in the power system. Controllability helps in regulating the power flow while on the other hand, observability provides accurate monitoring and control of the system.

Program:

```
A=[-1 -1;1 0]
B=[1 0 ; 0 0]
C=[0 1;0 0]
D=[0 0;0 0]
sys=ss(A,B,C,D)
ob=obsv(A,C)
if (rank(ob)==rank(A))
    disp('Given system is observable')
else
    disp('given system is unobservable')
end
cr=ctrb(A,B);
if(rank(cr)==rank (A))
     disp('Given system is Controllable')
else
    disp('given system is uncontrollable')
end
```

Program without in-built commands:

```
clc
clear all
A=[0 0 1; -2 -3 0; 0 2 -3]
B=[0; 2; 0]
C=[1 0 0]
```

```
D=0
Q=horzcat(B,A*B,(A^2)*B)
t1=transpose(C);
t2=transpose(A);
T=horzcat(t1,t2*t1,((t2)^2)*t1)
if rank(Q)==3
   fprintf('Controllable\n')
else
   fprintf('Not controllable\n')
end
if rank(T)==3
   fprintf('Observable\n')
else
   fprintf('Not Observable\n')
end
```

Examples: Check the controllability and observability of following state space model of the systems:

1.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 2 & -4 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

2.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -1 & 1 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 4 \\ 0 \end{bmatrix} u; \quad y = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

RESULT

Viva Questions:

1.What is MATLAB?

2. Define controllability?

3. What are the advantages of MATLAB software?

4. Define Observability?

5. Condition for controllability and observability by using Kalman’s test.

8.CHARACTERISTICS OF AC.SERVO MOTOR

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

APPARATUS REQUIRED:

1. AC.Servo Motor study unit containing of
   a) Ammeter

   b) Control Voltage Transformer

   c) Load Potentiometer

   d) Speed Indicator

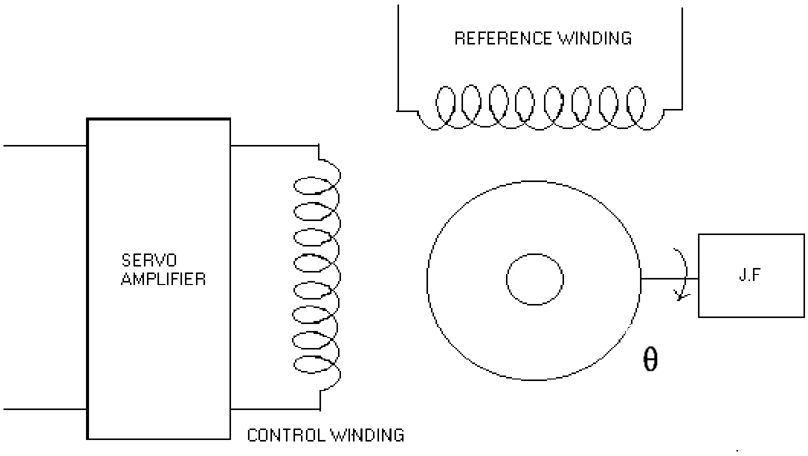
2. Digital Multi Meter

THEORY: Servo Motors are also called Control motors. They are used in feedback control systems as output actuators and does not use for continuous energy conversion. The principleof the Servomotor is similar to that of the other electromagnetic motor, but the construction and the operation are different. Their power rating varies from a fraction of a watt to a few hundred watts.

The stator of the Two Phase AC Servo Motor has the two distributed windings which are displaced from each other by 90 degrees electrical. One winding is known as a Reference orFixed Phase, which is supplied from a constant voltage source. The other one is known as Control Phase, and it is provided with a variable voltage

The control phase is usually supplied from a servo amplifier. The speed and torque of therotor are controlled by the phase difference between the control voltage and the reference phase voltage. By reversing the phase difference from leading to lagging or vice versa, the direction of the rotation of the rotor can be reversed.

CIRCUIT DIAGRAM:



CIRCUIT DIAGRAM:-AC SERVO MOTOR

PROCEDURE:

1. Study all the controls carefully on the front panel. Initially keep load current switch at off position, indicating that the armature circuit of dc machine is not connected to auxiliary dc supply -12 V ,keep servo motor supply switch at OFF position. Ensure load potentiometer andcontrol voltage auto transformer at minimum position.
2. Now switch ON main supply to the unit and also AC Servo motor supply switch. Vary the control voltage transformer ,you can observe that the AC Servo motor will starts rotating and the speed will be indicated by the tachometer
3. With load switch in OFF position ,vary the speed of the AC Servo motor by varying the control voltage and note down back emf generated by the dc machine for deferent values ofspeed (now working as dc generator or Taco).Enter results in tabular column.

Sl.No	Speed –RPM	Back EMF (E_b)Volts

4. switch at OFF position,switch „ON" AC Servo motor and keep the speed in minimum position. You can observe that the AC Servo motor starts moving with speed being indicated by the tacho meter .Now vary the control winding voltage by varying the auto transformer and set

thespeed for maximum speed .Now switch ON the load switch and start AC Servo motor by varying the load potentiometer slowly.

5. Note down the corresponding values of I_a ,Speed & E_b at controlvoltages of150,175,220V.

6. Take appropriate readings till speed is below 500 rpm and take more readings for above speed.

7. Calculate the power and torque developed.

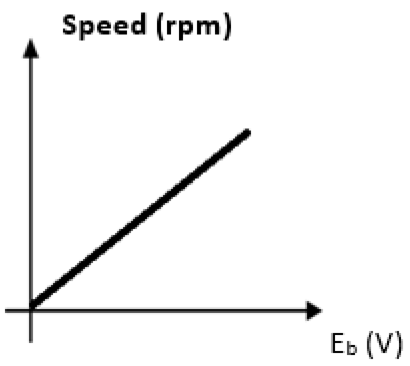
Draw the graphs between Back emf (E_b) Vs Speed ,and Speed Vs Torque

1. TABULAR COLUMN FOR SPEED (N)Vs (Eb) Back E.M.F

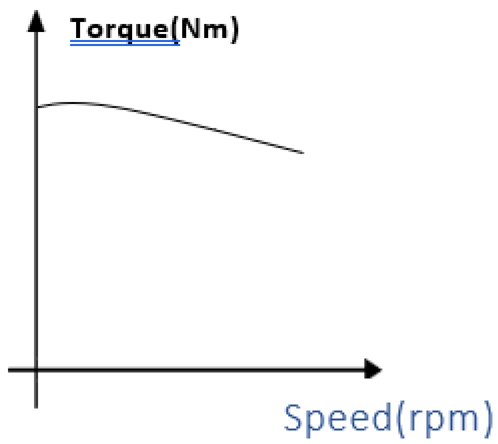
Sl.No	Ia (mA)	N-rpm	E_b -Back emf	P-watts E_b*I_a	T-Torque (NM)

MODEL GRAPHS

SPEED (N) Vs Back e.m.f (Eb)



SPEED (N) Vs Torque



RESULT:

VIVA QUESTIONS:

1) What is AC servo motor?

2) What is the use of AC servo motor?

3) What are the advantages of AC servo motor?
4) What is the importance

9.Study and verify the truth table of logic gates and simple Boolean expressions using PLC.

Aim: To develop the Ladder diagrams and verify the truth table of logic gates using PLC

Apparatus:

PLC
Make & model: Allen Bradly, Micro 820 2080-LC20-20QBB
Digital Input: 12(4 Analog)
Digital Output: 7
Analog Output:2
Power Supply: 20.4-26.4V DC
CPU and Memory Module
Patch Cards

Theory:

Ladder Diagrams
As an introduction to ladder diagrams, consider the simple wiring diagram for an electrical circuit in Figure.1a. The diagram shows the circuit for switching on or off an electric motor. We can redraw this diagram in a different way, using two vertical lines to represent the input power rails and stringing the rest of the circuit between them. Figure.1b shows the result. Both circuits have the switch in series with the motor and supplied with electrical power when the switch is closed. The circuit shown in Figure.1b is termed a ladder diagram.

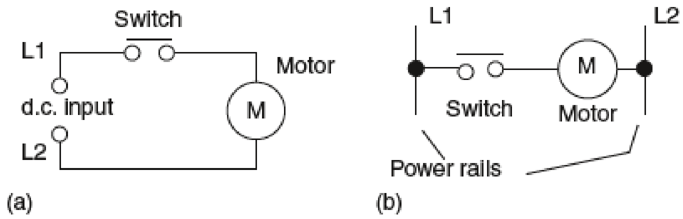


Figure.1 Ways of drawing the same electrical circuit

With such a diagram the power supply for the circuits is always shown as two vertical lines with the rest of the circuit as horizontal lines. The power lines, or rails as they are often termed, are like the vertical sides of a ladder with the horizontal circuit lines like the rungs of the ladder. The horizontal rungs show only the control portion of the circuit; in the case of Figure .1 it is just the switch in series with the motor. Circuit diagrams often show the relative physical location of the circuit components and how they are actually wired. With ladder diagrams no attempt is made to show the actual physical locations and the emphasis is on clearly showing how the control is exercised.

Figure .2 shows an example of a ladder diagram for a circuit that is used to start and stop a motor using push buttons. In the normal state, push button 1 is open and push button 2 closed. When button 1 is pressed, the motor circuit is completed and the motor starts. Also, the holding contacts wired in parallel with the motor close and remain closed as long as the motor is running. Thus when the push button 1 is released, the holding contacts maintain the circuit and hence the power to the motor. To stop the motor, button 2 is pressed. This disconnects the power to the motor and the holding contacts open. Thus when push button 2 is released, there is still no power to the motor. Thus we have a motor which is started by pressing button I and stopped by pressing button 2.

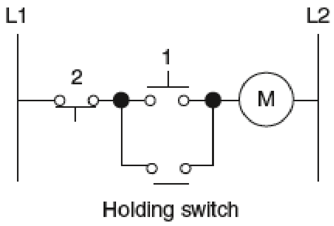


Figure.2. Stop-start switch

PLC Ladder Programming

A very commonly used method of programming PLCs is based on the use of ladder diagrams. Writing a program is then equivalent to drawing a switching circuit. The ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines, i.e., the rungs of the ladder, between these two verticals.

In drawing a ladder diagram, certain conventions are adopted:

1. The vertical lines of the diagram represent the power rails between which circuits are connected. The power flow is taken to be from the left-hand vertical across a rung.
2. Each rung on the ladder defines one operation in the control process.
3. A ladder diagram is read from left to right and from top to bottom, Figure.3 showing the scanning motion employed by the PLC. The top rung is read from left to right. Then the second rung down is read from left to right and so on.

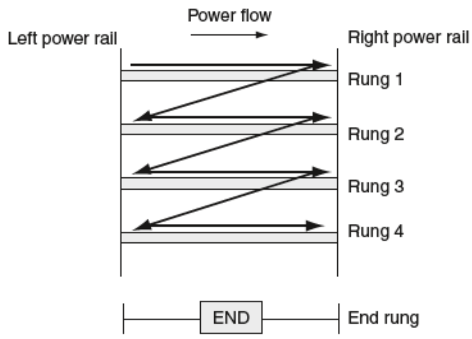


Figure .3: Scanning the ladder program

When the PLC is in its run mode, it goes through the entire ladder program to the end, the end rung of the program being clearly denoted, and then promptly resumes at the start. This procedure of going through all the rungs of the program is termed a cycle. The end rung might be indicated by a block with the word END or RET for return, since the program promptly returns to its beginning.

4. Each rung must start with an input or inputs and must end with at least one output. The term input is used for a control action, such as closing the contacts of a switch, used as an input to the PLC. The term output is used for a device connected to the output of a PLC, e.g., a motor.

5. Electrical devices are shown in their normal condition. Thus a switch, which is normally open until some object closes it, is shown as open on the ladder diagram. A switch that is normally closed is shown closed.
6. A particular device can appear in more than one rung of a ladder. For example, we might have a relay that switches on one or more devices. The same letters and / or numbers are used to label the device in each situation.
7. The inputs and outputs are all identified by their addresses, the notation used depending on the PLC manufacturer. This is the address of the input or output in the memory of the PLC.

Figure .4 shows standard IEC 1131-3 symbols that are used for input and output devices. Some slight variations occur between the symbols when used in semi-graphic form and when in full graphic. Note that inputs are represented by different symbols representing normally open or normally closed contacts. The action of the input is equivalent to opening or closing a switch. Output coils are represented by just one form of symbol.

To illustrate the drawing of the rung of a ladder diagram, consider a situation where the energizing of an output device, such as a motor, depends on a normally open start switch being activated by being closed. The input is thus the switch and the output the motor.

Figure 5 shows the ladder diagram.

Starting with the input, we have the normally open symbol ❘❘ for the input contacts. There are no other input devices and the line terminates with the output, denoted by the symbol ( ). When the switch is closed, i.e., there is an input, the output of the motor is activated. Only while there is an input to the contacts is there an output. If there had been a normally closed switch ❘/❘ with the output , then there would have been an output until that switch was opened. Only while there is no input to the contacts is there an output.

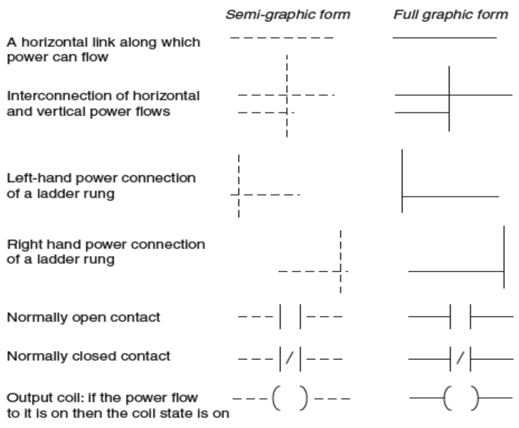


Figure .4: Basic symbols

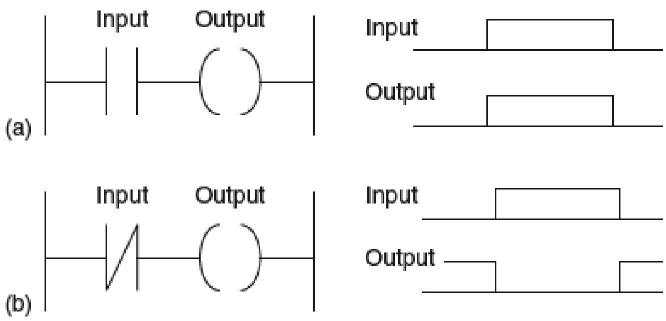


Figure .5: A ladder rung

In drawing ladder diagrams the names of the associated variable or addresses of each element are appended to its symbol. Thus Figure .6 shows how the ladder diagram of Figure .5 would appear using (a) Mitsubishi, (b) Siemens, (c) Allen-Bradley, (d) Telemecanique notations for the addresses. Thus, Figure 11.6a indicates that this rung of the ladder program has an input from address X400 and an output to address Y430. When wiring up the inputs and outputs to the PLC, the relevant ones must be connected to the input and output terminals with these addresses.

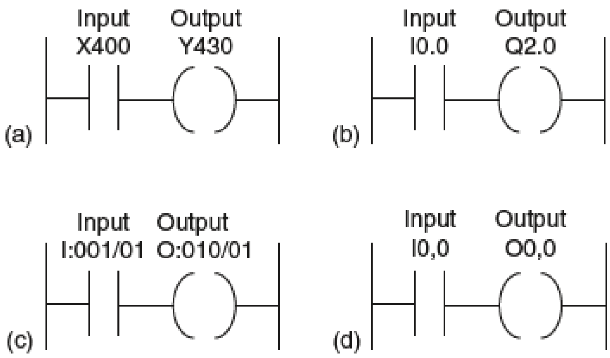


Figure .6: Notation: (a) Mitsubishi (b) Siemens (c) Allen-Bradley (d) Telemecanique

<u>Procedure:</u>

NOT Gates or Inverters

The output of a *NOT gate* is the inverse of the input. The NOT gate is sometimes called an *inverter*. The function of a NOT gate is simulated by the electric circuit displayed in Figure 7. When the switch is closed, the electric bulb is short circuited, and it turns off. When the switch is open, electric current flows through the light bulb, and the light bulb turns on. Like the NOT gate, the output is on when the input is off and vice versa. The input is inverted to generate an output. Figure 8 displays the NOT logic gate symbol, its Boolean expression, and its truth table.

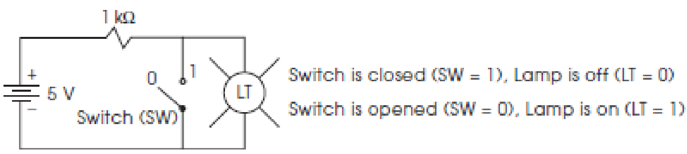


Figure:7. Electric circuit emulating the function of a NOT gate.

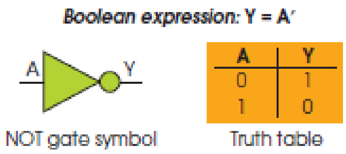


Figure 8. Boolean expression, gate symbol, and truth table for NOT logic gate.
Figure 9 displays that there are two different types of PLC lad-der logic diagrams that perform the NOT function.

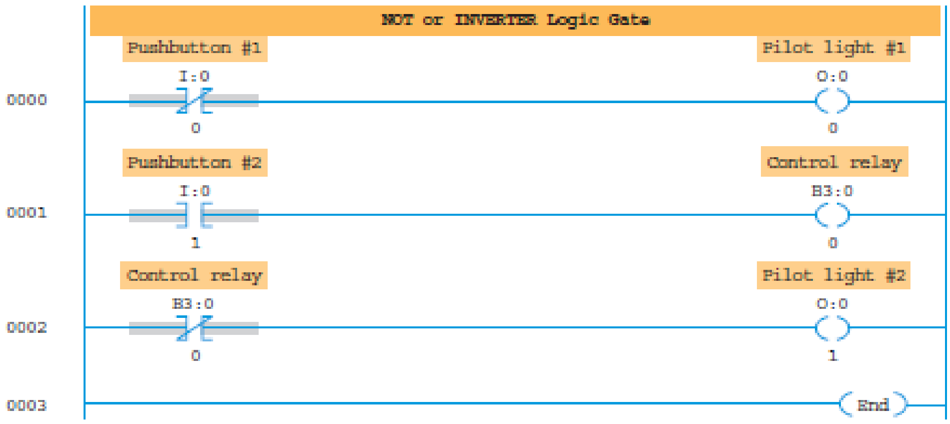


Figure 9 Two ways to program a NOT function in a PLC.

1. In rung 0000, the XIO (examine if open) device is connected to the output. Therefore, the XIO device is normally closed and output zero is ON. When you press pushbutton #1 (I:0/0), the output zero (pilot light #1) is turned off. (Notice that address I:0/0 references the port 0 on module 0.)

2. In rung 0001, pushbutton #2 (I:0/1) is connected to internal coil bit B3:0/0. (Notice that address I:0/1 references the port 1 on module 0.) In rung 0002, the internal contact bit B3:0/0 is inverted and connected to output one (pilot light #2). When normally open input I:0/1 is open, output one (O:0/1) is ON. Press input 0/1 to close it, then output one will turn OFF.

AND Gates
The function of an ***AND gate*** is simulated in the electric circuit displayed in **Figure 10.** Notice that the lamp will be on only when both switches are closed.

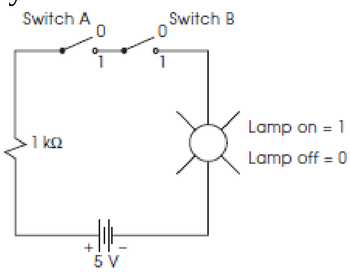


Figure 10. Electric circuit emulating an AND gate.

Figure 11 displays a two-input AND logic gate symbol, its Bool-ean expression, and its truth table. In the truth table, you can see that there is only one set of inputs that produces a logic high output.

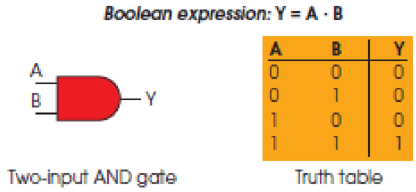


Figure 11. Boolean expression, gate symbol, and truth table for AND logic gate

Figure 12 displays a ladder logic diagram that performs the function of a two-input AND gate.

- ➢ When normally open inputs I:0/0 and I:0/1 are closed, output O:0/0 is energized.

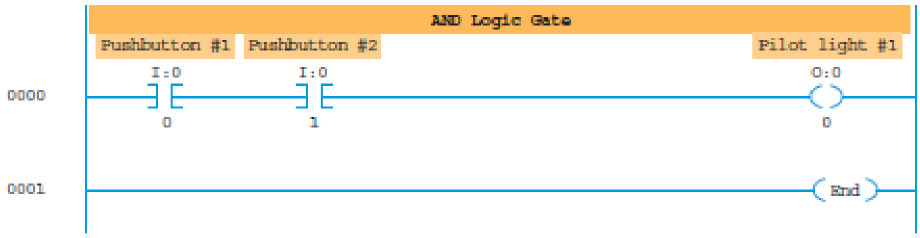


Figure 12. AND gate ladder logic diagram.

OR Gates

The function of an ***OR gate*** is simulated in the electric circuit dis-played in **Figure 13.** Notice that the lamp will be ON when one *or* both of the switches are closed.

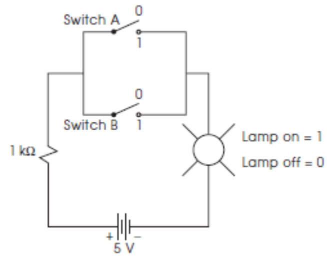


Figure 13. Electric circuit emulating an OR gate.

Figure 14 displays a two-input OR logic gate symbol, its Bool-ean expression, and its truth table. The truth table shows a logic high output for all combinations of inputs except where both A and B are low. When either input A, B, or both are on, the output is on.

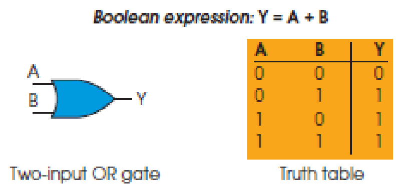


Figure 14. Boolean expression, gate symbol, and truth table for OR logic gate

Figure 15 displays a ladder logic diagram that performs the function of a two-input OR gate.

- ➢ When either normally open (NO) inputs I:0/0, I:0/1, or both are closed, output O:0/0 is energized

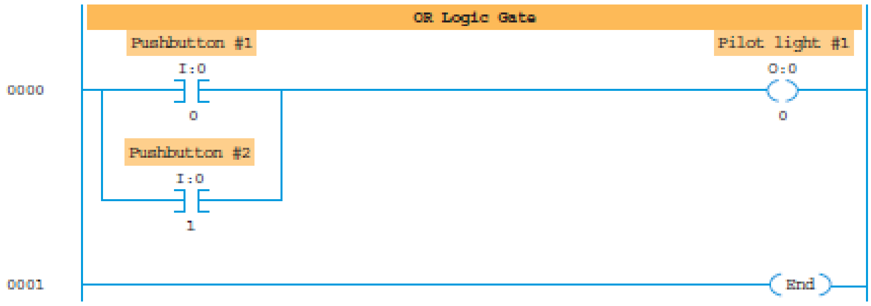


Figure 15. OR gate ladder logic diagram

NAND Gates

The function of a ***NAND gate*** is simulated in the electric circuit displayed in **Figure 16.** Notice that the lamp will be off when both switches are closed. The NAND gate takes its name from NOT and AND. Its outputs are the inverse of the AND gate.

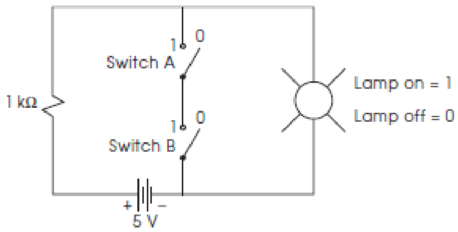


Figure 16. Electric circuit emulating an OR gate

Figure 17 displays a two-input NAND logic gate symbol, its Boolean expression, and its truth table. Notice that the NAND gate can be built by connecting an AND gate in series with a NOT gate. Using the De-Morgan theorem, sometimes also called the Bubble method, you can convert a NAND gate to an OR gate with inverted inputs where (A · B) ′ = A′ + B′.

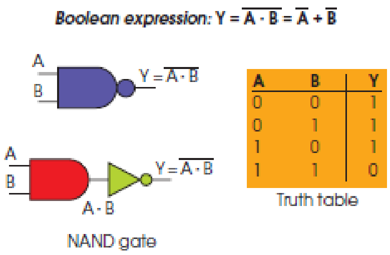


Figure 17. Boolean expression, gate symbol, and truth table for NAND logic gate

Figure 18 displays that there are two different types of ladder logic diagrams that perform the NAND function.

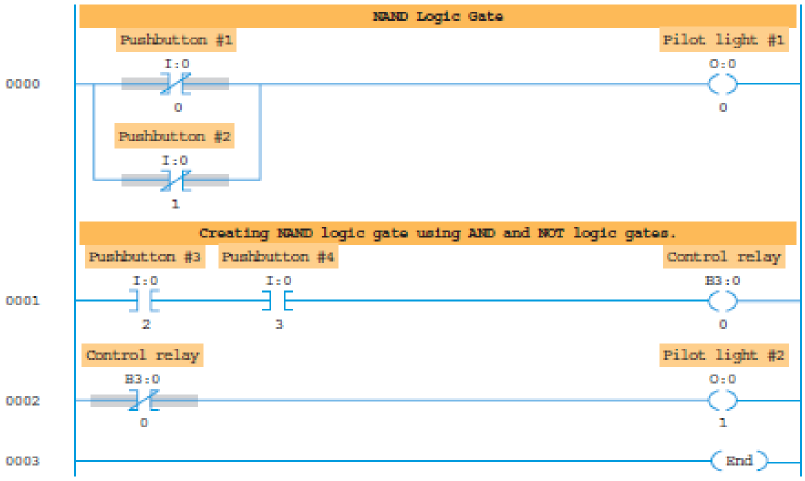


Figure 18. NAND gate ladder logic diagram

- ➢ Both normally closed inputs I:0/0 and I:0/1 must be energized (opened) to turn off the output O:0/0.
- ➢ When both normally open inputs I:0/2 and I:0/3 are energized (closed), the relay coil B3:0/0 is energized. Then the normally closed contact B3:0/0 is opened to turn off output O:0/1.

NOR Gates

The function of a NOR logic gate is simulated in the electric circuit displayed in **Figure 19.** Notice that the lamp will be ON when both switches are open. The ***NOR gate*** takes its name from NOT and
OR. Its outputs are the inverse of the OR gate.

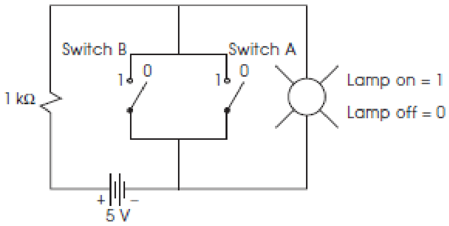
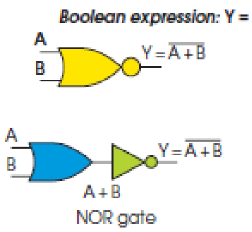


Figure 19. Electric circuit emulating an NOR gate

Figure 20 displays a two-input NOR logic gate symbol, its Boolean expression, and its truth table. Notice the NOR gate can be built by connecting an OR gate in series with a NOT gate. Using the
De-Morgan theorem, you can convert a NOR gate to an AND gate with inverted inputs where (A + B) ′ = A′ · B′.



A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

Figure 20. Boolean expression, gate symbol, and truth table for NOR logic gate

Figure 21 displays that there are two different types of ladder logic diagrams that perform the NOR gate function.

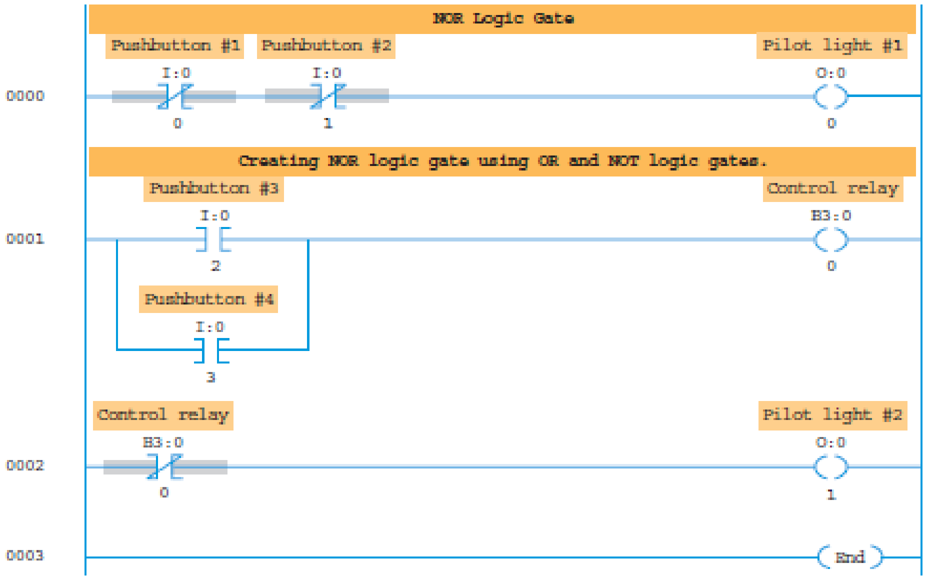


Figure 21. NOR gate ladder logic diagram

- Both normally closed inputs I:0/0 and I:0/1 must be deenergized (remain closed) to turn on the output O:0/0.
- When both normally open inputs I:0/2 and I:0/3 are de-energized, the relay coil B3:0/0 is de-energized. Then the normally closed contact B3:0/0 remains closed to turn on output O:0/1.

Result:

Viva-Voce Questions:

1. What is PLC?
2. What are the Different types of PLCs available in the Market?
3. Draw the Ladder diagram of NOT, AND, OR Gate?
4. Draw the Ladder diagram of NAND, NOR Gate?
5. What are the advantages of PLC?
6. What are the applications of PLCs?
7. What is Ladder diagram?
8. Scan time of PL

10. Temperature controller using PID

Aim: To study the effect of P, PD, PI, PID controller on temperature control system.

Apparatus: PID controller kit, CRO, Probes.

Theory: The PID controller can be designed both in the frequency domain and in the S-plane through the classical or trail and error design procedure. The method needs the pole-zero locations or frequency- phase responses of the plant, for its implementation. A large number of process control systems are however characterized by

* Incomplete or inaccurate plant equations
* Extremely slow response
* Presence of time delays
* High order transfer function
* Limited possibility of experimentation for identification of the plant
* Need for fine trimming the compensator at site.

In such a situation alternative simpler techniques of setting the controller parameters (K_c, T_i, T_d) or tuning, are of great importance.

PID controller unit:-

Front panel details:-

1) Main : Main on/off switch
2) Square : Variable square wave out 0-2v.
3) Level : Potentio meter to vary the amplitude of square wave and triangular wave
4) Frequency : Potentio meter to vary the frequency of square wave and triangular wave
5) Triangle : Triangle wave O/P for triggering purpose in x-y mode
6) Amplitude : Potentio meter to vary the D.C voltage from 0-12v
7) Dc : Variable Dc O/P 0-12v
8) GND : Ground terminal
9) DPM : 31/2 digit DC volt meter to measure DC voltage at different points
10) Vin : +ve I/P of error detector feedback voltage
11) V_f : -ve I/P of error detector feedback voltage
12) V_e : Error voltage
13) P : 10 turn potentio meter to vary potential gain from 0-20 with indicating dial

14) I : 10 turn potentio meter to vary the integral gain from 10-1000

15) D : 10 turn potentio meter to vary the derivative gain from 1-0.01

16) Controller : PID controller with variable PID parameters.

17) ON/OFF : On/off switch for P,I,D individually

18) + : Adder

19) INV AMP : Units gain inverting amplifier to find the effect of Positive feed back

20) Process:

A) First order system : First order system with time constant of – 3msec.

B) Second order system: Second order system with time constant of 5 sec.

C) Time constant : 1m sec – Suitable for square wave I/P

D) Integrator : 2m sec. Time with 180^0 phase shift

Procedure:

b) Proportional Control:

7. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
8. Connect P Controller and Disconnect I and D controllers
9. Apply a 1 volt P-P square wave input.
10. Observe the output of the system on CRO.
11. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
12. Repeat the steps for different values of K_p and tabulate.

K_p	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

c) Proportional +Integral (PI)Control:

8. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
9. Connect P Controller, Integral Controller Disconnect D controllers
10. Apply a 1 volt P-P square wave input.
11. Set K_p=----- .
12. Observe the output of the system on CRO.
13. Calculate the percentage peak overshoot, settling time, rise time and steady state error.

14. Repeat the steps for different values of K_i and tabulate.

K_i	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

d) <u>Proportional +Derivative(PD)Control:</u>

8. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
9. Connect P Controller, Derivative controllers Disconnect Integral Controller
10. Apply a 1 volt P-P square wave input.
11. Set K_p=----- .
12. Observe the output of the system on CRO.
13. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
14. Repeat the steps for different values of K_d and tabulate.

K_d	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

e) <u>Proportional +Derivative+Integral(PID)Control:</u>

8. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
9. Connect P Controller, Derivative controllers and Integral Controller
10. Apply a 1 volt P-P square wave input.
11. Set K_p=----- and K_d=------.
12. Observe the output of the system on CRO.
13. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
14. Repeat the steps for different values of K_i and tabulate.

K_i	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

e)Proportional +Derivative+Integral(PID)Control:

8. Make the connections as shown in the figure. (Connect first order plant with Delay in Closed loop)
9. Connect P Controller, Derivative controllers and Integral Controller
10. Apply a 1 volt P-P square wave input.
11. Set K_p=----- and K_i=------.
12. Observe the output of the system on CRO.
13. Calculate the percentage peak overshoot, settling time, rise time and steady state error.
14. Repeat the steps for different values of K_d and tabulate.

K_d	t_r	$C(t_P)$	$C(\infty)$	$\%M_p$	e_{ss}

Result:

Viva-Voce Questions:

1. Define second order system?
2. Where shall we apply PID controller?
3. What is the Effect of Proportional Controller?
4. What is the Effect of PI Controller?
5. What is the Effect of PD Controller?
6. What is the Effect of PID Controller?
7. Why steady state error is non zero incase of PI controller?
8. What are draw backs of PD Controller?