

Experiment No. _____

Date: _____

SYNCHRO TRANSMITTER AND RECEIVER PAIR

OBJECTIVES:

To determine the following characteristics of a synchro pair.

- a) The angular position of rotor of synchro transmitter Vs. the set of stator voltages.
- b) The rotor position of synchro transmitter Vs. the rotor position of synchro receiver. (Transmitting motion to a distance by electrical means)
- c) The rotor position of synchro transmitter Vs. the voltage across the rotor of the synchro receiver. (Synchro as a transducer).

INSTRUMENTS REQUIRED:

Synchro transmitter and receiver unit, Multimeter, Patch cord

INTRODUCTION:

A synchro is an electromagnetic transducer commonly used to convert an angular position of a shaft into an electrical signal. The basic synchro is usually called a synchro transmitter. Its construction is similar to that of a three-phase alternator. The stator is of laminated silicon steel and is slotted to accommodate a balanced three-phase winding which is usually of concentric coil type and is star connected. The rotor is of dumb bell construction and wound with a concentric cell. An A.C. voltage is applied to the rotor winding through slip rings.

Let an A.C. voltage $V_t = V_r \sin \omega_c t$ be applied 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 along stator 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 axes 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 synchro transmitter (TX) acts like a single phase transformer in which rotor coil is the

primary and the stator coils form three secondaries. Let V_{s1N} , V_{s2N} and V_{s3N} are the voltages induced in the stator coils S_1 , S_2 and S_3 with respect to the neutral respectively. Then for the rotor position of the synchro transmitter shown in Fig. 1 where the rotor axis makes an angle θ with the axis of the stator coil S_2 .

Let,

$$V_{s1N} = k V_r \sin(\omega_c t) \cdot \cos(\theta + 120)$$

$$V_{s2N} = k V_r \sin(\omega_c t) \cdot \cos(\theta)$$

$$V_{s3N} = k V_r \sin(\omega_c t) \cdot \cos(\theta + 240)$$

The three terminal voltages of the stator are

$$\begin{aligned} V_{S1-S2} &= V_{S1N} - V_{S2N} \\ &= 3 k V_r \sin(\theta + 240) \sin(\omega_c t) \end{aligned}$$

$$\begin{aligned} V_{S2-S3} &= V_{S2N} - V_{S3N} \\ &= 3 k V_r \sin(\theta + 120) \sin(\omega_c t) \end{aligned}$$

$$\begin{aligned} V_{S3-S1} &= V_{S3N} - V_{S1N} \\ &= 3 k V_r \sin(\theta) \sin(\omega_c t) \end{aligned}$$

When θ is zero, it is seen that the maximum voltage is induced in the stator coil S_2 while the terminal voltage V_{S3-S1} is zero. This position of rotor is defined as the electrical zero of the TX and is used as a reference for specifying the angular position of the rotor. Thus, it is seen that the input to the synchro transmitter is the angular position of its rotor shaft and the output is a set of three single-phase voltages given by the above equations and the magnitudes of these voltages are functions of a shaft position.

The synchro receiver is having almost the same constructional features. The two units are connected as shown in Fig. 2. Initially the winding S_2 of the stator of transmitter is positioned for maximum coupling with rotor winding. Suppose its voltage is V . The coupling between S_1 and S_2 of the stator and primary (rotor) winding are proportional to $\cos 60^\circ$ or they are $V/2$ each. So long as the rotors of transmitter and receiver remains in this position, no current will flow between windings because of the voltage balance.

When the rotor of TX is moved to a new position, the voltage balance is disturbed. Assume that the rotor of TX is moved through a certain angle, the stator winding voltages will change accordingly. Thus there is a voltage imbalance between the stator winding of

OBSERVATIONS:

Sl. No.	θ_T in degrees	V_{S2-S1} Volts	V_{S1-S3} Volts	V_{S3-S2} Volts
1.	0			
2.	30			
3.	60			
4.	90			
5.	120			
6.	150			
7.	180			
8.	210			
9.	240			
10.	270			
11.	300			
12.	330			

Sl. No.	θ_T in degrees	α in degrees
	0	
	30	
	60	
	90	
	120	
	150	
	180	
	210	
	240	
	270	
	300	
	330	

TX and TR. This voltage imbalance between the windings causes currents to flow through the closed 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 the TX. The TX-TR pair thus serves to transmit information about angular position at one point to a remote point.

PROCEDURE:

To obtain synchro transmitter characteristics:

1. Connect the system to main supply
2. Switch on the main switch and SW1
3. Do not connect any wires between the stator of TX and TR
4. Starting from zero position, note down the voltages between terminals V_{S2-S1} , V_{S1-S3} and V_{S3-S2} in a sequential fashion. Enter the readings in a tabular form and plot a graph of angular position Vs. voltage for all the three phases.

To obtain the characteristic of synchro transmitter and receiver pair:

1. Connect the system to main supply
2. With the help of patch cords, establish connection between corresponding terminals of TX and TR stators.
3. Switch on SW1 and SW2
4. Move the pointer(rotor position) of TX in steps of 30° and observe the new rotor position of TR.
5. Enter the input angular position and output angular position in tabular form and plot the graph.

To use synchro transmitter and receiver pair as a transducer:

1. Connect the system to main supply
2. With the help of patch cords, establish connection between corresponding terminals of TX and TR stators.
3. Keep SW1 in on position and SW2 in off position.
4. Move the pointer(rotor position) of TX in steps of 30° and measure the voltage across R1 – R2.
5. Enter the input angular position and receiver rotor voltage in tabular form and plot the graph.

Sl. No.	θ_T in degrees	V_{R1-R2} Volts
	0	
	30	
	60	
	90	
	120	
	150	
	180	
	210	
	240	
	270	
	300	
	330	

Experiment No. _____

Date: _____

TWO PHASE A.C. SERVO MOTOR

OBJECTIVES:

To draw the speed - torque characteristics of a two phase A.C. servo motor.

INSTRUMENTS REQUIRED:

1. Light alloy brake disc
2. Motor unit (150U)
3. Attenuator (150B)
4. Servo Amplifier (150D)
5. Power supply (150E)
6. Load unit (150L)
7. AC Pre amplifier (150V)
8. Base plate
9. Oscilloscope
10. Stop watch

INTRODUCTION:

AC Servo Motors: Two phase induction servo motors are normally used in control systems where AC signals are used through out. One winding (reference winding) is energised from the AC power supply. The other winding (control winding) is energised by a signal 90° out of phase with the reference supply. By varying the supply to the control winding, the torque of the motor at any speed can be varied.

AC Tachogenerator: It produces an AC voltage proportional to speed. The rotor is a cylindrical metal drag cup. The voltage - speed characteristic is approximately linear. The stator consists of two windings. The reference winding energised from the supply and the output winding set at 90° to it.

Motor Tachogenerator Unit (150U): The reference windings of the motor and Tachogenerator are permanently connected to the reference supply. The motor control winding is connected to sockets and the collector circuits of the power transistors, located in the servo amplifier. The bases of these power transistors are connected to the output terminals of AC pre amplifier (150V).

AC Pre amplifier (150V): It is a combination of an operational amplifier able to sum several error signals together, and an adjustable phase shifter for the total error signal. The phase shift between the voltages applied to the reference winding and control winding of a servo is achieved by using the 90° input terminals and the phase control. The output is fed to the bases of the power transistors driving the control winding of the AC servo.

Attenuator Unit (150B): This unit contains two variable 10kΩ potentiometers. The proportion of the resistance being selected is indicated by a dial graduated from 0 to 10.

Load Unit (150L): An aluminium disc can be mounted on the motor shaft and when rotated between the poles of the magnet of the load unit, the eddy currents generated have the effect of a brake. The strength of the magnetic brake can be controlled by the positions of the magnet.

Servo Amplifier (150D): To drive the motor in either direction or to pass AC through the control winding, two power transistors are used. The bases are driven by the output of the AC pre amplifier in this experiment.

Power Supply Unit (150E): This unit supplies a 24V DC, 2A, unregulated supply to the motor through an 8 way connector to the servo amplifier, as it is this unit that controls the motor.

Both 150E as well as 150D have stabilized DC supplies of +/- 15V sockets on the front panel which can operate the smaller amplifiers.

PROCEDURE:

1. Fix the light alloy brake disc to the high speed shaft of motor unit 150U
2. Attach the attenuator 150B, servo amplifier 150D, power supply 150E, 150U, 150L and the AC pre amplifier 150V to the base plate by means of the magnetic fixings.
3. Connect the octal sockets from 150D to 150E and from 150U to 150D.
4. Interconnect the 150B, 150D, 150E, 150U and 150V as in the figure.
5. Set the oscilloscope Y amplifier to 1 V/div and time base to 5ms/div.
6. Plug the 150E and oscilloscope to mains supply sockets.
7. Set the potentiometer slider (150B) and brake to zero.
8. Switch on the supply. Set the input pot to 2.

OBSERVATIONS:

Speed of the low speed shaft =

Speed of the high speed shaft =

Sl. No.	Brake position	Tacho output Volts	Speed in rpm.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Record the time taken for a known number of rotations of the low speed shaft of the motor using a stop watch. Note down the corresponding peak to peak Tachogenerator output voltage. Calculate the speed of the low speed shaft and hence the speed of the motor shaft using gear ratio (1:30)

9. Plot the variation (straight line) of Tachogenerator peak to peak voltage versus speed.
10. For brake settings from 0 to 10, determine the tacho voltage and the corresponding speed in rpm by referring to the plot stated in step 10.
11. Plot the variation of torque (brake position) against speed in rpm.

RESULT:

Experiment No. _____

Date: _____

TIME RESPONSE CHARACTERISTICS OF A SECOND ORDER SYSTEM

OBJECTIVES:

To determine the time response of a second order system using a step input and hence to determine its time response specifications.

INSTRUMENTS REQUIRED:

- | | |
|--------------------------|-------|
| 1. Decade resistance box | 1 no. |
| 2. Capacitance box | 1 no. |
| 3. Inductance box | 1 no. |
| 4. Signal generator | 1 no. |
| 5. Oscilloscope | 1 no. |
| 6. Connecting wires | |

PRINCIPLE:

Since time is used as an independent variable in most control systems, it is usually of interest to evaluate the output response with respect to time, or simply, the time response. In the analysis problem, a reference input signal is applied to a system, and the performance of the system is evaluated by studying the system response in the time domain. The time response of a control system is usually divided into two parts: the transient response and the steady-state response. The transient response of a control system is necessarily important, since both the amplitude and time duration of the transient response must be kept within tolerable or prescribed limits. For linear control systems, the characterization of the transient response is often done by use of the step function as the input. The response of a control system when the input is a step function is called the step response.

Let us consider a series RLC circuit shown in figure. When a unit step input is applied to the circuit, the differential equation that represent the system will be

$$E_i = Ri + L \frac{di}{dt} + \frac{1}{c} \int i dt$$

and $E_0 = \frac{1}{c} \int i dt.$

The transfer function of the system will be obtained as

$$\frac{E_0(s)}{E_i(s)} = \frac{1}{LCs^2 + RCs + 1} = \frac{1/LC}{s^2 + R/L s + 1/LC} = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n + \omega_n^2}$$

Where, $\zeta\omega_n = \frac{R}{2L}$, $\omega_n = \frac{1}{\sqrt{LC}}$ and $\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}$

For a unit step input,

$$E_0(s) = \frac{\omega_n^2}{s(s^2 + 2\zeta\omega_n + \omega_n^2)}$$

and hence,

$$e_0(t) = 1 - \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sin\left(\omega_n \sqrt{1-\zeta^2} + \cos^{-1} \zeta\right)$$

The roots of the characteristic equation are $-\frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \left(\frac{1}{\sqrt{LC}}\right)^2}$

$$S_1, S_2 = -\zeta\omega_n \pm \omega_n \sqrt{\zeta^2 - 1} = \alpha + j\omega_d \quad \text{Where } \omega_d = \omega_n \sqrt{1-\zeta^2}$$

In the above equation of $e_0(t)$, α appears as the constant that is multiplied to t in the exponential term. Therefore, α controls the rate of rise or decay of the unit step response $e_0(t)$. In other words, α controls the damping of the system and is called the damping factor or damping constant.

When the two roots of the characteristic equation are real and equal, the system is called critically damped. The critical damping occurs when $\zeta = 1$. Under this condition, the damping factor is simply $\alpha = \omega_n$. Thus ζ is known as damping ratio, that is, $\zeta = \alpha/\omega_n$. The parameter ω_n is defined as the natural undamped frequency. When $\zeta = 0$, the damping is zero, the roots of the characteristic equation are imaginary, and the output equation shows that the response is purely sinusoidal. Therefore, ω_n corresponds to the frequency of the undamped sinusoidal response. That is, when $0 < \zeta < 1$, the imaginary parts of the roots have the magnitude of ω_d , known as damped frequency and the system is called under damped. When $\zeta \geq 1$, the step response does not exhibit any overshoot; that is, $e_0(t)$ never exceeds its final value during the transient. When $\zeta > 1$, the system is called over damped system.

OBSERVATIONS:

$\zeta =$

$L = 200\text{mH}$

$C = 0.1 \mu\text{F}$

$R = \frac{2\zeta}{\sqrt{\frac{C}{L}}} =$

Quantities	Theoretical Value	Practical Value
Delay Time (T_d)		
Rise Time (T_r)		
Peak Time (T_p)		
Settling Time (T_s)		
Maximum Overshoot (M_p)		

Transient Response Specifications:

Delay Time (T_d): It is the time required for the response to reach 50% of the final value the very first time. It is given by the formula

$$T_d = \frac{1 + 0.7\zeta}{\omega_n}$$

Rise Time (T_r): It is the time required for the response to rise from zero to 100% of the final value. It is given by the formula

$$T_r = \frac{\pi - \beta}{\omega_d} \quad \text{Where } \beta = \tan^{-1}\left(\frac{\sqrt{1-\zeta^2}}{\zeta}\right)$$

Peak Time (T_p): It is the time required for the response to reach first peak of the overshoot. It is given by the formula

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

Peak Overshoot (M_p): It is defined as the maximum peak value of the response curve measured from unity.

$$M_p = e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}$$

Settling Time (T_s): It is the time required for the response curve to reach and stay within a range about the final value.

$$T_s = \frac{4}{\zeta\omega_n}$$

PROCEDURE:

1. Connections are made as shown in figure.
2. A step input is given to the system. (A square wave with large time period from an oscillator)
3. Output across the capacitor is observed in the CRO.
4. Observe the effect of ζ on the output by varying the value of R, keeping L and C constant.
5. The time response specifications are measured/calculated for under damped condition.

RESULT:

Experiment No. _____

Date: _____

RC LEAD AND LAG COMPENSATING NETWORKS

OBJECTIVES:

- a) To design a passive RC lead compensating network for the given specifications, viz., the maximum phase lead and the frequency at which it occurs and to obtain its frequency response. To determine experimentally the transfer function of the lead compensator.
- b) To design a passive RC lag compensating network for the given specifications, viz., the maximum phase lag and the frequency at which it occurs and to obtain its frequency response. To determine experimentally the transfer function of the lag compensator.

INSTRUMENTS REQUIRED:

Resistors

Capacitor 1 μ F 1 no.

Bread board 1 no.

Signal generator 1 no.

Transfer function analyzer 1 no.

INTRODUCTION:

Control systems are designed to perform specific tasks. The requirements imposed on the control system are usually spelled out as performance specifications. Setting the gain is the first step in adjusting the system for satisfactory performance. It is then necessary to redesign the system and such a redesign or addition of a suitable device is called compensation. Among the mainly employed compensators, lead and lag networks are widely used.

Lead Compensation: Lead compensation essentially yields an appreciable improvement in transient response and a small change in steady state accuracy. It may accentuate high frequency noise effects. There are many ways to realise a lead compensator. An electrical RC circuit shown in figure is the one method. The parameters R & C can be selected depending on the requirements of the system. The following equations are useful to design the network.

$$Z_1 = \frac{R_1}{R_1 C s + 1} \quad Z_2 = R_2$$

The transfer function $V_0(s)/V_i(s)$ is given by

$$\frac{V_0(s)}{V_i(s)} = \frac{Z_2}{Z_1 + Z_2} = \frac{R_2}{R_1 + R_2} \cdot \frac{R_1 C s + 1}{\frac{R_1 R_2 C s}{R_1 + R_2} + 1}$$

By taking $R_1 C = \tau$ and $R_2 / (R_1 + R_2) = \alpha$, the transfer function becomes

$$\frac{V_0(s)}{V_i(s)} = \alpha \left(\frac{\tau s + 1}{\alpha \tau s + 1} \right)$$

α is less than one for lead compensators. Also we have the equation

$$\alpha = \frac{1 - \sin \phi_m}{1 + \sin \phi_m} \quad \omega_m = \frac{1}{\tau \sqrt{\alpha}}$$

Where, Φ_m is the maximum phase lead and ω_m is the frequency at which Φ_m occurs.

Lag Compensation:

Lag compensation yields an appreciable improvement in steady state accuracy at the expense of increasing the transient response time. Lag compensation will suppress the effects of high frequency noise effects. A lag compensator using an RC network is shown in figure.

From figure, we have,

$$Z_1 = R_1 \quad Z_2 = R_2 + 1/Cs$$

$$\text{The transfer function } \frac{V_0(s)}{V_i(s)} = \frac{Z_2}{Z_1 + Z_2} = \frac{R_2 C s + 1}{(R_1 + R_2) C s + 1}$$

Defining $\tau = R_2 C$ and $\beta = (R_1 + R_2) / R_2$, the transfer function can be rewritten as

$$\frac{V_0(s)}{V_i(s)} = \frac{\tau s + 1}{\beta \tau s + 1} = \frac{1}{\beta} \left(\frac{s + 1/\tau}{s + 1/\beta \tau} \right)$$

β is always greater than one. Also we have,

$$\beta = \frac{1 + \sin \phi_m}{1 - \sin \phi_m} \quad \omega_m = \tau \sqrt{\beta}$$

Where Φ_m is the maximum phase lag and ω_m is the frequency at which Φ_m occurs.

PROCEDURE:

1. The circuit designed for the given values of Φ_m and ω_m .
2. The connections are made as shown in Fig. 1 for lag network and as in Fig. 2 for lead network.

OBSERVATIONS:

Sl. No.	f Hz.	Lag Network			Lead Network		
		$V_0 (a+jb)$	$V_0 (V_0 < \theta)$	Gain	$V_0 (a+jb)$	$V_0 (V_0 < \theta)$	Gain
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
21.							
22.							

3. Transfer function analyzer is adjusted for zero error.
4. Keeping the input voltage at a specified value (say 15V), the frequency is varied in steps and in each case the output voltage in the form $(a+jb)$ is noted.
5. The magnitude and phase angle plots are drawn and the values of maximum phase angle Φ_m and corresponding frequency ω_m are verified.
6. The band width, corner frequencies and transfer function of the circuit are also determined.

RESULT:

Experiment No. _____

Date: _____

RC LEAD - LAG COMPENSATING NETWORKS

OBJECTIVES:

To obtain the frequency response and transfer function of a given RC lag - lead network.

INSTRUMENTS REQUIRED:

Bread board, Signal generator, Transfer function analyzer, Resistors and Capacitors

INTRODUCTION:

The lead compensator is suitable for systems having unsatisfactory transient response, but it provides only a limited improvement in steady state response. If the steady state behaviour is unsatisfactory, the lead compensator may not be the choice. On the other hand, for systems with unsatisfactory steady state response, the lag compensation is found to be a good choice. When both transient and steady state responses are quite unsatisfactory, we must draw upon the combined power of lag and lead compensates in order to meet specifications. A more convenient choice is the combined lag-lead compensator.

The general form of the transfer function of the lag-lead compensator in pole-zero form is

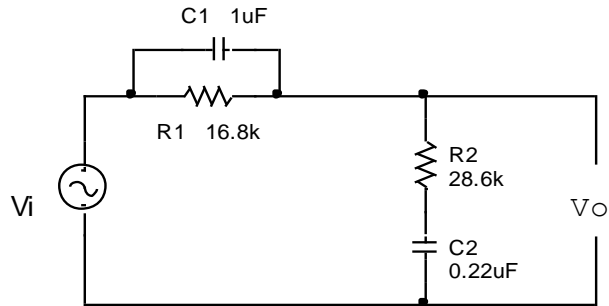
$$G(s) = \frac{\left(s + \frac{1}{\tau_1}\right)\left(s + \frac{1}{\tau_2}\right)}{\left(s + \frac{1}{\beta\tau_1}\right)\left(s + \frac{1}{\alpha\tau_2}\right)}$$

In general, the phase-lead portion of the controller is used primarily for the purpose of achieving a shorter rise time and higher bandwidth, and the phase-lag portion is brought into provide major damping of the system. Either phase-lead or phase-lag control can be designed first.

PROCEDURE:

Connections are made as shown in figure. The input voltage is kept at 15V with phase angle zero. Now the frequency is varied in steps and the output voltage is noted in rectangular form using transfer function analyser. The gain is calculated and bode plot is drawn.

RESULT:



$$\tau_1 = R_1 C_1 \quad \tau_2 = R_2 C_2 \quad \alpha\beta = 1$$

Transfer function

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

Sl. No.	f Hz.	Lag Network		
		$V_0 (a+jb)$	$V_0 (V_0 < \theta)$	Gain
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

Experiment No. _____

Date: _____

P, PI, AND PD CONTROLLERS

OBJECTIVES:

To obtain the closed loop system response of a system with Proportional, Proportional-Integral and Proportional-Derivative controllers.

INSTRUMENTS REQUIRED:

Process control module, function generator, CRO and patch cords.

INTRODUCTION:

A controller is a device which when introduced in feedback or forward path of system, controls the steady state and transient response as per the requirement. Such device converts input to the controller to some other form of error than proportional to error due to which steady state and transient response gets improved. In general, good time response demands less settling time, less overshoot, less rise time and smallest steady state error. In most of the practical systems, controller input is proportional to error generated. Such systems are called proportional to error mechanisms.

For Proportional controller, actuating signal is $K_P \cdot e(t)$

In an integral error compensation scheme, the output response depends in some manner upon the integral of the actuating signal. This type of compensation is introduced by using a controller which produces an output signal consisting of two terms, one proportional to the actuating signal and the other proportional to its integral. An integral error compensation changes a second order system into a third order one.

The actuating signal for PI Controller is $K_P e(t) + K_i \int e(t) dt$. The effects of PI controller are i) it increases order of the system ii) it increases type of the system iii) it makes system relatively less stable iv) reduces steady state error tremendously.

A system is said to possess derivative error compensation when the generation of its output depends in some way on the rate of change of actuating signal. The type of compensation introduced by using a device which provides an output signal containing two terms, one proportional to the derivative of the actuating signal and the other proportional to the actuating signal itself is called proportional plus derivative controller.

The actuating signal for PD controller is $K e(t) + T_d \frac{de(t)}{dt}$. The PD controller has following effects on system. i) It increases damping ratio ii) ω_n for system remains

unchanged iii) Type of the system remains unchanged iv) It reduces peak overshoot v) It reduces settling time vi) Steady state error remains unchanged. In general, PD controller improves transient part without affecting steady state.

PROCEDURE:

P – Controller: Connections are made as shown in figure. A step input is given to set disturbance using function generators. Set value is adjusted so as to obtain zero deviation. Percentage proportion band is varied from maximum to minimum in steps of 20 and the corresponding deviation is noted.

PI Controller: Connections are made as shown in figure and the integral control action is also included using patch cord. The percentage proportional band is kept constant (say 100). Integral band is varied and the corresponding deviations are noted.

PD Controller: Connections are made as shown in figure and the derivative control action is also included using patch cord. The measured value is given to a CRO. The percentage proportional band is kept constant (say 100). T_d is varied from 0 to 2 in steps of 0.2 and in each case the number of oscillations is noted.

RESULT:

OBSERVATIONS:

P – Controller		PI – controller		PD - Controller	
% Proportional Band	Deviation	T _i	Deviation	T _D	Number of oscillations
200		25		0	
100		5		0.8	
50		2.5		1.2	
5		1.2		1.6	
				2.0	

Experiment No. _____

Date: _____

CLOSED LOOP SPEED CONTROL OF DC MOTOR

OBJECTIVES:

To obtain a simple closed loop speed control system for an armature controlled DC motor using a Tachogenerator.

INSTRUMENTS REQUIRED:

Operational amplifier unit (150A), Attenuator unit (150B), Pre-amplifier unit (150C), Servo amplifier (150D), Power supply (150E), Motor unit (150F), Voltmeter (0 – 30)V

INTRODUCTION:

A system in which the controlling action or input is somehow dependent on the output or changes in output is called a closed loop system. To obtain more accurate control than an open loop system, the controlled signal should be fed back and compared with the reference input, and an actuating signal proportional to the difference of the input and the output must be sent through the system to correct the error. To control the speed of a DC motor using armature voltage control method, the field current is kept constant and armature voltage is changed to obtain the desired speed. The feedback is taken by using a tachometer. The tachometer generates a voltage proportional to speed which is compared with the reference voltage required for the desired speed. This difference is used to change the input to controller which cumulatively changes the speed of the motor as required.

PROCEDURE:

1. Fix the light alloy brake disc to the high speed shaft of motor unit 150U
2. Attach the attenuator 150B, servo amplifier 150D, power supply 150E, 150F, 150L and the pre amplifier 150C to the base plate by means of the magnetic fixings.
3. Connect the octal sockets from 150D to 150E and from 150F to 150D.
4. Interconnect the 150B, 150C, 150D, 150E and 150F as shown in the figure.
5. Set the oscilloscope Y amplifier to 1 V/div and time base to 5ms/div.
6. Plug the 150E and oscilloscope to mains supply sockets.
7. Set the potentiometer slider (150B) and brake to zero.
8. Switch on the supply. Set the input pot to 1.
9. Record the time taken for a known number of rotations of the low speed shaft of the motor using a stop watch. Note down the corresponding peak to peak Tachogenerator

output voltage. Calculate the speed of the low speed shaft and hence the speed of the motor shaft using gear ratio (1:30)

10. Plot the variation (straight line) of Tachogenerator peak to peak voltage versus speed.
11. For different values of reference voltage, measure tacho voltage and error voltage. Determine corresponding speed in rpm by referring the graph obtained from previous step.
12. Plot the variation of speed against reference voltage.
13. To obtain the torque characteristics, for different brake settings from 0 to 10, determine the tacho voltage and the corresponding speed in rpm by referring to the plot stated in step 10.
14. Plot the variation of torque (brake position) against speed in rpm.
15. Repeat the steps 13 and 14 without feedback (open loop system) and compare the results.

RESULT:

OBSERVATIONS:

Speed of the low speed shaft =

Speed of the high speed shaft =

Sl. No.	Reference voltage	Tachogenerator voltage	Error voltage	Speed in rpm

Sl. No.	Brake position	Tacho output Volts	Speed in rpm.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Experiment No. _____

Date: _____

SPEED – TORQUE CHARACTERISTICS OF DC SERVO MOTOR

OBJECTIVES:

To obtain the speed – torque characteristic of armature controlled and field controlled DC servo motor.

INSTRUMENTS REQUIRED:

Base plate, Attenuator unit (150B), Servo amplifier (150D), Power supply (150E), Motor unit (150F), Load unit (150L), Stop clock.

INTRODUCTION:

The motor in 150F is always connected so as to pass the same current through both field and armature. However, the two types of connection do give different characteristics. Connected for field control the machine has a high torque with poor speed regulation, so that if unloaded the speed will become dangerously high. In this it resembles a normal series motor. With armature control connection the negative feedback of the back emf will oppose the input signal and so tend to maintain a steady motor current; this results in a more constant speed over the torque range. As a result the torque - speed characteristic becomes more similar to that produced by a shunt wound motor. The gain for this connection is very much lower than if the motor is connected for field control. The armature controlled shunt wound motor is extensively used in control systems.

PROCEDURE:

1. Fix the light alloy brake disc to the high speed shaft of motor unit 150F
2. Attach the attenuator 150B, servo amplifier 150D, power supply 150E, 150F and 150L to the base plate by means of the magnetic fixings.
3. Connect the octal sockets from 150D to 150E and from 150F to 150D.
4. Interconnect the 150B, 150D, 150E and 150F as shown in the figure 1.
5. Set the oscilloscope Y amplifier to 1 V/div and time base to 5ms/div.
6. Plug the 150E and oscilloscope to mains supply sockets.
7. Set the potentiometer slider (150B) and brake to zero.
8. Switch on the supply. Set the input pot to 2.
9. Record the time taken for a known number of rotations of the low speed shaft of the motor using a stop watch. Note down the corresponding peak to peak Tachogenerator

output voltage. Calculate the speed of the low speed shaft and hence the speed of the motor shaft using gear ratio (1:30)

10. Plot the variation (straight line) of Tacho-generator peak to peak voltage versus speed.
11. To obtain the torque characteristics, for different brake settings from 0 to 10, determine the tacho voltage and the corresponding speed in rpm by referring to the plot stated in step 10.
12. Plot the variation of torque (brake position) against speed in rpm.
13. Repeat the steps 5 to 12 after making the connections as in Fig. 2

RESULT:

OBSERVATIONS:

Speed of the low speed shaft =

Speed of the high speed shaft =

Sl. No.	Brake position	Tacho output Volts	Speed in rpm.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

Experiment No. _____

Date: _____

FREQUENCY RESPONSE OF A SECOND ORDER SYSTEM

OBJECTIVES:

To obtain the frequency response of a second order system and hence to determine its frequency response specifications.

INSTRUMENTS REQUIRED:

Decade resistance box	1 no.
Capacitance box	1 no.
Inductance box	1 no.
Signal generator	1 no.
Transfer function analyser	1 no.
Connecting wires	

PRINCIPLE:

The basic objective of control system design is to meet the performance specifications. These specifications are the constraints or limitations put on the mathematical functions describing the system characteristics.

Band Width (BW): It is the range of frequencies over which the system will respond satisfactorily. It can also be defined as range of frequencies in which the magnitude response is almost flat in nature. Hence, it is defined as range of frequencies over the magnitude of closed loop response does not drop by more than 3 dB from its zero frequency value.

Resonant peak (M_r): It is the maximum value of magnitude of the closed loop frequency response. Larger the value of resonant peak more is the value of peak overshoot of the system for step input. It is a measure of relative stability of the system.

Resonant frequency (ω_r): The frequency at which resonant peak M_r occurs in closed loop frequency response is called resonant frequency. It is inversely proportional to the rise time.

Cutoff frequency: The frequency at which the magnitude of the closed loop response is 3 dB down from its zero frequency value is called cutoff frequency.

Cutoff rate: The slope of the resultant magnitude curve near the cutoff frequency is called cutoff rate.

Gain cross over frequency (ω_{gc}): The frequency at which magnitude of $G(j\omega).H(j\omega)$ crosses zero dB is called gain cross over frequency.

Phase cross over frequency (ω_{pc}): The frequency at which phase angle of $G(j\omega).H(j\omega)$ is -180° is called phase cross over frequency.

Gain margin (GM): Gain margin is defined as the margin in gain allowable by which gain can be increased till system reaches on the verge of instability. Mathematically it is the reciprocal of the magnitude of the $G(j\omega).H(j\omega)$ measured at phase crossover frequency.

Phase margin (PM): The amount of additional phase lag which can be introduced in the system till it reaches on the verge of instability is called phase margin. Mathematically it is the phase angle of the $G(j\omega).H(j\omega)$ measured at gain crossover frequency plus 180° .

PROCEDURE:

Connections are made as shown in figure. The input voltage is kept at 15V with phase angle zero. Now the frequency is varied in steps and the output voltage is noted in rectangular form using transfer function analyser. The gain is calculated and bode plot is drawn.

RESULT:

OBSERVATIONS:

	f Hz.	$V_0 (a + j b)$	$V_0 (V_0 \angle \theta)$	Gain in dB
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

Experiment No. _____

Date: _____

FREQUENCY RESPONSE OF A THIRD - ORDER SYSTEM

OBJECTIVES:

To obtain the frequency response of a third - order system and hence to determine its gain cross over frequency and phase cross over frequency.

PRINCIPLE:

The gain cross over frequency can be calculated using the relation; $|G(j\omega)H(j\omega)|=1$.

To determine phase cross over frequency; rationalise the open loop transfer function, separate real and imaginary parts and then equate imaginary part to zero.

PROCEDURE:

Connections are made as shown in figure. The input voltage is kept at 15V with phase angle zero. Now the frequency is varied in steps and the output voltage is noted in rectangular form using transfer function analyser. The gain is calculated and bode plot is drawn.

RESULT:

OBSERVATIONS:

	f Hz.	$V_0 (a+jb)$	$V_0 (V_0 < \theta)$	Gain
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

MATLAB

MATLAB is a software package for high-performance numerical computation and visualization. The name MATLAB stands for MATrix LABoratory. The basic building block of MATLAB is the matrix. The fundamental data type is the array. Vectors, scalars, real and complex matrices are all automatically handled as special cases of the basic data type. You almost never have to declare the dimensions of a matrix.

MATLAB Windows:

Matlab works through three basic windows; command window, graphics window and edit window.

1. Command window: This is the main window. It is characterized by the MATLAB command prompt '»'. All commands are typed in this window at the matlab prompt.
2. Graphics window: The output of all graphics commands typed in the command window are flushed to the graphics or figure window. The user can create as many as figure windows as the system memory will allow.
3. Edit window: This is where you write, edit, create, and save your own programs in files called 'M-files'. You can use any text editor to carry out these tasks. Matlab provides its own built-in editor.

Input – output:

Matlab supports interactive computation, taking the input from the screen, and flushing the output to the screen. In addition, it can read input files and write output files. The following features hold for all forms of input-output.

- Data type: The fundamental data type in matlab is the array. In most cases you never have to worry about the data type or the data object declarations.
- Dimensioning: Dimensioning is automatic in matlab. No dimension statements are required for vectors or arrays.
- Case sensitivity: Matlab is case-sensitive; that is, it differentiates between the lowercase and uppercase letters. Most matlab commands and built-in function calls are typed in lowercase letters.

- Output display: The output of every command is displayed on the screen unless matlab is directed otherwise. A semicolon at the end of a command suppresses the screen output, except for graphics and on-line help commands.
- Command history: Matlab saves previously typed commands in a buffer. These commands can be recalled with the up-arrow key.

File types:

Matlab has three types of files for storing information. They are M-files, Mat-files and Mex-files.

- **M-files** are standard ASCII text files, with a '.m' extension to the filename. There are two types of these files: script files and function files. All built-in functions in matlab are M-files.
- **Mat-files** are binary data-files, with a '.mat' extension to the filename. Mat-files are created by matlab when you save data with the *save* command. The data is written in a special format that only matlab can read.
- **Mex-files** are matlab callable Fortran and C programs, with a '.mex' extension to the filename.

General commands:

help	lists topics on which help is available
help <i>topic</i>	provides help on <i>topic</i>
who	lists variables currently in the workspace
whos	lists variables currently in the workspace with their size
what	lists m, mat and mex files on the disk
clear	clears the workspace, all variables are removed
clear x y z	clears only variables x, y and z
clear all	clears all variable and functions from workspace
clc	clears command window, command history is lost
home	same as clc
clf	clears figure window
pwd	shows the current working directory
cd	changes the current working directory
dir	lists contents of the current directory
ls	lists contents of the current directory

path	gets or sets matlab search path
mkdir	creates a directory
computer	tells you the computer type you are using
clock	gives you time and date as a vector
date	tells you the date as a string
quit	quits matlab
exit	same as quit

Matlab commands / operators:

The matlab commands/operators used are:

+, -, *, /, ^, ;,

sin, cos, tan, csc, sec, cot, sinh, cosh, tanh, asin, acos, atan etc. - arguments should be given in radians

e^x , $\ln x$ and $\log x$ are calculated with $\exp(x)$, $\log(x)$ and $\log_{10}(x)$ respectively.

π is represented as **pi** in matlab.

A complex number is input as $x + yi$ or $x + yj$

Examples:

$$Y = 2^4 + \log(x) * \sin(\pi/4)$$

$$Z = (4 + 5i) / (2 + 7i)$$

$$K = \exp(i*\pi /4)$$

Matrices and Vectors:

A matrix is entered row-wise, with consecutive elements of a row separated by a space or a comma, and the rows separated by semicolons or carriage returns. The entire matrix must be enclosed within square brackets. Elements of the matrix may be real numbers, complex numbers, or valid matlab expressions.

Examples:

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix} \text{ is input as } A = [1 \ 2 \ 3; 4 \ 5 \ 6; 7 \ 8 \ 9]$$

$$B = \begin{bmatrix} 5x & \ln x \\ 4+8i & \sin y \end{bmatrix} \text{ is input as } B = [5*x \log(x);4+8i \sin(y)]$$

$u = [1 \ 5 \ 9]$ produces a row vector and

$v = [2;4;6]$ produces a column vector

$x = []$ produces a null matrix

$p = A(2,3)$ returns the value of p as 2nd row 3rd column element of A . ie. $P = 6$

$A(2,3) = 10$ changes the value of 2nd row 3rd column element of A to 10.

$$\text{Now } A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 10 \\ 7 & 8 & 9 \end{bmatrix}$$

$\text{eye}(n)$ creates an $n \times n$ identity matrix.

$\text{eye}(m,n)$ creates an $m \times n$ matrix with 1's on the main diagonal.

$\text{zeros}(m,n)$ creates an $m \times n$ matrix of zeros

$\text{ones}(m,n)$ creates an $m \times n$ matrix of ones

$\text{rand}(m,n)$ creates an $m \times n$ matrix of random numbers

$\text{diag}(v)$ generates a diagonal matrix with vector v on the diagonal

$\text{diag}(A)$ extracts the diagonal of matrix A as a vector

$\text{diag}(A,1)$ extracts the first upper off-diagonal vector of matrix A

$\text{tril}(A)$ extracts the lower triangular part of matrix A

$\text{triu}(A)$ extracts the upper triangular part of matrix A

$\text{inv}(A)$ evaluate inverse of A

$\text{det}(A)$ evaluate determinant value of A

$\text{eig}(A)$ evaluate eigen values of A

A' evaluate transpose of A

$p = \text{Poly}(A)$ produces a row vector p , the elements of which are the coefficients of the characteristic polynomial of A

$\text{roots}(p)$ evaluate the roots of the polynomial 'p'

$\text{polyval}(p,k)$ evaluate the value of polynomial p with $s = k$

$\text{conv}(a,b)$ produces the convolution of two polynomials a and b

Indexing and Reshaping:

Once a matrix exists, its elements are accessed by specifying their row and column indices. Matlab allows a range of rows and column to be specified at the same time. For example, the statement $Q(m:n,k:l)$ specifies rows m to n and column k to l of matrix Q . When the rows (of column) to be specified range over all rows (or column) of a matrix, a colon can be used as the row (or column) index. Thus $Q(:,3:10)$ refers to the elements in column 3 through 10 of all the rows of matrix Q .

$$\text{If } v = [1 \ 3], \text{ then } A(v,:) = \begin{bmatrix} 1 & 2 & 3 \\ 7 & 8 & 9 \end{bmatrix} \text{ and } A(:,v) = \begin{bmatrix} 1 & 3 \\ 4 & 6 \\ 7 & 9 \end{bmatrix}$$

All the elements of a matrix A can be strung into a single column vector b by the command $b = A(:)$. If matrix A is an $m \times n$ matrix, it can be reshaped into a $p \times q$ matrix, as long as $m \times n = p \times q$, with the command $reshape(A,p,q)$

Appending a row or column:

A row can be easily appended to an existing matrix provided the row has the same length as the length of the rows of the existing matrix. The same thing goes for columns. The command $B = [A \ u]$ appends the column vector u to the columns of A , while $C = [A;v]$ appends the row vector v to the rows of A . A row or column vector of any size may be appended to a null matrix.

Deleting a row or column:

Any row(s) or column(s) of a matrix can be deleted by setting the row or column to a null vector.

Examples:

$Q(2,:) = []$ deletes the 2nd row of matrix Q
 $Q(:,3:5) = []$ deletes 3rd through 5th column of Q
 $Q([1 \ 3],:) = []$ deletes 1st and 3rd row of Q

Creating Vectors:

The general commands to create vectors are

1. $u = \text{initial value} : \text{increment} : \text{final value}$
2. $v = \text{linspace}(a,b,n)$ generates a linearly spaced vector of length n from a to b

3. $w = \text{logspace}(a,b,n)$ generates a logarithmically spaced vector of length n from 10^a to 10^b

Examples:

$u = 0:2:10$ produces $u = [0\ 2\ 4\ 6\ 8\ 10]$

$v = \text{linspace}(0,20,5)$ produces $v = [0\ 5\ 10\ 15\ 20]$

$w = \text{logspace}(0,3,4)$ produces $w = [1\ 10\ 100\ 1000]$

Matrix and Array operation:

- + addition
- subtraction
- * multiplication
- / division
- ^ exponentiation
- \ right division { $A \setminus B$ is almost same as $\text{inv}(A)*B$ }
- .* element by element multiplication
- ./ element by element division
- .\ element by element right division
- .^ element by element exponentiation
- .' nonconjugated transpose

Relational operations:

- < less than
- <= less than or equal
- > greater than
- >= greater than or equal
- == equal
- ~= not equal

Matrix functions:

$\text{expm}(A)$ finds the exponential of matrix A , e^A

$\text{logm}(A)$ finds $\log(A)$ such that $A = e^{\log(A)}$

$\text{sqrtm}(A)$ finds \sqrt{A} .

The array counterparts of these functions are exp , log , and sqrt .

Round off functions:

fix round towards 0
 floor round towards $-\infty$
 ceil round towards ∞
 round round towards nearest integer
 rem remainder after division

Programming in MATLAB:

Function Files:

A function file is also a m-file except that the variables in a function file are all local. Function files are like functions in C. The syntax of the function definition line is as follows:

```
function[output_variables] = function_name(input_variables);
```

There are two ways a function can be executed, whether it is built-in or user-written.

```
[output_variables] = function_name(input_variables);
```

```
function_name(input_variables);
```

feval evaluates a function whose name is specified as a string at the given list of input variables. Eg. `feval('function_name',x,y,z)`; where x,y,z are input variables.

Loops, branches, and control flow:

For loops:

```
for i = 1:5
    for j = 1:5
        A(i,j) = 1/(i + j -1);
    end
end
```

While loops:

```
while n < 100
    statements
end
```

If, elseif and else statements:

```
if i > 5
    k = 1;
elseif (i>1) & (j == 20)
    k = 5*i+j;
```

```
else
    k =1;
end
```

Graphics:

The most basic and perhaps the most useful command for producing a simple 2-D plot is

```
plot(xvalues,yvalues,'style-option')
```

<code>plot(x,y,'r')</code>	plots y vs. x with a red solid line
<code>plot(x,y,'b:')</code>	plots y vs. x with a blue dotted line
<code>xlabel('time')</code>	labels the x-axis with time
<code>ylabel('voltage')</code>	labels the y-axis with voltage
<code>title('Voltage wave')</code>	titles the plot with Voltage wave
<code>grid</code>	provides grid lines on the graph
<code>hold</code>	holds the current plot and all axis properties so that subsequent graphing commands add to the existing graph.

`axis([xmin xmax ymin ymax])` change the axes limits to the specified new values xmin and xmax for the x – axis and ymin and ymax for the y – axis.

<code>axis('equal')</code>	sets equal scale on both axes
<code>axis('square')</code>	sets the default rectangular frame to a square
<code>axis('normal')</code>	sets the axis to default values
<code>axis('off')</code>	removes the surrounding frame and the tick marks

If you want to make a few plots and place the plots side-by-side, use the ***subplot*** command to design your layout. **`subplot(m,n,p)`**

Subplot divides the graphics window into $m \times n$ sub-windows and puts the plot generated by the next plotting command into the p^{th} sub-window where the sub-windows are counted row wise.

The general syntax for the 3-D plot is **`plot3(x,y,z,'style-option')`**

The viewing angle of the observer is specified by the command **`view(azimuth,elevation)`**

Control System Toll Box:

Any control system can be represented by its dynamic equations. These in turn can be arranged in a variety of ways. They are:

1. Transfer function model: Pole-zero model, Rational polynomial
2. State space model

Consider a system transfer function as $G(s) = \frac{10(s+1)}{s(s+4)(s+5)} = \frac{10s+10}{s^3+9s^2+20s}$

To represent this transfer function in MATLAB the following methods can be used.

1. Polynomial method

```
num = [10 10];
den = [1 9 20 0];
G = tf(num,den)
```

2. Pole-zero method

```
k = [10];
z = [-1];
p = [0,-4,-5];
G = zpk(z,p,k)
```

3. `s = tf('s');`

```
G = 10*(s+1) / (s * (s + 4) * (s + 5))
or G = (10*s + 10) / (s^3 + 9*s^2 + 20*s)
```

4. State Space model

```
A = [-9 -20 0; 1 0 0; 0 1 0], B = [1 0 0]', C = [0 10 10] and D = [0]
```

`[r,p,k] = residue(num,den)` finds the residues, poles and direct term of a partial fraction expansion of the ratio of two polynomials $B(s)/A(s)$.

<code>[A,B,C,D] = tf2ss(num,den)</code>	Transfer function to state space conversion
<code>[A,B,C,D] = zp2ss(z,p,k)</code>	Zero-pole to state space conversion
<code>[z,p,k] = tf2zp(num,den)</code>	Transfer function to zero-pole conversion
<code>[z,p,k] = ss2zp(A,B,C,D)</code>	State space to zero-pole conversion
<code>[num,den] = ss2tf(A,B,C,D)</code>	State space to transfer function conversion
<code>[num,den] = zp2tf(z,p,k)</code>	zero-pole to transfer function conversion

To find the step response of a system: `step(num,den)`, `step(A,B,C,D)`, or `step(G)`

To find root locus of a system: `rlocus(num,den)`, `rlocus(A,B,C,D)` or `rlocus(G)`

To find bode plot of a system: `bode(num,den)`, `bode(A,B,C,D)` or `bode(G)`

To find Nyquist plot of system: `nyquist(num,den)`, `nyquist(A,B,C,D)` or `nyquist(G)`

To find impulse response of a system: `impulse(num,den)`, `impulse(A,B,C,D)` or `impulse(G)`

Experiment No. _____

Date: _____

1. Write a MATLAB program to sketch the step response of a second order system having transfer function $G(s) = 36 / (s^2 + 2.4s + 36)$ and hence obtain the performance indices of the system. Verify theoretically.
2. Write a MATLAB program to sketch the step responses of a general second order system having natural frequency 25rad/sec., for different values of damping ratio varying from 0.2 to 1.2 in steps of 0.2. Comment on the results.

Programme 1

```
num = [36];  
den = [1 2.4 36];  
step(num,den);  
title('Step response for G(s) = 36 / (s^2 + 2.4s + 36)');
```

Programme 2

```
num = 25;  
hold;  
for i = 0.2:0.2:1.2  
    z = 2*i*5;  
    den = [1 z 25];  
    step(num,den);  
end  
title('Step responses for different damping coefficients')  
hold;
```

OBSERVATIONS & COMMENTS:

Experiment No. _____

Date: _____

Write a MATLAB program to determine the open loop poles and zeros and the closed loop poles of the given system having transfer function $G(s) = (s^2 + 2s + 4) / (s^3 + 10s^2 + 24s)(s^2 + 1.4s + 1)$. Also obtain the root locus plot and comment on the stability of the system.

Programme

```
%MATLAB program to determine poles and zeros and also to
sketch root locus
num = [1 2 4];
a = [1 10 24 0]; b = [1 1.4 1];
den = conv(a,b);
s = tf('s');
sys = (s^2+2*s+4)/((s^3+10*s^2+24*s)*(s^2+1.4*s+1));
z = zero(sys)
p = pole(sys)
z1 = roots(num)
p1 = roots(den)
rlocus(sys);
title('Root Locus plot: G(s) = (S^2+2s+4) / ((s^3+10s^2+24s)
(s^2+1.4s+1))');
rltool(sys);
clpp = den + [0 0 0 1 2 4]
p3=roots(clpp)
```

OBSERVATIONS & COMMENTS:

Experiment No. _____

Date: _____

Write a MATLAB program to sketch the root locus plots of the following systems and comment on the system stability.

$$G_1(s) = (s+1) / s(s-1)(s^2 + 4s + 16)$$

$$G_2(s) = 1 / (s^2 + 6s + 25)$$

$$G_3(s) = (s + 0.4) / s^2 (s + 3.6)$$

$$G_4(s) = (s + 2) / (s^2 + 2s + 2)$$

Programme

```
%Program to obtain the root locus for different systems to
compare %the nature of their stabilities
```

```
s=tf('s');
g1=(s+1)/(s*(s-1)*(s^2+4*s+16));
g2=1/(s*(s^2+6*s+25));
g3=(s+0.4)/(s^2*(s+3.6));
g4=(s+2)/(s^2+2*s+2);
subplot(2,2,1); rlocus(g1);xlabel(''); title('G(s) =
(s+1)/(s(s-1)(s^2+4s+16))');
%rltool(g1);
subplot(2,2,2); rlocus(g2); xlabel('');title('G(s) =
1/(s(s^2+6s+25))')
%rltool(g2);
subplot(2,2,3); rlocus(g3); title('G(s) =
(s+0.4)/(s^2(s+3.6))')
%rltool(g3);
subplot(2,2,4); rlocus(g4); title('G(s) = (s+2)/(s^2+2s+2)')
%rltool(g4);
```

OBSERVATIONS & COMMENTS:

Experiment No. _____

Date: _____

Write a MATLAB program to study the effect on the step response of a given system under the following conditions.

- System with P – Controller for different values of proportional gain
- System with PI – Controller for different values of integral gain
- System with PD – Controller for different values of derivative gain

Programme

```
%Step response of P, PI, PD, controllers
s = tf('s');
sys = 36/(s^2+2.4*s+36);
i = 0;
for p = 1:5:16
    opsys = p*sys;
    clsys = opsys/(1+(opsys));
    i=i+1;
    subplot(2,2,i);
    step(clsys);
    title(['Step Response for Kp = ',num2str(p)]);
end
i = 0;
kp = 5;
for ki = 0.5:0.5:2
    cont = kp + ki/s;
    opsys = cont*sys;
    clsys = opsys/(1+(opsys));
    i = i+1;
    figure(2);
    subplot(2,2,i);
    step(clsys);
    title(['Step Response for Ki = ',num2str(ki)]);
end
i = 0;
kp = 5;
for kd = 0:0.2:0.6
    cont = kp + kd*s;
    opsys = cont*sys;
    clsys = opsys/(1+(opsys));
    i = i+1;
    figure(3);
    subplot(2,2,i);
    step(clsys);
    title(['Step Response for Kd = ',num2str(kd)]);
end
```


Experiment No. _____

Date: _____

Write a MATLAB program to sketch the Bode plot and polar plot for the system having transfer function $G_1 = 10 / s(s+1)(s+5)$; $G_2 = 100 / s(s+1)(s+5)$. Determine the phase margin and gain margin from the plot and comment on the stability of the system.

Programme

```
% MATLAB program to obtain Bode plot and Polar plot for
different open loop gains
s = tf('s');
sys = 1/(s*(s+1)*(s+5));
k1 = 10; k2 = 100;
sys1 = k1*sys; sys2 = k2*sys;
figure(1); subplot(1,2,1); bode(sys1); subplot(1,2,2);
bode(sys2);
figure(2); subplot(1,2,1); nyquist(sys1); subplot(1,2,2);
nyquist(sys2);
ltiview('bode',sys1); ltiview('bode',sys2);
ltiview('nyquist',sys1); ltiview('nyquist',sys2);
```

OBSERVATIONS & COMMENTS:

Experiment No. _____

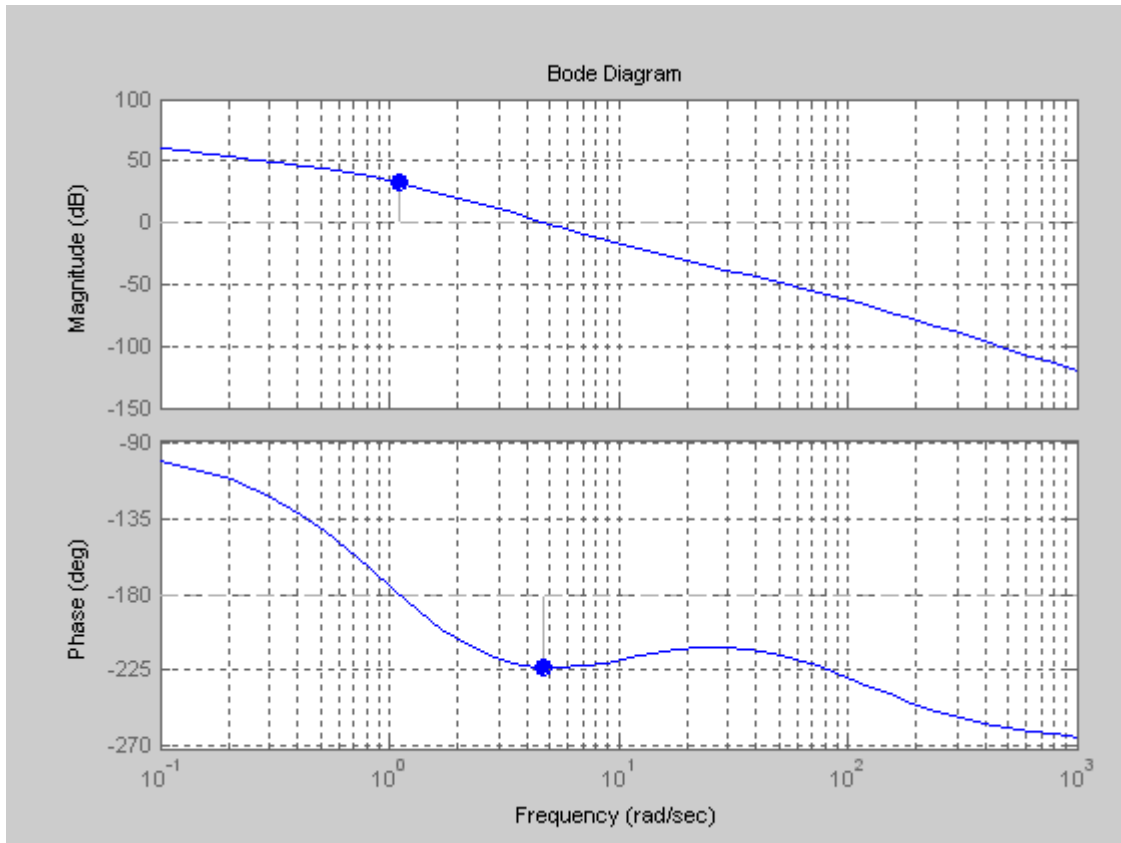
Date: _____

BODE PLOTS

OBJECTIVES:

- a) To obtain the phase margin and gain margin for a given transfer function by drawing bode plots and verify the same using MATLAB.
- b) For the same system find the value of gain K for a specified phase margin/gain margin and verify the same using MATLAB.

$$G(s)H(s) = \frac{100(0.1S + 1)}{S(S + 1)^2(0.01S + 1)}$$



Experiment No. _____

Date: _____

ROOT LOCI

OBJECTIVES:

Draw the root loci for a given transfer function to show its breakaway points and intersection with imaginary axis. Obtain the range of K for stability of the system. Verify using MATLAB.

$$G(s)H(s) = \frac{K}{S(S+3)(S^2+2S+2)}$$

