LENDI INSTITUTE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

CONTROL SYSTEM LABORATORY

LENDI INSTITUTE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

Class: B. Tech III/ IV **Semester: I** **Branch: EEE**

Laboratory: Control System Laboratory

List of Experiments

1. Time Response Analysis of Second Order System
2. Transfer function of a DC Motor
3. Speed- Torque characteristics of AC Servomotor
4. Characteristics of Synchros
5. Effect of P, PD, PI, PID Controller on a second order system
6. Characteristics of Magnetic Amplifier
7. Lag & Lead compensation-Magnitude and phase plot
8. Speed- Torque characteristics of DC Servomotor
9. Root locus plot, Bode plot from MATLAB
10. State space model for classical transfer function using MATLAB-verification

SPEED – TORQUE CHARACTERISTICS OF A.C. SERVO MOTOR

SPEED – TORQUE CHARACTERISTICS OF A.C. SERVO MOTOR

AIM: To Plot Speed – Torque Characteristics of A.C. Servo Motor.

APPARATUS REQUIRED:

THEORY:

An A.C. servomotor is basically a two-phase induction motor except for certain special design features. A two-phase induction motor consisting of two stator windings oriented 90 degrees electrically apart in space and excited by A.C. voltages which differ in time phase by 90°. Generally voltages of equal magnitude and 90° phase difference are applied to the two-stator phases thus making their respective fields 90° apart in both time and space, at synchronous speed. As the field sweeps over the rotor, voltages are induced in it producing current in the short-circuited rotor. The rotating magnetic field interacts with these currents producing a torque on the rotor in the direction of field rotation.

The shape of the characteristics depends upon ratio of the rotor reactance (X) to the rotor resistance(R). In normal induction motor X/R ratio is generally kept high so as to obtain the maximum torque close to the operating region, which is usually around 5% slip.

A two-phase servomotor differs in two ways from normal induction motor.

1. The rotor of the servomotor is built with high resistances so that its X/R ratio is small and the torque speed characteristics are as shown in the figure (2).Curve (3) is nearly linear in contrast to highly non-linear characteristics with large X/R ratio is used for servo applications, then because of the positive slope for part of the characteristics, the system using such a motor becomes unstable.

   The motor construction is usually squirrel cage or drag cup type. The diameter of the rotor is kept small in order to reduce inertia and thus to obtain good accelerating characteristics. Drag cup construction is used for very low inertia operations.

2. In servo applications, the voltages applied to the two-stator windings are seldom balanced. One of the phases known as the reference phase is excited by constant voltage and the other phase known as the control phase with respect to the voltage supplied to the reference windings and it has a variable magnitude and polarity. (fig-2) The control

winding voltage is supplied from a servo amplifier. For low power applications, A.C. servomotors are preferred because they are light weight, rugged and there are no brush constant to maintain.

The reference winding of the motor is excited from a fixed voltage of 100 volts. The control winding voltage is obtained through an R-C combination. The voltage available to control winding is varied by the control of resistance R. The capacitance is used to generate a phase shift. By varying the magnitude of the control voltage, it is possible to vary the speed of the A.C. servomotor. The secondary of the transformer T1 provided the reference winding and control winding voltage.

Torque Measurement:

$$T = \frac{P*1.019*10^4*60}{2pi*N} \text{ gm-cm}$$

Where E_b = Back E.M.F

I_a = Armature current

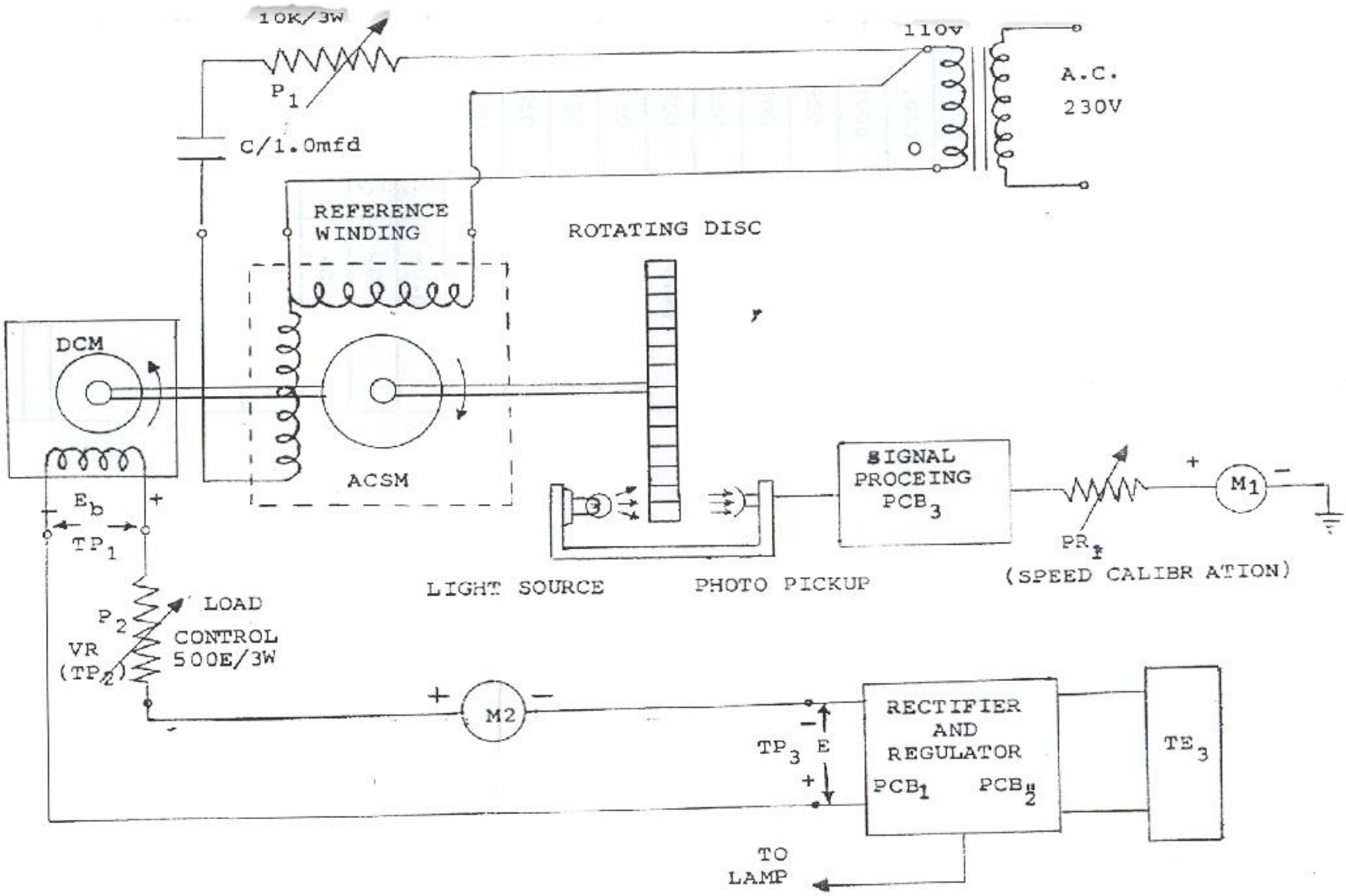
P = power in watts = $E_b * I_a$

N = R.P.M

Mechanical power developed at the motor shaft.

$$P = \frac{2Pi*NT}{60}$$

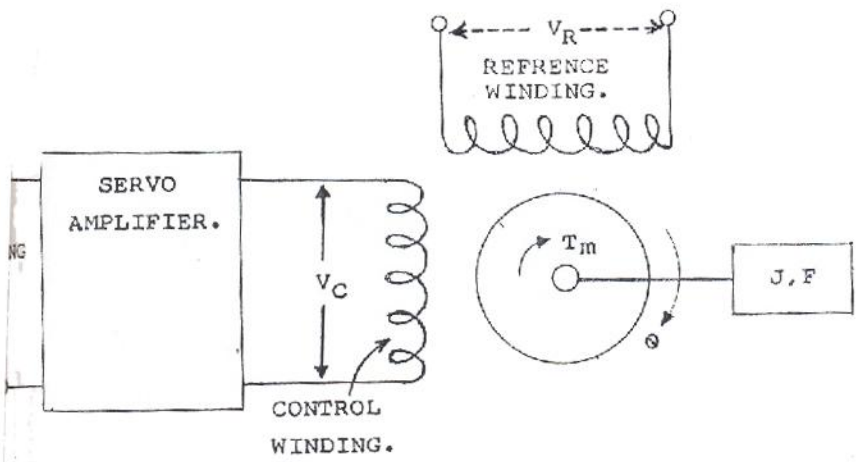
Circuit Diagram:



BLOCK DIAGRAM FOR A.C. SERVOMOTOR

SPEED TORQUE CHARACTERISTICS.

FIGURE NO.(5)



FIGURE

SCHEMATIC DIAGRAM OF TWO PHASE INDUCTION MOTOR.

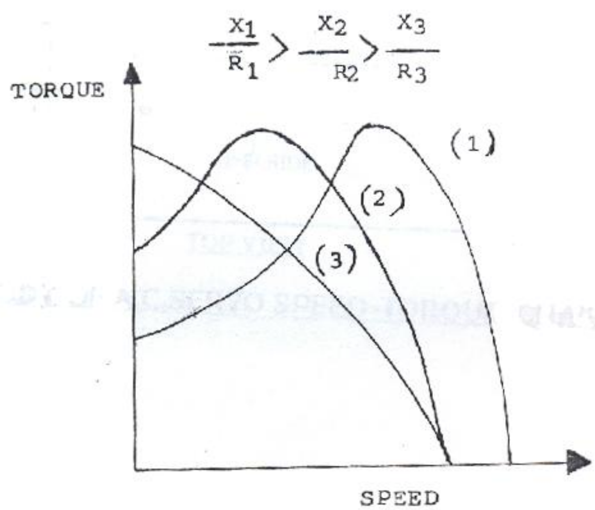


FIGURE .

TORQUE - SPEED CHARACTERISTICS OF INDUCTIOM MOTOR.

CHARACTERISTICS(3) ≡ A.C. SERVOMOTOR.

PROCEDURE:

1. Study all the controls carefully on the front panel.
2. Keep the switch SW3 in upward position, switch SW2 should also be in OFF position.
3. Ensure P1 and P2 are in fully anticlockwise position.
4. Now, switch on SW1 and also switch on SW2. You can observe that A.C. servo motor will start rotating and the speed will be indicated by the meter M1 on the front panel.
5. With SW3 in OFF condition, vary the speed of the A.C. servomotor by moving P1 in clockwise direction and note the E.M.F. generated by the D.C. machine (Now working as D.C. generator or tacho). Enter the results in Table no. 1 (use a D.C. voltmeter in the range 0 to 2 volts or so).
6. Now switch SW3 in OFF condition, switch ON SW2 and keep the pot P1 in minimum position. You can observe that the A.C. servomotor starts moving with speed being indicted by the RPM indicator and control winding voltage (which is variable by P1). Note the speed of A.C. servo motor. Now switch on SW3 and start loading A.C. servo motor by controlling pot P2 in a slow fashion. Note down corresponding values on I_a and N. Enter these values in Table 2.
7. Now you may set control-winding voltage to a new value of 30 volts after switching off SW3. Again repeat the process as indicated in step No. 5 i.e. Table 2 for a new value of control winding voltage.
8. Plot, the speed torque characteristics for various values of control winding voltages. Study their nature.

OBSERVATIONS:

Table No.1

S.NO.	R.P.M.	E_b = volts
1		
2		
3		

Table No.2

Control Voltage V_c =

S.NO	I_a(mA)	N RPM	E Volts	P Watts	T= Toque (gm-cm) $\frac{P*1.019*10^4*60}{2pi*N}$
1					
2					
3					

RESULT:

Viva Questions:

1. How a AC servomotor different from a polyphase Induction motor?
2. Write about the construction features of AC servomotor rotor?
3. Why AC servo motor T ~N Characteristics are made Linear?
4. Give Any two applications of AC Servomotor?
5. What type of leading is provided in the AC servomotor?

BODE PLOT & ROOT LOCUS FOR CLASSICAL TRANSFER FUNCTION

BODE PLOT AND ROOTLOCUS FOR CLASSICAL TRANSFER FUNCTION

AIM: To Plot Root locus and Bode plot for a given transfer function using MATLAB.

Apparatus Required:

1. PC compatible with MATLAB software.
2. Control System Toolbox.

Theory:

MATLAB has a rich collection of functions immediately useful to the control engineer or system theorist. Complex arithmetic, eigen values, root-finding, matrix inversion, and FFTs are just a few examples of MATLAB's important numerical tools. More generally, MATLAB's linear algebra, matrix computation and numerical analysis capabilities provide a reliable foundation for control system engineering as well as many other disciplines.

The Control System Toolbox builds on the foundations of MATLAB to provide functions designed for control engineering. The Control system Toolbox is a collection of algorithms, written mostly as M-files, that implements common control system design, analysis and modeling techniques. Convenient graphical user interfaces (GUI's) simplify typical control tasks.

Control systems can be modeled as transfer functions, in zero-pole-gain, or state-space form, allowing you to use both classical and modern control techniques. We can manipulate both continuous-time and discrete-time systems. Systems can be single-input / single-output (SISO) or multiple-input / multiple-output (MIMO). In addition, we can store several LTI models in an array under a single variable name. Conversions between various model representations are provided. Time responses, frequency responses, and root loci can be computed and graphed. Other functions allow pole placement, optimal control, and estimation. Finally, the Control System Toolbox is open and extensible. We can create custom M-files to suit your particular application.

Typically, control engineers begin by developing a mathematical description of the dynamical system that they want to control. This to-be-controlled system is called a plant. The Control System Toolbox contain LTI viewer, a graphical user interface (GUI) that simplifies the analysis of linear, time-invariant systems. The time responses and pole/zero plots are available only for transfer function, state-space, and zero/pole/gain models.

The Control System Toolbox provides a set of functions that provide the basic time and frequency domain analysis plots used in control system engineering. These functions apply to any kind of linear model (continuous or discrete, SISO or MIMO or arrays of models). Time responses investigate the time-domain transient behavior of linear models for particular classes of inputs and disturbances. We can steady-state error from the time response. The Control System Toolbox provides functions for step response, impulse response, initial condition response, and general linear simulations.

In addition to time-domain analysis, the Control System Toolbox provides functions for frequency-domain analysis using the following standard plots: Bode plots, Nichols plots, Nyquist plots and Singular value plots.

Theoretical Calculations:

Let us choose the open loop transfer function as

$$G(S)\,H(S) = \frac{7S}{S^3 + 15S^2 + 50S}$$

A) Root locus:

1. Root locus is symmetrical about real axis.
2. The root locus plot starts at an open loop pole and ends at an open loop zero.
3. The poles are

S = 0 ; S = - 5 ; S = -10

No. of poles = 3

No. of zero's = 0

No. of root locus branches, N = 3

P if P > Z

Z if Z > P

4. No. of asymptotic lines, n = p – z = 3
5. Angle of asymptotes

$$\theta = \frac{(2q+1)}{p-z} \times 180 \quad , q = 0, 1, 2$$

= 60, 180, 300

6. Centroid

$$S = \frac{\varepsilon\ poles - \varepsilon\ zero's}{p-z}$$

= - 5

7. Break away point $\longrightarrow$

The characteristic equation is given by

$$1 + G(S)\,H(S) = 0$$

$$1 + \frac{k}{S(S+5)(S+10)} = 0$$

$$S^3 + 12S^2 + 50S + k = 0$$

$$K = -(S^3 + 15S^2 + 50S)$$

$$\frac{dk}{ds} = -(3S^2 + 30S + 50) = 0$$

S = -2.113 S = -7.866

K = 182.05 K = 187.55

8. Intersection points of the roots locus branches with imaginary axis

Characteristic Equation is $S^3 + 15S^2 + 50\,S + K = 0$.

S^3	1	50
S^2	15	K
S	$\frac{750-K}{15}$	0
S^0	K	0

For stable systems,

$$\frac{750-K}{15} > 0$$

$$750 - K > 0$$

$$K < 750$$

For marginal stability K = 750

The auxiliary equation is

$$15S^2 + K = 0$$

$$S = \text{Ij } 7.0710$$

B. Bode plot:

1. The open loop transfer function is

$$G(S)\,H(S) = \frac{75}{S(S+5)(S+10)}$$

$$G(S) = \frac{75}{S\;5\left(\frac{S}{5}+1\right)\;10\left(\frac{S}{10}+1\right)}$$

$$= \frac{1.5}{S(0.2\;S+1).(0.1\;S+1)}$$

To set the sinusoidal transfer function put S = jw

$$= \frac{1.5}{jw(1+0.2\,jw)(1+0.1\,jw)}$$

θ = $-90 - \tan^{-1}(0.2\text{ w}) - \tan^{-1}(0.1\text{ W})$

2. Phase Plot:

W	θ

3. Magnitude Plot:

type of the system is 1

initial slope = - 20 db / du

Intersection point on the db axis or given value,

= 20 + 20 log K

= 20 + 20 log 1.5

= 23.52

Corner frequency = 5, 10.

Factor	Corner Frequency	Slope db/sec	Change in slope	Asymptotic log magnitude characteristic

PROCEDURE:

1. Open MATLAB command window by clicking on the MATLAB.exe icon.
2. Enter the given transfer function in the command window by using the syntax – SYS=TF (NUM, DEN) where 'num' is the matrix containing the elements of numerator and 'den' is the matrix containing the elements of denominator.
3. Enter the command: RLOCUS (NUM, DEN) to generate root locus of the given transfer function.
4. Enter the command: BODE (NUM, DEN) to generate bode plot of the given transfer function.
5. Copy the obtained plot.
6. Type: EXIT at the command window to close MATLAB.

Example: Obtain the Root Locus of the given transfer function:

G(S).H(S) = K/S^3+3S^2+5S+8)

Solution:

```
NUM = [K]
DEN = [1 2 5 8]
SYS = TF(NUM, DEN)
RLOCUS (SYS)
BODE (SYS)
```

Plots Obtained:

RESULT:

CHARACTERISTICS OF SYNCHROS

CHARACTERISTICS OF SYNCHROS

AIM : To study the characteristics of synchros.

APPARATUS:

1. Synchro transmitter
2. Synchro receiver
3. Multi meter
4. Connecting wires.

THEORY:

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

The basic synchro is usually called a synchro transmitter. Its construction is similar to that of a three phase alternator. The stator (stationary member) is of laminated silicon steel and is slotted to accommodate a balanced three phase winding (which is usually of concentric coil type three identical coils are placed in the stator with their axis 120 degree apart) and is Y connected. The rotor is a dumb bell construction and wound with a concentric coil. An AC voltage is applied to the rotor winding through slip rings. Ref. Fig. No.1A.

Let an a.c. voltage Vr(t) = Vr sin wt . . . (1)
Is 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 sinusoid ally, 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 sinusoid ally 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.

shown in fig. No. 1 where the rotor axis makes an angle 0 with the axis of the stator coil Let Vs1 N, Vs2 N and Vs3 N respectively be the voltages induced in the stator coils S1, S2 and S3 with respect to the neutral. Then for the rotor position of the sychro transmitter S2.

Let Vs_{1N} = KVr sin wt cos (θ + 120) . . . . . (2)

Vs_{2N} = KVr sin wt cos (θ) . . . . . .(3)

Vs_{3N} = KVr sin wt cos (θ + 240) . . . . . .(4)

The three terminal voltages of the stator are

Vs_1s_2 = $Vs_{1N} - Vs_{2N}$

= 3 KVr sin (θ + 240) sin wt . . . .(5)

Vs_{2S3} = $Vs_{2N} - Vs_{3N}$

= 3 KVr sin (θ + 120) sin wt . . . . (6)

Vs_{3S1} = $Vs_{3N} - Vs_{1N}$

= 3 KVr sin (θ) sin wt . . . . (7)

When 0 is zero from equation (2) and (3) it is seen that maximum voltage is induced in the stator coil s2 while it follows from eq.(7) that the terminal voltage Vs3s1 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 eq. (5), (6) and (7). The magnitudes of these voltages are function of a shaft position.

The classical synchro systems consists of two units.

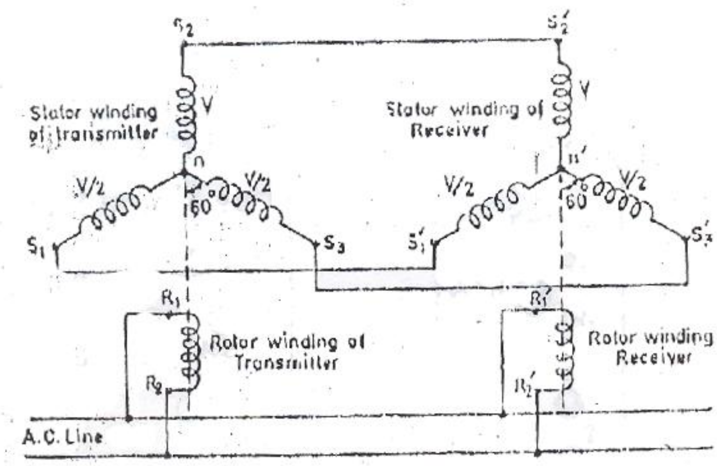
1. Synchro transmitter (Tx)
2. Synchro receiver (Tr)

The synchro receiver is having almost the same constructional features. The two units are connected as shown in figure no.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 S1 and S_2 of the stator and primary (Rotor) winding is a cosine function. Therefore the effective voltages in these winding are proportional to cos 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.

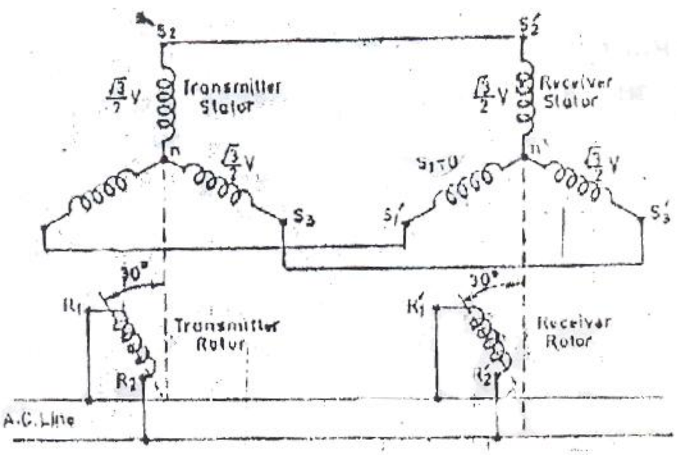
When the rotor of Tx is moved to a new position, the voltage balance is disturbed. Assume that the rotor of Tx is moved through 30 degrees, the stator winding voltages will be changed to zero, 0.866V and 0.866V respectively. Thus there is a voltage imbalance between the windings causes currents to flow 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 Tx.

The Tx Tr pair thus serves to transmit information regarding angular position at one point to a remote point.

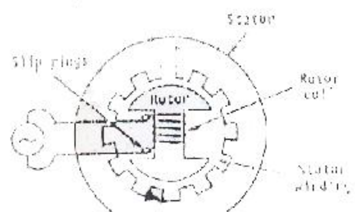
Circuit Diagram:



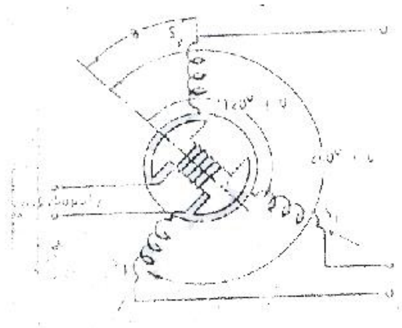
(a) Torque transmission using synchro transmitter.



FELLOW UP SYSTEM OF SYNCHRO TRANSMITTER AND RECEIVER



Constructional features of synchro transmitter.



Schematic diagram of synchro transmitter

CONSTRUCTIONAL DETAILS OF SYNCHRO TRANSMITTER

PROCEDURE:

Part-A: .

1. Apply 50 V 1 - ϕ AC to the rotor of the synchro transmitter.
2. Measure voltages between $S_1 - S_2$ for various shaft positions from 0° - 360°. (These voltages which have positive sign has to be decided from the knowledge of voltage waveform). Similarly measure voltages between $S_2 - S_3$ and $S_3 - S_1$ for various shaft positions and tabulate readings.
3. Plot the graph of rotor position in degree Vs voltage across stator terminal voltages.

Part – B:

1. Connect the system to main supply.
2. With the help of patch cards establish connections between corresponding terminals of Tx and Tr stators i.e., connect S_1 to S_1, S_2 to S_2 and S_3 to S_3 of Tx and Tr respectively.
3. Switch on SW_1 and SW_2.

4. Move the pointer of the Tx and observe the new rotor position of Tr. Enter input angular position and output angular position and plot the graph.

This is the study the phenomenon of transmission distance by electrical means.

OBSERVATIONS:

Rotor Shaft position in degrees	**$V_{s1} - s_2$ (Volts)**	**$V_{s2} - s_3$ (Volts)**	**$V_{s3} - s_1$ (Volts)**

PRECAUTIONS:

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

RESULT:

Viva Questions:

1) What you mean by synchro & write any two uses of it?
2) Construction wise a synchro transmitter resembles with which electrical equipment?
3) Can you obtained 3 – phase supply from 1- phase AC supply by using a synchro?
4) What you mean by "electrical Zero" of a synchro transmitter & what is its significance?
5) When we shift the rotor position of synchro transmitter, receiver rotor rotates automatically how?

LAG AND LEAD COMPENSATION – MAGNITUDE AND PHASE PLOT

LAG AND LEAD COMPENSATION – MAGNITUDE AND PHASE PLOT

AIM: To plot the response of Land and Lead compensators – magnitude and phase plot.

COMPONENTS REQUIRED:

1. Resistor - 10 kΩ
2. Capacitor – 0.1 μF
3. Lag – Lead Compensation Kit
4. Cathode Ray Oscilloscope
5. Probes and Patch Cords

THEORY:

All the control systems are designed to achieve specific objectives. A good control system has less error, good accuracy, good speed of response, good relative stability, good damping which will not cause under overshoots etc. For satisfactory performance of the system, gain is adjusted first. In practice, adjustment of gain alone cannot provide satisfactory results. This is because when gain is increased, steady state behavior of the system improves but results into poor transient response, in some cases may even instability. In such cases it is necessary to redesign the entire system. Practically the design specifications are provided in terms of precise numerical values according to which the system is designed.

The set of such specifications include peak overshoot, peak time, W_n , k_p , k_v , k_a , G.M and P.M. etc. In practice, if a system is to be redesigned so as to meet the required specifications, it is necessary to alter the system by adding an external device to it. Such a redesign or alteration of system using an additional suitable device is called compensation of a control system. While an external device, which is used to alter the behavior of the system so, as to achieve given specification is called compensator.

Compensating Networks:

The compensator is a physical device. It may be an electrical network, mechanical unit, pneumatic, hydraulic or combination of various types of devices.

The commonly used electrical compensating networks are

1. Lead network or Lead Compensator

2. Lag network or Lag Compensator

1. Lead Network: When a sinusoidal i/p is applied to a network and it produces a sinusoidal steady output having a phase lead w.r.to input then the network is called Lead network.

The transfer Function of Lead Compensator is

$$\frac{E_0(s)}{E_1(s)} = \frac{S+\frac{1}{T}}{S+\frac{1}{\alpha T}} \qquad T = R_1 C \alpha = \frac{R^2}{R_1+R_2} < 1$$

2. Lag Network: If the steady state output has phase lag then the network is called lag network.

The transfer function of lag compensator is

$$\frac{E_0(s)}{E_1(s)} = \frac{1}{\beta}.\frac{S+\frac{1}{T}}{S+\frac{1}{\beta T}} \qquad T = R_2 C \; ; \; \beta = \frac{R_1+R_2}{R_2} > 1$$

$$T(s) = \frac{1+ST}{1+S\beta T}$$

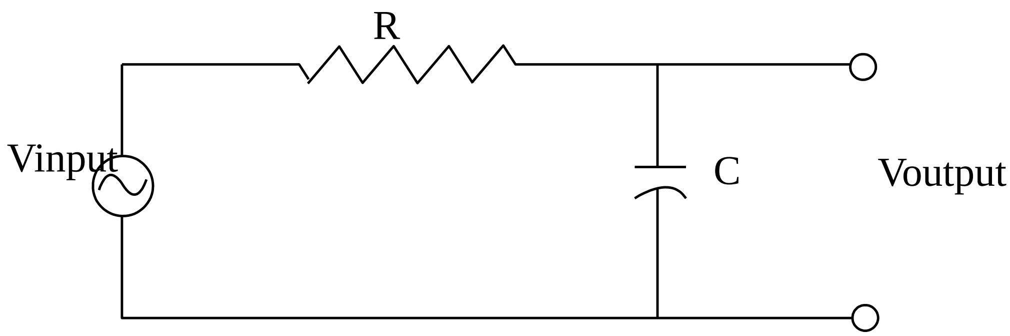
<u>Effects of lead compensation</u>

1. The lead compensator adds a dominant zero and a pole. This increases the damping of the closed loop system.
2. The increased damping means less overshoot, less rise time, less settling time.
3. It improves the phase margin of the closed loop system.
4. It increases bandwidth of the closed loop system. More the Band Width, faster is the response.
5. The steady state error doesn't get affected.
6. The slope of magnitude plot in Bode diagram of the forward path T.F. is reduced at the gain cross over frequency.
7. This improves gain & phase margins improve the relative stability.

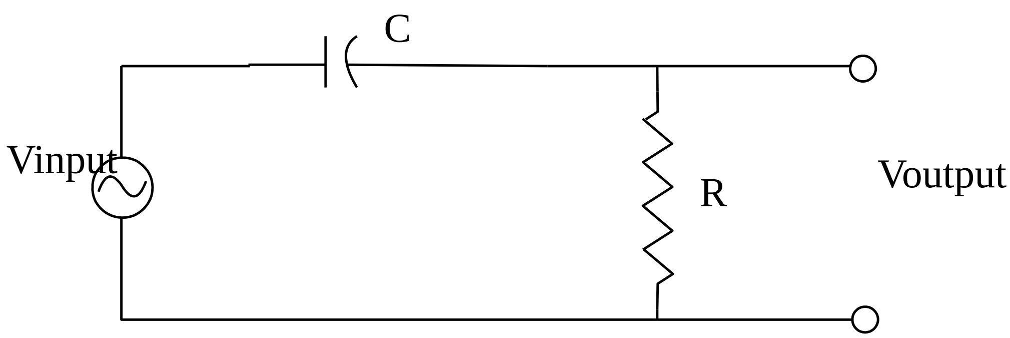
Lag compensator:

1. Lag compensator allows high gain at low frequencies then it is basically a low pass filter. If improves the steady state performance.
2. The alternation characteristics is used for the compensation. The phase lag characteristics are of no use in the compensation.
3. The alternation due to lag compensator shifts the gain cross – over frequency to a lower frequency pt. Thus the BW of the system gets reduced.
4. Reduced BW means slower response. Thus rise time & settling are usually longer. The transient response lasts for longer time.
5. The system becomes more sensitive to the parameter variation.
6. It approximately cuts as proportional plus integral controller and then to make system Less stable.

Circuit Diagram:



Lag Network



Lead Network

PROCEDURE:

1. LEAD COMPENSATOR

a. Connections are made as per the Circuit diagram shown in Fig 1 so as to form a phase lead network by selecting R_1 = 10kΩ and C = 0.22μF

b. Switch ON the supply.

c. Using the CRO in X-Y mode, give input of the network to X – input of CRO and output of the network to Y – input of CRO.

d. Set the sine wave amplitude to 3V.

e. Now vary the frequency from 25 Hz to 1000 Hz in steps and note down the readings in the Table given below:

f. Calculate the gain and phase difference from the readings.

g. Now calculate the theoretical values of gain and phase difference.

h. Draw the Bode plot for both the theoretical & Practical Values.

2. LAG COMPENSATOR

a. Connections are made as per the Circuit diagram shown in Fig 2 so as to form a phase lag network by selecting $R_1 = 10k\Omega$, $R_2 = 10k\Omega$ and $C = 0.22\ \mu F$.

b. Switch ON the supply.

c. Using the CRO in X – Y mode, give input of the network to X – input of CRO and output of the network to Y – input of CRO.

d. Set the sine wave amplitude to 3V.

e. Now vary the frequency from 25 Hz to 1000 Hz in steps and note down the readings in the Table given below:

f. Calculate the gain and phase difference from the readings.

g. Now calculate the theoretical values of gain and phase difference.

h. Draw the Bode plot for both the theoretical & Practical Values.

OBSERVATIONS:

Frequency	A	X_0	B	Y_0	θ Practical	Gain Practical	θ Theoretical	Gain Theoretical

Bode plot of lead compensator:

Comer frequencies of the lead compensators are

$w_{c1} = \frac{1}{T}$ for a zero at $s = \frac{-1}{T}$ & $w_{c2} = \frac{1}{\alpha T}$ for a pole at $s = \frac{-1}{\alpha T}$ and $k = \alpha$

Bode Plot of Lag Compensator:

Viva Questions:

1) What you mean by gain margin & phase margin?
2) What is the function of a compensation?
3) Write few names of series compensations?
4) Function of lag compensation?
5) Function of lead compensation?

MAGNETIC AMPLIFIER

MAGNETIC AMPLIFIER

AIM: To plot the load characteristics of

1. Series Connected Magnetic Amplifier
2. Parallel Connected Magnetic Amplifier
3. Self Saturated Magnetic Amplifier

APPARATUS REQUIRED:

1. Magnetic Amplifier Kit
2. 100 W Bulb, Patch Cords

THEORY:

Magnetic Amplifier is a device consisting of combination of saturable reactors, rectifiers and conventional transformers, used to control large AC loads with a small DC current control. In magnetic amplifiers, the load current in the circuit is controlled by a DC magnetizing current, which is comparatively very low as compared with load current. A large current value is controlled by a small current value, hence such type of circuits are termed as current amplifiers. The saturable reactor is sued as the interface between the load circuit and control circuit. The reactance of the reactor depends upon the DC control current. Thus the load current is controlled by using magnetic property and hence the term magnetic amplifier.

Small electron tube and transistors, by themselves are not sufficient to control larger AC circuits. Using a magnetic device such as saturable reactor in association with these active components, a large AC load (of up to hundred of amperes and kilowatts) may be controlled by a small direct current(in milli ampere).

The most common basic saturable reactor (which is used in magnetic amplifier circuits) consists of a three legged closed laminated core with coils wound on each leg. The coil wound on central limbs are called as Load winding. Due to DC current in the control winding, the degree of magnetization in the core is changed. An increase in control current, increases the flux density until core saturation is approached. After this change in flux density will not be applicable. Hence one can change the flux density, i.e., reactance of the core by changing the DC current in the control winding. If the load winding is connected in series with the load, one can control the current in the load by changing reactance of the coil with the help of DC control current. The load current can be controlled still saturation of reactance is approached. This property of saturable reactor is used in magnetic amplifier.

Magnetic amplifier can be connected in the following ways to controlled the load current. They type of connection depends on the interconnection of the load windings. They are:

1. Series Connected Magnetic Amplifier
2. Parallel Connected Magnetic Amplifier
3. Self Saturated Magnetic Amplifier

1. Series Connected Magnetic Amplifier

In series connected Magnetic Amplifier, the two Load windings are connected in series. The control winding of two reactors controls the flow of load current in the load winding. The total reactance is twice and it is controlled by control winding. In Series Connected Magnetic Amplifier the load current can be controlled from nearly zero to maximum depending upon the rating of the load. By increasing the control current.

Procedure for series connection:

1. Keep the Toggle switch in position 'E' on the front panel.
2. Keep control current setting knob at its extreme left position which ensure zero control current at starting.
3. With patch cords, connect following terminals on the front panel of the unit.
    - **a. Connect AC to C_1**
    - **b. Connect A_3 to B_3**
    - **c. Connect B_3 to L**
4. Connect 100 watt lamp in the holder provided on the front panel.
5. Now, once again check that the switch is in position 'E' and connections.
6. Switch ON the unit.
7. Now, gradually increase control current by rotating control current setting knob clockwise in steps and note down control current and corresponding load current.
8. Plot the graph of load current V/s control current.

Observation Table:

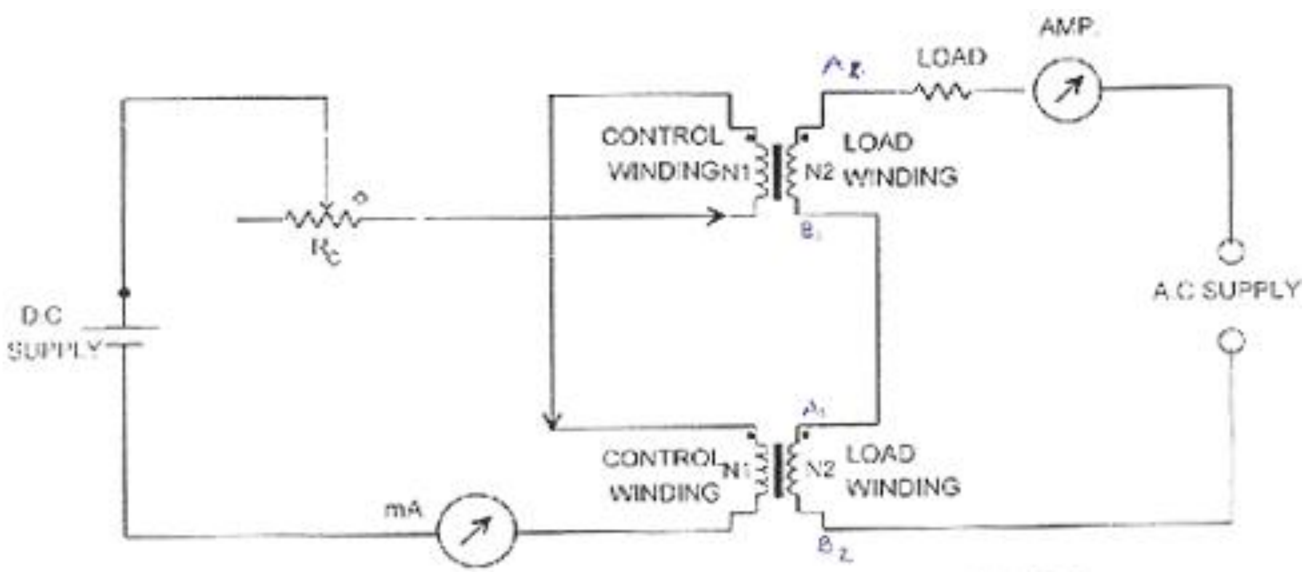
S.NO.	Control Current (mA)	Load Current (mA)

Model Graph:

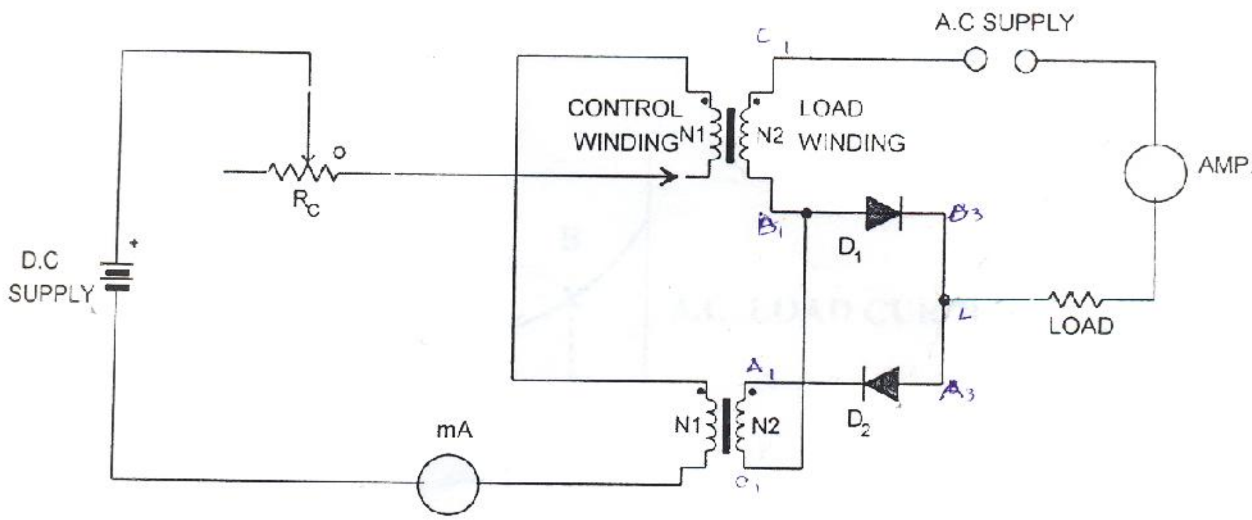
2. Parallel Connected Magnetic Amplifier:

In parallel connected Magnetic Amplifier the two reactors (Load windings) are connected in parallel as shown in Fig. The total reactance in this case will be decreased. At zero control current there will be appreciable load current as compared to series connected Magnetic Amplifier. We can observe only a little control in the load current. Secondly, saturation level of load current is more as that of series connected series.

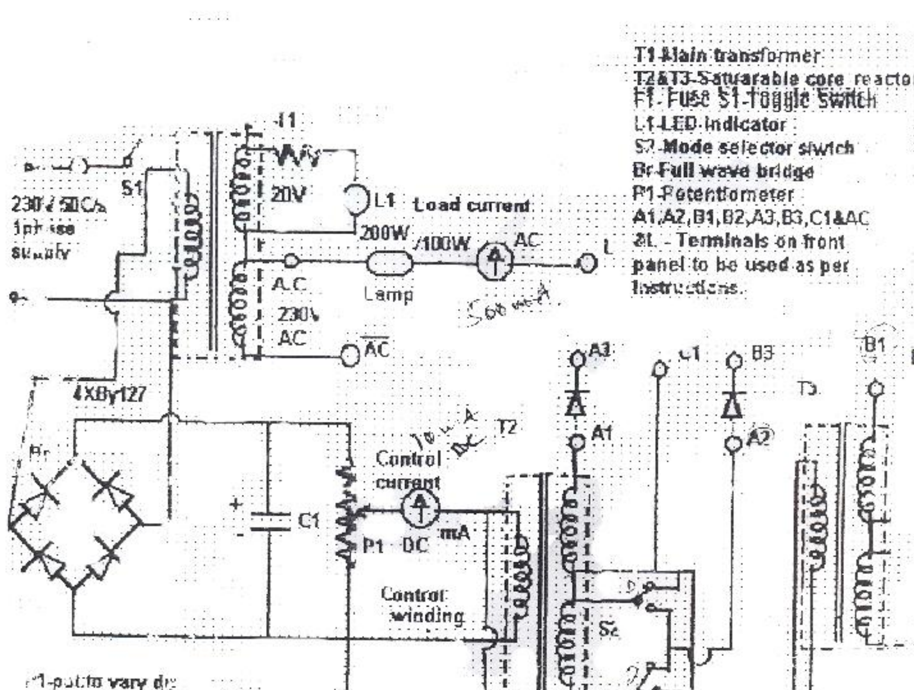
<u>Circuit Diagram:</u>



SERIES CONNECTED MAGNETIC AMPLIFIER.



SELF SATURATED MAGNETIC AMPLIFIER.



Circuit digram of Magnetic Amplifier

Procedure for Parallel Connection

1. Keep the Toggle switch in position ‘D’ on the front panel.
2. Keep control current setting knob at its extreme left position, which ensures zero control current at starting.
3. Wire the unit as given below with patch cords.
    - **a. Connect A_1 to AC**
    - **b. Connect A_1 to A_2**
    - **c. Connect B_2 to L**
    - **d. Connect B_2 to B_1**
4. Connect 100 – watt lamp load in the holder provided for this purpose.
5. Switch On the unit.
6. Now gradually increase control current by rotating control current setting knob clockwise in steps and noted down control current and corresponding load current.
7. Plot the graph of load current V/s control current.

Observation Table:

S.NO.	Control Current (mA)	Load Current (mA)

Model Graph:

3. Self Saturated Magnetic Amplifier:

The two diodes shown in the circuit will saturate the cores. Hence in such type of connections the load current is maximum at zero control current. Now if the control current is passed in such a reactance will go on increasing and hence the load current will decrease. But the minimum value of current will depend upon the magnetic core used in the reactors. As we go on increasing DC current in control winding the load current will decrease to certain minimum value and stay there for certain increase of DC current. If it is further increased the reactance will go on decreasing. But the load current will increase again to a certain value with for the increase in load current. This happens because the additional DC current tries to increase the magnetic linkage and hence the current will increase.

Procedure for Self Saturated Magnetic Amplifier:

1. Keep Toggle switch in position 'D' on the front panel.
2. Keep control current setting knob at its extreme left position (Rotate in Anti – clockwise direction), which ensures zero control current at starting.
3. With the help of Patch cords, connect following terminals on the front panel of the unit:
    - **a. Connect AC to A_1**
    - **b. Connect B_1 to B_2**
    - **c. Connect B_2 to L**
4. Now, put the 100 – watt lamp load in the holder provided on the front pane.
5. Now, once again check the switch position and wiring (Switch in 'D' position).
6. Switch ON the unit.
7. Now gradually increase control current by rotating control current setting knob clockwise in steps and noted down control current and corresponding load current.
8. Plot the graph of load current V/s control current.

Observation Table:

S.NO.	Control Current (mA)	Load Current (mA)

Model Graph:

<u>Viva Questions:</u>

1. For wide range of amplification which type of connection is preferred & why?
2. what you mean by saturable reaction?
3. Any two applications of magnetic amplifier?
4. Which type of connection in a magnetic amplifier can be used for voltage regulation?
5. what are the merits of magnetic amplifier over electronic amplifier?

PID CONTROLLER

PID CONTROLLER

AIM: To study the effect of P, PD, PI, PID Controller on a second order system.

APPARATUS REQUIRED:

THEORY:

To meet two independent specifications a second order systems need modifications. This modification is termed as compensation should allow for high open loop gains to specification steady state accuracy and yet preserve a satisfactory dynamic performance. Some of the practical modification schemes are discussed below.

DERIVATIVE ERROR COMPENSATION:

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. A controller producing such a signal is called a proportional plus derivative controller or PD controller. The advantage here is that as the damping increases due to compensation with ω_n remaining fixed, the system setting time reduces.

INTEGRAL ERROR COMPENSATION

In this scheme, the output response depends is some manner up on 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 other proportional to its integral. Such a controller is called proportional plus Integral or PI controller. This scheme is used to have high accuracy requirements.

PROPORTIONAL PLUS INTEGRAL PLUS DERIVATIVE CONTROLLER

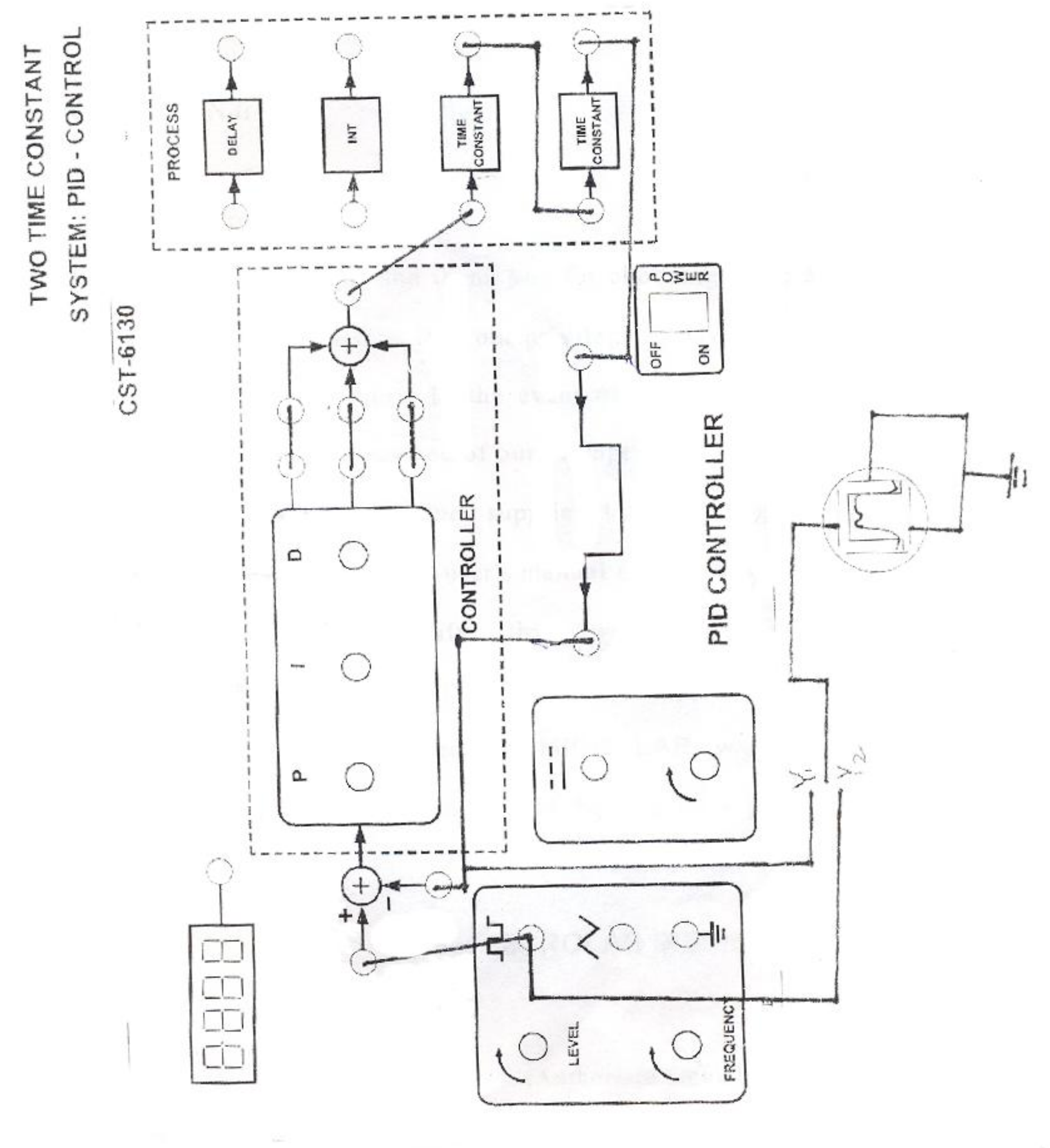
Error integration in the forward path eliminates steady state velocity error but it increases systems order making it more susceptible to instability. It also introduces a zero into the forward path so that peak overshoot to step i/p cannot be easily eliminated. To increase the damping factor of the dominant poles of a PI controlled system, we take advantage of adding with derivative system.

TUNING RULES FOR PID CONTROLLERS

If a mathematical model of a plant can be derived, then it is possible to apply various design techniques for determining parameters of the controller that will meet the transient and steady state specifications of the closed loop system. However, if the plant is so complicated that its mathematical model cannot be easily obtained, then an analytical approach to the design of a PID controller is not possible. Then we must resist to experimental approaches to the running of PID controllers.

The process of selecting the controller parameters to meet given performance specifications is known as controller tuning. Ziegler and Nichols suggested rules for tuning PID controllers to set values of K_p, T_i, T_d based on transient response characteristics of a given plant.

Circuit Diagram:



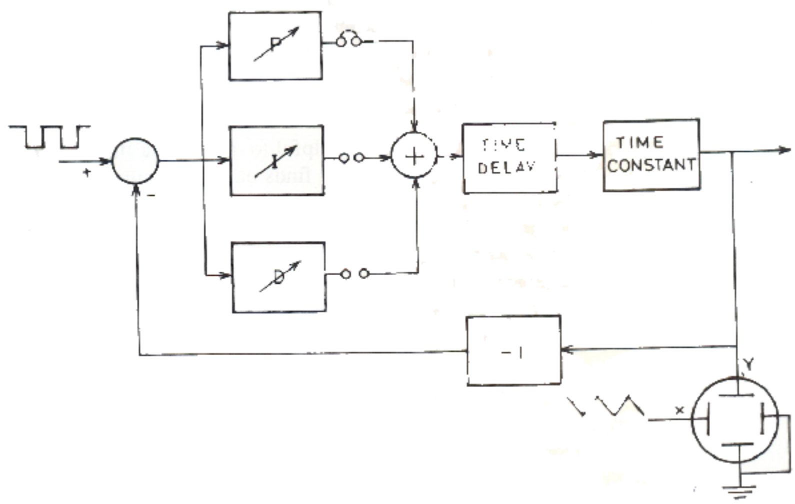
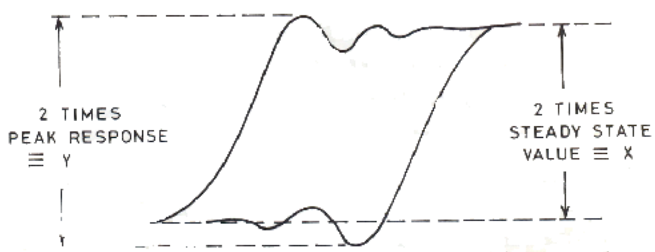


FIG. CONNECTION DIAGRAM OF PID CONTROL



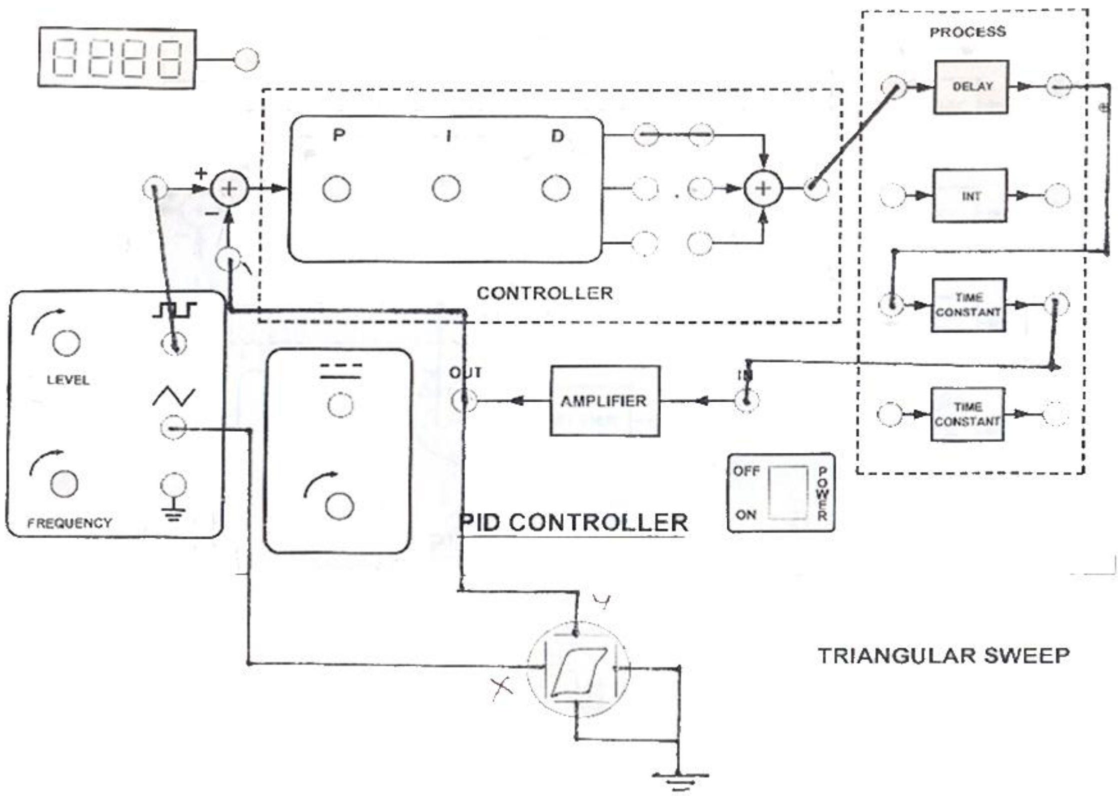
$$\text{S. S. ERROR} = \frac{(p-p)\ \text{INPUT} - X}{(p-p)\ \text{INPUT}}$$

$$\text{PEAK PERCENT OVERSHOOT} = \frac{Y - X}{X}\ 100\ \%$$

FIG. CRO DISPLAY OF STEP RESPONSE USING TRIANGULAR TIME BASE

FIRST ORDER TIME DELAY
SYSTEM: P - CONTROL

CST-6130



TRIANGULAR SWEEP

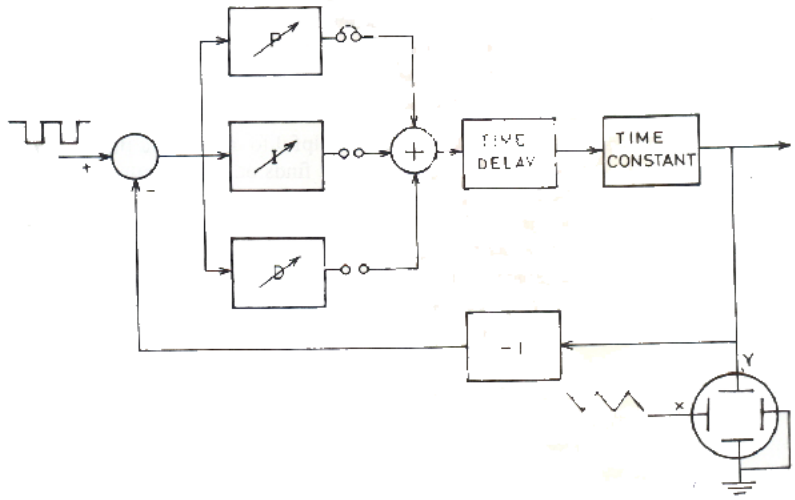
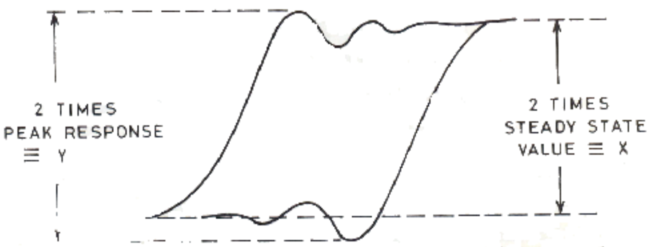


FIG. CONNECTION DIAGRAM OF PID- CONTROL



$$\text{S. S. ERROR} = \frac{(p-p)\ \text{INPUT} - X}{(p-p)\ \text{INPUT}}$$

$$\text{PEAK PERCENT OVERSHOOT} = \frac{Y - X}{X}\ 100\ \%$$

FIG. CRO DISPLAY OF STEP RESPONSE USING TRIANGULAR TIME BASE

PROCEDURE:

The frequency is set at the lower end of the range and its actual value may be experimentally determined.

P – CONTROLLER

Step – 1: Make the connection as shown with process made up of time delay and time constant blocks. Notice that the CRO operation in the X – Y mode ensures stable display even at low frequencies.

Step – 2 : Set input amplitude to 1 V (P – P) and frequency to low value.

Step – 3: For various k_c measure from the screen the values of peak over shoot and steady state error.

PI CONTROLLER:

The integral term results in increasing the system type number by unity and thus causes improvement in steady state performance. To verify the above with step input one starts with a type 0 system having a non-zero error. Introducing PI control with a properly selected value of τ_i should reduce error to zero.

Step – 1: Make the connection for the first order type 0 system with time delay with P1I blocks connected.

Step – 2 : Set input amplitude to 1 V (P – P) and frequency to low value and k_i to zero.

Step – 3: For k_c = value, observe and record the peak overshoot and steady state error.

Step – 4 : With k_c as above, increase in k_i small steps and record peak overshoot and steady state error.

PID CONTROLLER

This improves the transient performance buy the introduction of derivative control.

Step – 1: The connections are made as shown with PID blocks connected.

Step – 2: Set input amplitude to 1V (P-P) , frequency to a low value $k_c = 0.8$, $k_i = 0.8$, $k_d = 0$.

Step – 3: The system shows a fairly large overshoot. Record the peak overshoot and steady state error.

Step – 4: For k_c = 0.8 adjust kI & k_d by trial and error to obtain overall response. Record the values of k_c, τ_i, τ_d. Repeat for k_c = 0. 4, 0, 2 . . . .

PRECAUTIONS

1. Readings should be taken without any errors.
2. Excessive increase of k_i results in an inferior transient response. Hence experiment is performed at low values of k_i.

RESULT:

Viva Questions:

1. Write few lines about 'P' Controller?
2. write about 'I' controller & how it influence the steady state error?
3. write about 'D' controller & how it influence the peak over shoot?
4. How to set the values of P, I, D?
5. Effect of Integral gain & differential gain on steady state & transient performance of the system?

SPEED – TORQUE CHARACTERISTICS

OF

D.C. SERVOMOTOR

SPEED –TORQUE CHARACTERISTICS OF D.C. SERVOMOTOR

AIM: To plot Speed – Torque characteristics of D.C. Servomotor.

Apparatus Required : D.C. Servo Motor kit

Theory:

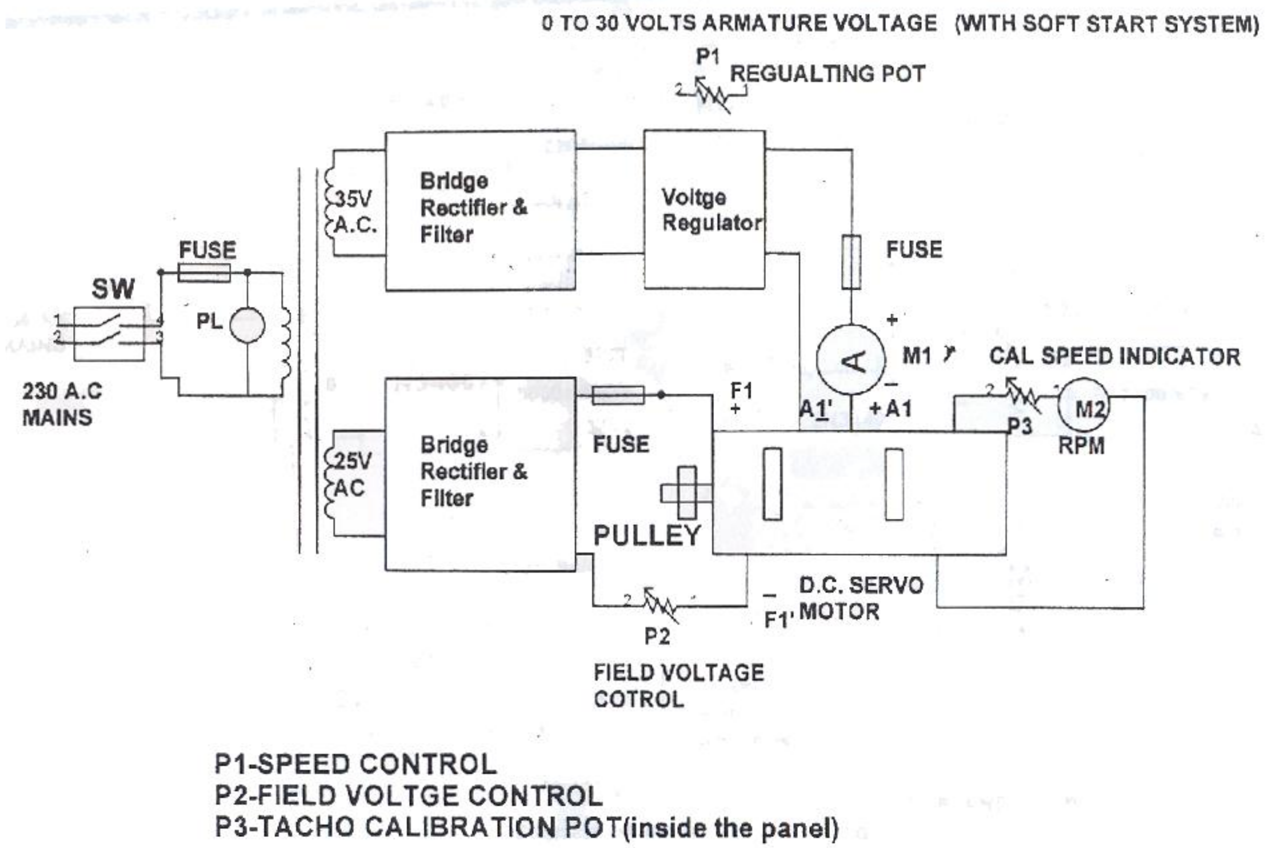
There are many types of D.C. motors used in industries. D.C. motors that are used in control systems are called D.C. servomotors. In D.C. servomotors the rotor inertia have been made very small, with the result that motors with very high torque to inertia ratio are commercially available. Some D.C. motors with relatively small power rating are used in instruments and computer related instruments. D.C. Series, shunt and permanent magnet D.C. servo motors with medium and large power ratings are used in robot systems and CNC machines. And normally they are available with built in tacho generator for speed sensing in closed loop control applications. Most important among the characteristics of the D.C. servomotor is the maximum acceleration obtainable. For a given available torque the rotor moment of inertia must be maximum. Since the servomotor operates under continuously varying conditions, acceleration of the rotor occur from time to time. The servo motor must be able to absorb the mechanical energy as well as to generate it. The performance of servomotor when used as a brake is satisfactory.

.

Torque Measurement:

In order to measure the torque produced by the D.C. servomotor we have an arrangement to produce the variable load on the D.C. servomotor. The D.C. servomotor is fitted to the front panel and its shaft is extended outside the front panel. A small aluminum break drum is fitted to the shaft for loading. A small leather belt and two spring balances are fitted to the belt on both the sides and fitted to an MS channel. A wheel is fitted to the one side of the shaft or varying the speed.

Circuit Diagram:



BLOCK DIAGRAM FOR D.C. SERVOMOTOR SPEED TORQUE CHARACTERISTICS SET UP

FIGURE

Observations:

Voltage (V)	Current (A)	Speed (N) rpm	Load W in gram	Torque T = W × R

Procedure:

1. Remove the load in no load condition. Switch ON the module.
2. Note down the no load current and no load speed.
3. Adjust the potentiometer for the rated voltage of 24V.
4. Adjust the load in steps to a maximum of 200 gm – cm and current of 0.8 Amps (do not exceed 0.8 amps)
5. At each load note down the speed.
6. Calculate the corresponding torque and plot the torque speed characteristics.
7. Repeat the procedure for 60% and 40% of the rated voltage
    a. Rated Voltage
    b. 60% rated voltage
    c. 40% rated voltage

Viva Questions:

1. What are the control methods of a DC servomotor?
2. What are the Applications of DC servomotors?
3. Which control field on armature of DC servomotor requires higher current?
4. Why the NNT characteristics of DC servo motor in Linear?

STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING MATLAB

STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING MATLAB

AIM: To find State space model for a given transfer function and vice versa using MATLAB and verify the same theoretically.

APPARATUS REQUIRED:

1. PC compatible with MATLAB software
2. Control System Toolbox.

THEORY:

Modern control design and analysis required a lot of linear algebra (matrix multiplication, inversion, calculation of eigen values and eigenvectors, etc.), which is not very easy to perform manually. The repetitive linear algebraic operations required in modern control design and analysis is, however, easily implemented on a computer with the use of standard programming techniques. A useful high – level programming language available for such talks is the MATLAB, which not only provides the tools for carrying out the matrix operations, but also contains several other features, such as the time – step integration of linear or nonlinear governing differential equations, which are invaluable in modern control analysis and design. Nowadays, personal computer versions of MATLAB are commonly applied to practical problems across the board, including control of aerospace vehicles, magnetically levitated trains and even stock – market applications.

For solving many problems in control systems, Control System Toolbox for MATLAB is very useful. It contains a set of MATLAB M-files of numerical procedures that are commonly used to design and analyze modern control systems. The Control System Toolbox is available with the MATLAB.

THEORETICAL CALCULATIONS:

$$\frac{Y(S)}{U(S)} = \frac{1}{S^3 + 10S^2 + 9S + 10}$$

There are many possible state space representation for this system.
One possible state space representation is

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -10 & -9 & -10 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} U$$

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

Transformation from state –space transfer function:

To obtain the transfer function from state space equations, we use the following command

[num, den] = SS2tf [A, B, C, D, in]

in must be specified for systems with more than one input. If the system has only one i/p then either,

[num, den] = SS2tf [A, B, C, D]

(or)

[num, den] = SS2tf [A, B, C, D, 1]

A. The given transfer function

$$\frac{Y(S)}{U(S)} = \frac{1}{S^3 + 10S^2 + 9S + 10}$$

$$S^3\ Y(S) + 10S^2\ Y(S) + 9S\ Y(S) + 10\ Y(S) = U(S)$$

Taking laplane transform on both sides,

$$\frac{d^3x}{dt^3} + \frac{10d^2x}{dt^2} + \frac{9dx}{dt} + 10x = U$$

Choosing state variation as $Y = x_1$, $\dot{x} = x_2$, $\ddot{x} = x_3$

$$\dot{x}_1 = x_2 \quad ; \quad \ddot{x}_2 = x_3$$

$$\dot{x}_3 = U - 10x_1 - 9x_2 - 10x_3$$

This system

One possible state space representation is

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -10 & -9 & -10 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} U$$

$$Y = x_1$$

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

B. From the state model, the following matrices are obtained.

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -10 & -9 & -10 \end{bmatrix} \qquad B = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \qquad D = [\,0\,]$$

$$SI - A = \begin{bmatrix} S & 0 & 0 \\ 0 & S & 0 \\ 0 & 0 & S \end{bmatrix} - \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -10 & -9 & -10 \end{bmatrix}$$

$$= \begin{bmatrix} S & -1 & 0 \\ 0 & S & -1 \\ 10 & 9 & S+10 \end{bmatrix}$$

$$(SI - A)^{-1} = S\,[S^2 + 10S + 9\,] + 10$$

$$= S^3 + 10S^2 + 9S + 10$$

$$\frac{1}{S^3 + 10S^2 + 9S + 10} \begin{bmatrix} S^2 + 10S + 9 & S + 10 & 1 \\ -10 & S^2 + 10S & S \\ -10S & -(9S + 10) & S^2 \end{bmatrix}$$

$$C(SI - A)^{-1} = \frac{1}{S^3 + 10S^2 + 9S + 10} \begin{bmatrix} S^2 + 10S + 9 & S + 10 & 1 \end{bmatrix}$$

$$C(SI-A)^{-1}B+D = \frac{1}{S^3+10S^2+9S+10} \begin{bmatrix} S^2+10S+9 & S+10 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} + [\ 0\ ]$$

$$T.F = \frac{1}{S^3+10S^2+9S+10}$$

PROGRAM:

```
    n      = input ( 'enter 1 for converting tf to SS and 2 for converting ss to tf');

Switch  n

    Care 1
            num   =  input ( 'enter the num of tf');
            den     = input  ('enter the den of tf') ;
            disp  ('the tf is') ;
            t = tf ( num, den)
    [ a, b, c, d ]  =  tf 2 SS (num,  den)
   Care  2
            a  =  input ('enter the system matrix A');
            b  = input ( 'enter the i/p matrix B') ;
            c  =  input ('enter the o/p matrix C;) ;
            d  =  input  ('enter the transmission matrix D'0 ;
    [num,  den ]  =  SS2 tf  ( a, b, c, d )
            tf (num,  den)
otherwise
    disp  ('the choice is invalid') ;
    end.
```

OUTPUT

Enter 1 for converting tf 2 SS and 2 for SS to tf

1

Enter the num 1

Enter the den $[1 \quad 10 \quad 9 \quad 10]$

Then tf is $\dfrac{1}{S^3+10S^2+9S+10}$

$$a = \begin{bmatrix} -10 & -9 & -10 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

$$b = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix} \qquad c = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix} \qquad \mathrm{d} = [\ 0\ ]$$

enter 1 for converting tf 2 SS and = for SS to tf

2

enter the system matrix A $\begin{bmatrix} 0 & 1 & 0\ ; & 0 & 0 & 1\ ; & -10 & -9 & -10 \end{bmatrix}$

enter i/p matrix B [0 ; 0 ; 1]

enter o/p matrix C $\begin{bmatrix} 1 & 0 & 0 \end{bmatrix}$

enter the transmission matrix D [0]

$$\text{num} = \begin{bmatrix} 0 & 0.000 & -0.000 & 1.000 \end{bmatrix}$$

$$\text{den} = \begin{bmatrix} 1.000 & 10.000 & 9.000 & 10.000 \end{bmatrix}$$

$$\text{The transfer function is } = \frac{1}{S^3 + 10S^2 + 9S + 10}$$

PROCEDURE:

1. Open the MATLAB Command window by clicking on the MATLAB.exe icon.
2. Enter the given transfer function in the command window by using the syntax- SYS = TF(NUM, DEN) where ‘num’ is the matrix containing the elements of numerator and ‘den’ is the matrix containing the elements of denominator.
3. To convert the given transfer function into state space enter the following syntax in the command window [A, B, C, D] = TF2SS (NUM, DEN)
4. Note the values of the matrices A, B, C and D and represent the state space model.
5. Type EXIT at the command window to close the MATLAB.

RESULT:

Viva Questions:

1. Determine transfer matrix for a system described below

$$X=Ax+Bu$$
$$Y=Cx+Du$$

A=

2. Draw the state block diagram for the transfer function

$$\frac{Y(S)}{U(S)} = \frac{1}{(S+2)} \quad \frac{1}{(S+3)}$$

3. Draw the state block diagram for the transfer function.================
4. Define state, state space, state vector & state variable .
5. Obtain the state model for the electrical network.

6. State equation of a system are given

$$x^{o}=Ax+Bu$$
$$y=Cx+Du$$

name A,B,C& D matrices.

TIME RESPONSE OF

SECOND ORDER CONTROL SYSTEM

&

FRIST ORDER CONTROL SYSTEM

TIME RESPONSE OF SECOND ORDER CONTROL SYSTEM & FRIST ORDER CONTROL SYSTEM

AIM: To study the time response of second order and first order control system.

APPARATUS:

Time response kit

CRO

Probes

Connecting wires

THEORY:

Second order control systems are characterized by two poles and two zeros. For the purpose of transient response studies usually zeros are not considered primarily because of simplicity in calculation and also because the zeros do not effect the internal nodes of the system. Overall transfer function of the second order system in standard form is given by

$$T(S) = \frac{C(S)}{R(S)} = \frac{W_n^2}{S^2 + 2\xi w_n S + w_n^2}$$

When ξ is called damping ratio ξ W_n is the un-damped natural frequency. In order to analyze the transient behaviour of the control systems, the first step is to obtain the mathematical model of the system these dynamic behaviour is analyzed under the application of standard test signals is generally used for testing as it can be easily generated. The time response performance is measured by computing time response performance is indicated below.

1. Delay time (t_d): It is the time required for the response to read 50% of the final value in first attempt.
2. Rise time (t_r): It is the time required by the response to rise from 10% to 90% of final value for over-damped systems and 0 to 100% of the final value for under-damped system.
3. Peak time (t_p): It is the time required for the response to reach the peak of time response or peak overshoot.

$$tp = \frac{\Pi}{W_n\sqrt{1-\xi^2}}$$

4. Peak overshoot (μ p): It indicates the normalized difference between the time response peak and steady state output and is defined as

$$\mu \text{ p} = e^{-\xi \pi / \sqrt{1-\xi^2}}$$

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

$$\text{for tolerance band of 2 \%} = \frac{4}{\xi W_n}$$

$$\text{for tolerance band of 5 \%} = \frac{3}{\xi W_n}$$

6. Steady state error (ess): It indicates the error between the actual and derived o/p as it tends to infinity.

$$\text{Ess} = \underset{f \to \infty}{lt} \{1 - C(t)\}$$

Circuit Diagram:

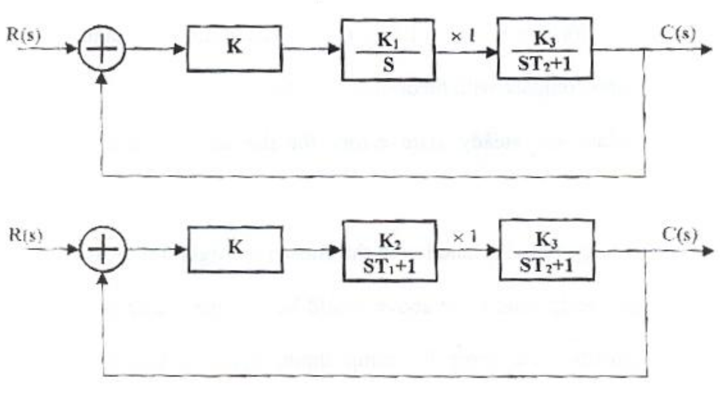
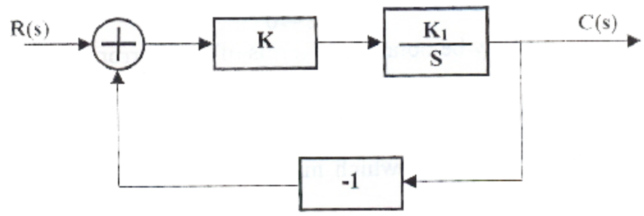


FIG. CLOSED LOOP OPTIONS FOR SECOND ORDER SYSTEMS.



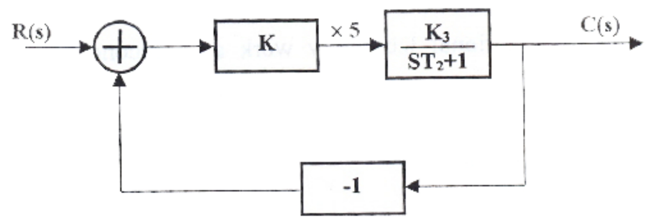


FIG. CLOSED LOOP OPTIONS FOR FIRST ORDER SYSTEMS.

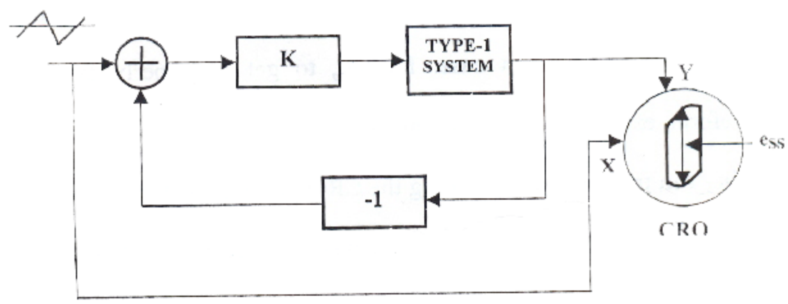


FIG. STEADY-STATE ERROR FOR RAMP INPUT.

PROCEDURE:

1. Connections were made as shown in fig.
2. Step input was applied by keeping the square wave frequency law.
3. CRO was connected across the input and the output of the system.
4. Necessary adjustments were made on CRO and input signal so as to read the time specifications for a final gain value.
5. The DC gain was increased and the time specifications were noted down.

RESULT:

TRANSFER FUNCTION OF A DC MOTOR

TRANSFER FUNCTION OF A DC MOTOR

Aim : To determine the transfer function of the given dc motor after determining various constants.

Name Plate Details of D.C. Motor:

Apparatus:

S.No.	Name of the item	Type	Range	Quantity

Theory:

Transfer function of a DC motor is designed as follows:

$$V_a(t) = e_b(t) + La\,\frac{di(t)}{dt} + R_a I_a(t)$$

$$e_b(t) = \phi\, Z\, N \left(\frac{P}{A}\right) \qquad \text{(N in rps)}$$

$$= \phi\, Z \times \left(\frac{P}{A}\right) \times \frac{d\theta}{2\pi\, dt}$$

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

here $K_b = \phi \; Z * \left(\frac{P}{A}\right) * \frac{1}{2\pi}$ = emf constant

Torque $T(t) = \phi \; Z \; I_a(t) * \left(\frac{P}{A}\right) * \frac{1}{2\pi}$

$= K_t * I_a(t)$

here $K_t = \phi \; Z \; I_a(t) * \left(\frac{P}{A}\right) * \frac{1}{2\pi}$ = Torque constant

here $K_0 = K_t$

and also $T(t) = J \frac{d^2\theta}{dt^2} + B \frac{d\theta}{dt}$

$V_a(t) = e_b(t) + L_a \frac{di(t)}{dt} + R_a \; I_a(t)$

By applying laplace transformer

$V_a(S) = E_b(S) + \left[L_a \frac{di(t)}{dt}\right] + R_a \; I_a(S)$

$V_a(S) = E_b(S) + S \; L_a \; I_a(S) + R_a I_a(S)$

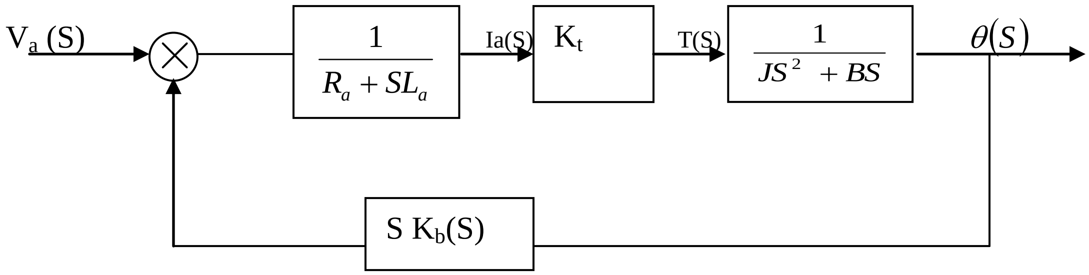
$I_a(S) = \frac{[V_a(S) - E_b(S)]}{S \; L_a + R_a}$

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

$K_t * I_a(S) = T(S)$

$T(S) = I \; S^2 \; \theta(S) + SB \; \theta(S)$

$\theta(S) = \frac{T(S)}{I \; S^2 + BS}$



$$\text{T . F} = \frac{\theta(S)}{V_a(S)} = \frac{K_t}{(I\ \ L_aS^3 + C\ \ R_aI + L_aB)S^2 + (R_aB + K + K_b)S}$$

The constants K_t, K_b, R_a and I are experimentally determined.

Observations:

To find out R_a

Voltage	**Armature Current I_a (A)**	**Armature resistance $R_a = V_t / I_a (\Omega)$**

To find one time t_1

Change in speed	**Time taken (t_1)**

To find t_2 (when load is connected to armature)

Voltage (V)	**Current (I)**	**Fall in speed**	**Time taken (t_2)**

Procedure:

1. Connections were made as per the circuit diagram.
2. Keep the motor field rheostats in the appropriate position. Adjust the speed to the rated value.
   K_b is calculated as follows:

   Under steady state $L_a \dfrac{di\ a}{dt} = 0$

   $V - I_a R_a = E_b = K_b W \qquad (W = \dfrac{2\pi\ N}{60})$

   $$\text{K}\, K_b = \frac{V - I_a R_a}{2\pi\ N/60}$$

   Measure the armature voltage, armature current and speed on no load and determine K_b.
3. Connections are made as per the circuit diagram (2).

   $R_a = 1.2 \times$ R average

   $Z_a = \sqrt{R_a{}^2 + (WL_a)^2}$

   $X\,L_a = \sqrt{Z_a{}^2 - R_a^2}$

   $L_a = \dfrac{X\ L_a}{W}$
4. The value of moment of inertia 'J' in kg-m^2 is calculated by retardation test.
5. Connection are made as show in fig (4)
6. Run the motor above 10% rated speed. Disconnect the supply to armature by opening DPST switch and simultaneously start a stop watch. Allow the speed to fall below 10% of the rated. Stop the watch. Note down the time taken t_1. Determine the average $\dfrac{dN}{dt}$ at rated speed.

   $$\frac{dN}{dt} = \text{change in speed} / t_1$$
7. Again run the motor at 10% above the rated speed. Discount the armature from supply. Note the voltmeter and ammeter reading and stop the watch simultaneously. When the speed falls to 10% below the rated speed note down the voltmeter, armature reading and stop the clock.

At t_2 be the average time for fall.

Calculate the average power $W^1 = \frac{W_1 + W_2}{2}$

Stray losses at rated speed $W = \frac{W^1 \times t_2}{t_1 - t_2}$

Calculation:

From armature drop test $R_a = 1.2 \times R_{avg}$

$L_a =$

$K_b = \frac{V - I_a R_a}{2\pi \ N / 00} = K\ t$

Stray losses $= \frac{W^1 t_2}{t_1 - t_2}$

$w = 5 \times 0.0109 \times \frac{dN}{dt}$

$J =$

Value of B is considered = 0.2626

Result:

The transfer function of a dc motor is determined.

T.F =