## 1. PREAMBLE:

Control Systems Lab consists of multiple workstations, each equipped with an oscilloscope, digital multi-meter, PID trainers, control system trainers and stand alone inverted-pendulum, ball and beam control, magnetic-levitation trainers. This lab also covers the industrial implementation of advanced control systems via different computer tools such as MATLAB and Simulink.

## 2 OBJECTIVE & RELEVANCE

The aim of this Control system laboratory is to provide sound knowledge in the basic concepts of linear control theory and design of control system, to understand the methods of representation of systems and getting their transfer function models, to provide adequate knowledge in the time response of systems and steady state error analysis, to give basic knowledge is obtaining the open loop and closed–loop frequency responses of systems and to understand the concept of stability of control system and methods of stability analysis. It helps the students to study the compensation design for a control system. This lab consist of DC,AC servomotor, synchros, DC position control, PID controller kit with temperature control, lead lag compensator kit, PLC kit, Stepper ,process control simulator

## OUTCOME

- After the completion of this course student able solve the control system problems by using the programs through MATLAB.
- Determination of transfer function useful to design the systems.

Introducing of MATLAB in control systems solutions

## 3 List of Experiments:

1. Time Response of Second order system
2. Study of characteristics of Synchros
3. Effect of feedback on DC servo motor
4. Transfer function of DC motor
5. Effect of P, PD, PI, PID controller on a second order systems
6. Simulation of OP – AMP based integrator and differentiator
7. Study of Lag leg compensation
8. Characteristics of magnetic amplifier
9. Root locus plot, Bode plot from MATLAB
10. State space model for classical transfer function using MATLAB Verification
11. Characteristics of AC servo motor
12. Programmable logic controller

## 4. Text and Reference Books

**TEXT BOOKS :**

**T1 :** B. C. Kuo ***"Automatic Control Systems"*** 8th edition– by 2003– John wiley and son's.,

**T2 :** I. J. Nagrath and M. Gopal, ***"Control Systems Engineering"*** New Age International (P) Limited, Publishers, 2nd edition.

**REFERENCE BOOKS** ***:***

**R1 :** Katsuhiko Ogata ***"Modern Control Engineering"*** Prentice Hall of India Pvt. Ltd., 3rd edition, 1998.

**R2 :** N.K.Sinha, ***"Control Systems"*** New Age International (P) Limited Publishers, 3rd Edition,1998.

**R3 :** NISE ***"Control Systems Engg."*** 5th Edition – John wiley

**R4 :** Narciso F. Macia George J. Thaler, ***" Modeling & Control Of Dynamic Systems"*** Thomson Publishers

## 5. SESSION PLAN

| Sl.No | Name of the Experiment | Week of Experiment |
|---|---|---|
| 1 | Time Response of Second order system | Week #1 |
| 2 | Study of characteristics of Synchro | Week #2 |
| 3 | Effect of feedback on DC servo motor | Week #3 |
| 4 | Transfer function of DC motor | Week #4 |
| 5 | Effect of P, PD, PI, PID controller on a second order systems | Week #5 |
| 6 | Simulation of OP – AMP based integrator and differentiator | Week #6 |
| 7 | Study of Lag leg compensation | Week #7 |
| 8 | Characteristics of magnetic amplifier | Week #8 |
| 9 | Root locus plot, Bode plot from MATLAB | Week #9 |
| 10 | State space model for classical transfer function using MATLAB Verification | Week #10 |
| 11 | Characteristics of AC servo motor | Week #11 |
| 12 | Programmable logic controller | Week #12 |

# 6 Experiment write up

## 6.1. TIME RESPONSE OF SECOND ORDER SYSTEM

**AIM :**

To obtain the time response of a second order system.

**APPARATUS :**

| Sl.No. | Item | Type | Range | Quantity | |
|---|---|---|---|---|---|
| 1 | Time Response Kit | | | | 1 |
| 2 | Patch Cords | | | | |
| 3 | Cathode Ray Oscilloscope | | | | 1 |

**THEORY:**

When a system is given an excitation (INPUT), there is a response (OUTPUT). This response varies with time, and is called the time response.

Time response is divided into two parts.

1) Transient Response - It is the part of response that goes to zero as the time increases.
2) Steady state Response - That part of the response that remains after the transients have died out

**TIME RESPONSE SPECIFICATIONS:**

1. Delay Time (td): - It is the value of time required for the response to reach 50% of final value in first attempt.

2. Rise Rime (tr):- It is the time required for the response to rise from 10% to 90% of the final value for the over damped system and 0 to 100% value for under damped system.

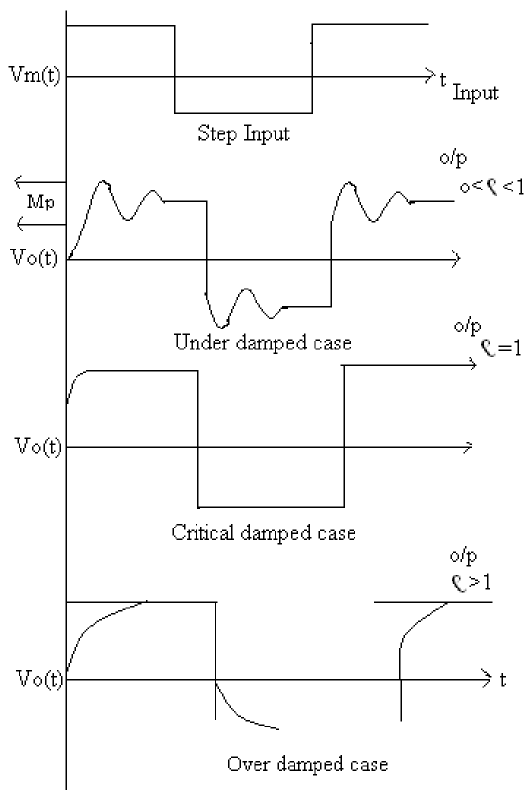
3. Peak Time (tp) : - It is the time required for the response to reach the peak of the time response or the peak overshoot.

4. Peak Overshoot (MP): - It indicates the normalized difference between the time response peak & steady state output. It is defined as peak percent overshoot.

$$\% \text{ M P} = \frac{C(tp) - C(00)}{C(00)} \times 100$$

Where C (tp) is output at t = tp & C (00) is steady state output.

5. Settling time (ts): - It is the time required for the response to reach and stay within a specific tolerance band (usually 2 to 5%) of its final value.

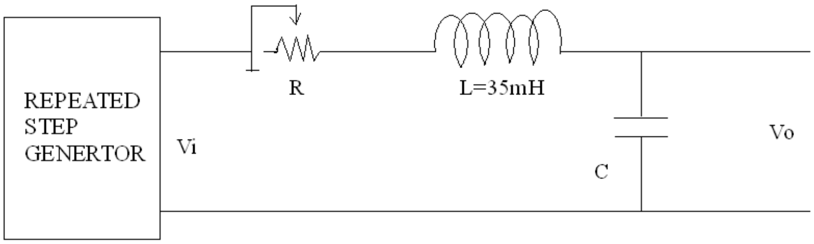



6. Steady State Error: - It indicates the error between the actual output & desired output as t tends to infinity.Ess=Lim[r(t) - c(t)]

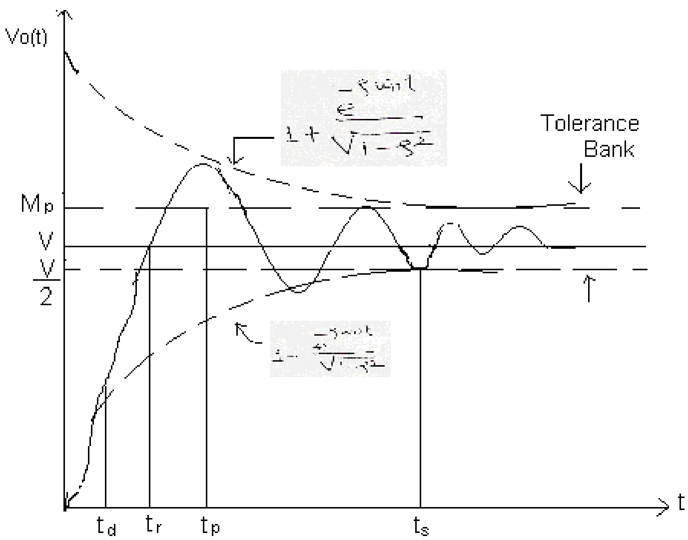
$t \rightarrow \infty$

## CIRCUIT DIAGRAM :

A SECOND ORDER SYSTEM




## GRAPHS :




TIME RESPONSE SPECIFICATIONS

**PROCEDURE :**

1. Make connections as shown in circuit diagram.
2. Connect repeated step input to RLC circuit.
3. Make power on to the unit.
4. Connect C.R.O. at the output and adjust C.R.O. to get stable pattern on C.R.O.
5. Vary R by potentiometer and for a given set of values of L & C, note down R for critically damped response
6. Vary R to obtain under damped response and measure R value, time response specifications.
7. Plot the same response on Graph paper.

**NOTE:** Actual value of R is R + resistance of Inductance

**OBSERVATIONS :**

| | **R** | **L** | **C** | $\zeta = R\sqrt{\frac{C}{L}}$ | $\omega_n = \frac{1}{\sqrt{LC}}$ | $\omega_d$ |
|---|---|---|---|---|---|---|
| **SET1** $0<\zeta<1$ | | | | | | |
| **SET2** $\zeta=1$ | | | | | | |
| **SET3** $\zeta>1$ | | | | | | |

**PRECAUTIONS :**

1. Loose connections are to be avoided.
2. Circuit connections should not be made while power is on.
3. Readings of meters must be taken without parallax error.

**RESULT:** Time Response specifications are obtained

**CALCULATIONS :**

1. $MP=e^{-\pi\zeta/\sqrt{1-\zeta^2}}$ X 100 %
2. $tr=\frac{\pi-\phi}{\omega_d}$
3. Damping Angle $\phi = Cos^{-1}\zeta$
4. $tp = \frac{\pi}{\omega_d}$ = ………………. $\mu s$
5. $ts=\frac{4}{\zeta\omega_n}$ = …………. For 2% tolerance.

**UNDER DAMPED SYSTEMS**

**OBSERVATION**

| Practical Specific | $t_d$ | $t_r$ | $t_p$ | $M_p$ | $e_{ss}$ | ts |
|---|---|---|---|---|---|---|
| Practical | | | | | | |
| Theoretical | | | | | | |

## 6.2 STUDY OF CHARACTERISTICS OF SYNCHROS

**AIM :**

To study the characteristics of synchro transmitter and receiver system.

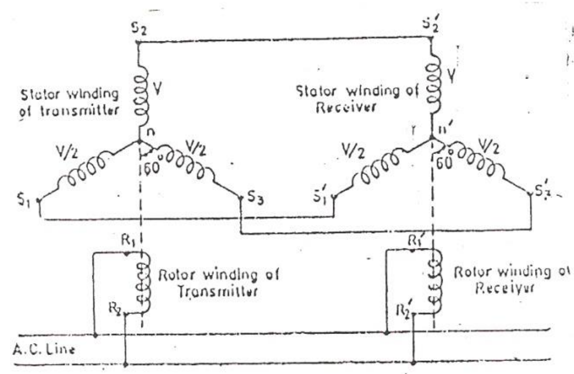
**APPARATUS :**

| S.NO | ITEM | TYPE | RANGE | QUANTITY |
|---|---|---|---|---|
| 1 | Synchros Kit | | | 1 |
| 2 | Patch Cords | | | |
| 3 | Multimeter | | | 1 |

**THEORY :**

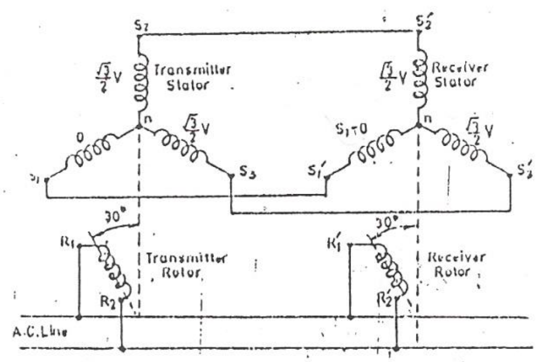
The term synchro is a generic name for a family of inductive devices which works on the principle of a rotating transformer basically they are electro- mechanical devices or electromagnetic transducers which produces an o/p voltage depending upon angular position of the rotor a synchro system is formed by inter connection. 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 f (three identical coils are placed in the stator with their axis 120 degree apart) and is Y connected. The rotor is a dumb bell shape type in construction and wound with a concentric coil. An a.c. voltage is applied to the rotor winding through slip rings. The system set up is consists of synchro transmitter and synchro receiver on a single rigid panel housed in MS cabinet plates, Rotor position of Tx and Rx is marked by graduated angular scale with pointer arrangement. AC input excitation supply for rotor of Tx and Rx is provided internally and panel switches are provided to make it On and Off independently. Test points for Tx and Rx stator and Rotor points are provided on panel.

**CIRCUIT DIAGRAM :**




(a) Torque transmission using synchro transmitter.

1Φ A.C



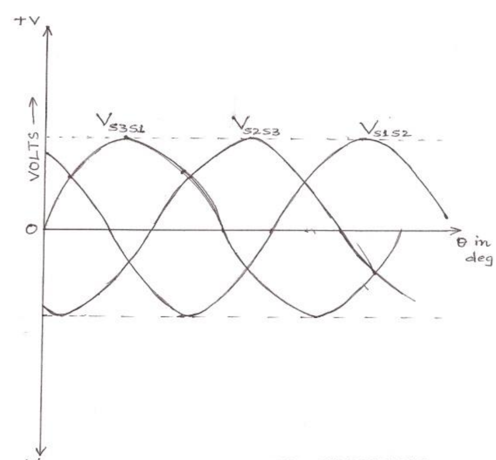

FOLLOW UP SYSTEM OF SYNCHRO TRANSMITTER AND RECEIVER

**PROCEDURE :**

1. Connect the mains supply to the unit.
2. Varying rotor position of Transmitter in steps of $30^0$ note down $V_{S1S2}$, $V_{S2S3}$, $V_{S3S1}$ readings.
3. Connect S1, S2, S3 of Transmitter to S1, S2, S3 of receiver respectively.
4. Move the rotor of synchro Transmitter in steps of 30 degrees and note down the change in Receiver rotor.
5. Enter the input angular position Transmitter rotor and output angular position of Receiver rotor in tabular form and plot a graph.
6. Plot graph settings :

   a) ($V_{s1s2}$, $V_{s2s3}$, $V_{s3s1}$) Vs $\theta_t$

   b) $\theta_r$ Vs $\theta_t$



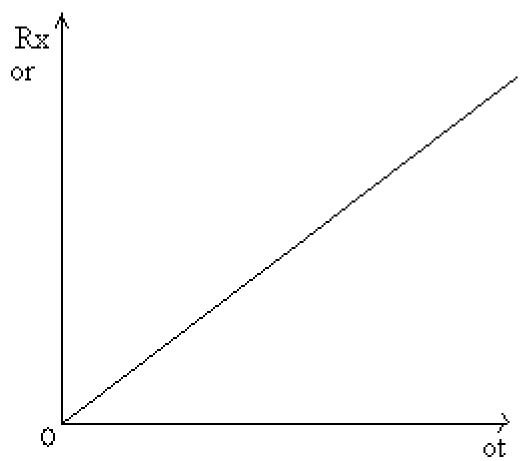
TRANSMITTER CHARACTERISTICS

| S.NO | TRANSMITTER | RECEIVER |
|---|---|---|
| | | |
| | | |
| | | |

**OBSERVATIONS :**

| S.NO | ROTOR POSITION | $V_{S3S1}$ | $V_{S1S2}$ | $V_{S3S2}$ |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**GRAPHS :**




Transmitter Rotor Position Vs Receiver Rotor Position

**RESULT :**

The characteristics of synchros are obtained from the graphs drawn.

# 6.3. EFFECT OF FEED BACK ON DC SERVO MOTOR

## AIM :

To Study the effect feed back on D C Servomotor.

## APPARATUS :

| S.No | ITEM | Type | Range | Quantity |
|---|---|---|---|---|
| 1 | D.C servomotor kit | | | 1 |
| 2 | Patch cords | | | As required |

## PROCEDURE :

1. Switch on the main power supply to the kit without the connecting the feedback path.
2. Adjust it to Zero position by using Zero adjustment knob.
3. Varying the input potentiometer (P1) & Tabulate the angular displacement (P5) of Servo motor
4. Note the observation in tabular form
5. Switch off the power supply now connect the feed back path.
6. Switch on the power supply and adjust the gain knob to certain value.

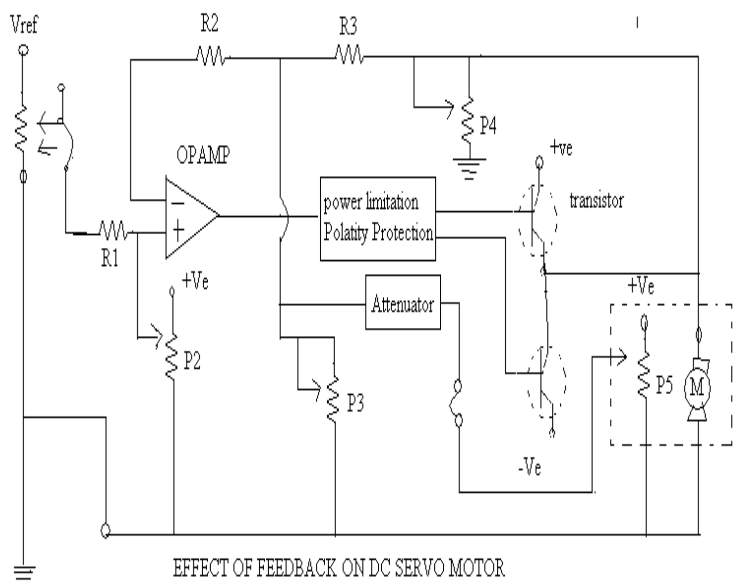
7. Varying the input potentiometer (P1) & Tabulate the angular displacement (P5) of Servo motor.

8. Repeat the procedure for 2 or 3 values of gain. Plot the graph between input and output angular displacement potent

9. Now tabulated the comments observed before and after feed back.

**CIRCUIT DIAGRAM :**

**DC SERVO MOTOR CONTROL SYSTEM**




EFFECT OF FEEDBACK ON DC SERVO MOTOR

**BSERVATIONS**

Without feedback

| S.No | Input angular displacement (decrees) | Output angular displacement (decrees) | Comment |
|---|---|---|---|
| | | | |

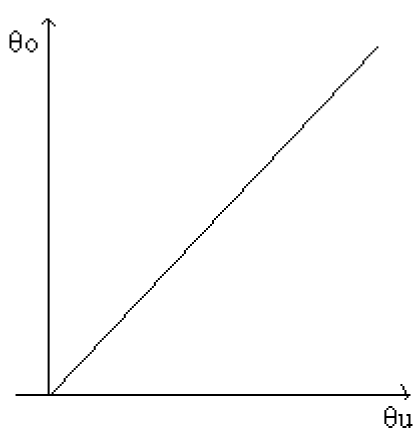
With feedback Gain P1 = Centre position

| S. No | Input angular displacement (decrees) | Output angular displacement (decrees) | Comment |
|---|---|---|---|
| | | | |

With feedback Gain P1 = Maximum position

| S. No | Input angular displacement (decrees) | Output angular displacement (decrees) | Comment |
|---|---|---|---|
| | | | |

**GRAPHS :**




**RESULT :**

The feedback characteristics are drawn & calculated by dc servomotor.

## 6.4. CHARACTERISTICS OF DC SERVO MOTOR

**AIM :**

To Study the D C Servomotor characteristics.

**APPARATUS :**

| S.No | ITEM | Type | Range | Quantity |
|---|---|---|---|---|
| 1 | D.C servomotor kit | | | 1 |
| 2 | Multimeter | | | 2 |
| 3 | Patch cords | | | |

**THEORY :**

DC Servomotor are broadly classified as:-

i) Armature controlled dc servomotor.

ii) Field controlled dc servomotor.

In Armature controlled DC Servo motor the field is excited by a constant dc supply. If the field current is constant then speed is directly proportional to armature voltage and torque is proportional to armature current. Hence torque and speed can be controlled by armature voltage reversible operation is possible by reversing the armature voltage. In small motors the armature voltage is controlled by a variable resistance.

In field controlled dc servomotor the armature is supplied with a constant current or voltage. When armature voltage is constant the torque is proportional to field flux since the field current is proportional to flux, the torque of the motor is controlled by controlling the field current. Reversible operation is possible by reversing the field current the response of field controlled motor is however slowed by field inductance.

$V_a(s) – E_b(s) = (R_a + SLa)\ I_a(s)$

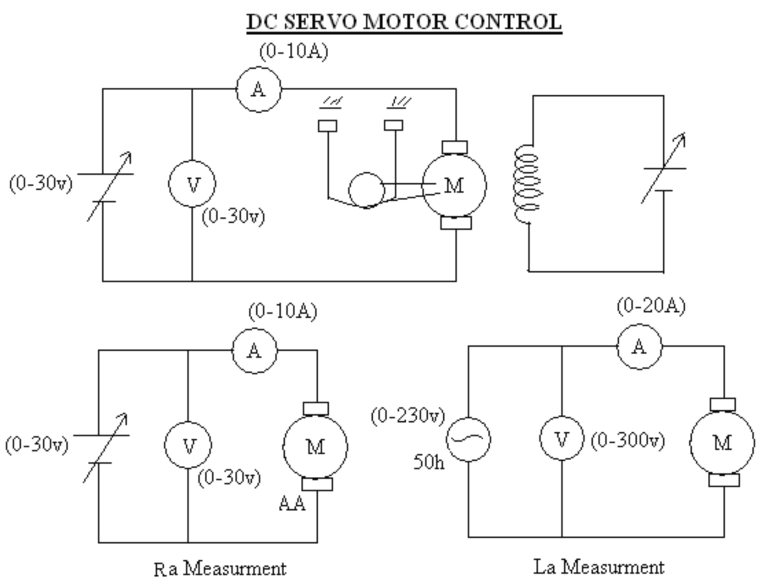
$E_b(s) = K_b\ \omega(s)$

$T(s) = K_T\ I_a(s)$

$T(s) = (JS^2 + fS)\ I_a(s)$

$$\frac{\theta(s)}{Va(s)} = \frac{K_T}{(R_a + SLa)(JS^2 + FS) + K_b K_T S}$$

Circuit diagram :



**PROCEDURE :**

## A) CONNECTION

1. Connect the power supply cables of motor to respective A, AA, F FF terminals on the kit.
2. Connect the speed measurement chord to the kit

## B) DETERMINATION OF $K_T$

1. Switch on the power supply to the kit.
2. Vary the armature voltage such that the motor runs at rated speed
3. Take the no load readings of $V_a$, $I_a$, $V_f$, $I_f$, speed and $S_1$, $S_2$
4. Repeat the step 3 by loading the machine, for 5 to 6 different sets of loads for 10v.
5. Calculate torque $T= (S_2 – S_1)\ 9.81\ r$.
6. Plot the graph between torque TVs Ia, to obtain $K_T$

## C) DETERMINATION OF Kb

1. Conect the circuit as per the circuit diagram and switch on the main power supply
2. Varying the armature voltage in steps and note down Va, Ia , Speed.
3. Bring the armature voltage pot to minimum porition and switch off the supply.
4. Calculate back emf $E_b = V_a – I_a R_a$
5. Plot graph between Eb Vs N and determine the slope of the curve, to obtain $K_b$

## D) DETERMINATION OF Ra

1. Conect the circuit as per the circuit diagram
2. Ensuring that armature is connected to D.C. supply. Switch on the main power supply.
3. Vary the armature voltage in steps and note down armature current
4. Determine Ra = Va/Ia and take the average of it

**OBSERVATIONS :**

**For 8v.**

| S.No. | $S_1$ | $S_2$ | T=9.81 ($S_1$-$S_2$) r Kg – m | Speed Nrpm | $I_A$ amp |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
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| | | | | | |

**For 10v.**

| S.No. | $S_1$ | $S_2$ | T=9.81 ($S_1$-$S_2$) r Kg – m | Speed Nrpm | $I_A$ amp |
|---|---|---|---|---|---|
| | | | | | |
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**BACK –EMF Characteristics:-**

| S. NO. | Armature Voltage $V_A$(V) | $I_A$ (Amp) | SPEED N(rpm) | $\omega$ $2\pi n/60$ (rad/sec ) | Back emf $E_b=V_A+I_AR_A$ | Feed back Voltage $V_f$(V) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
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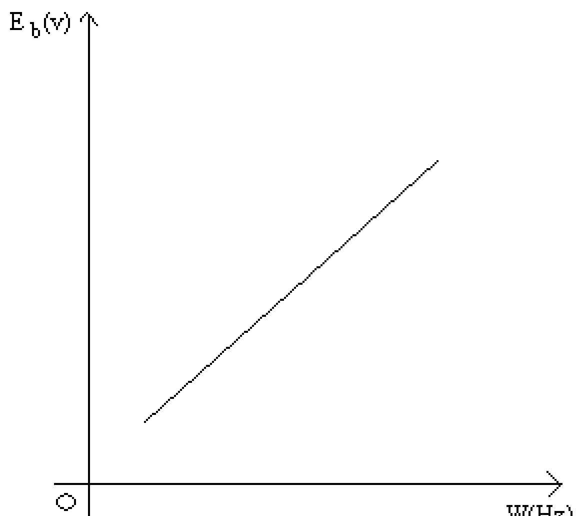
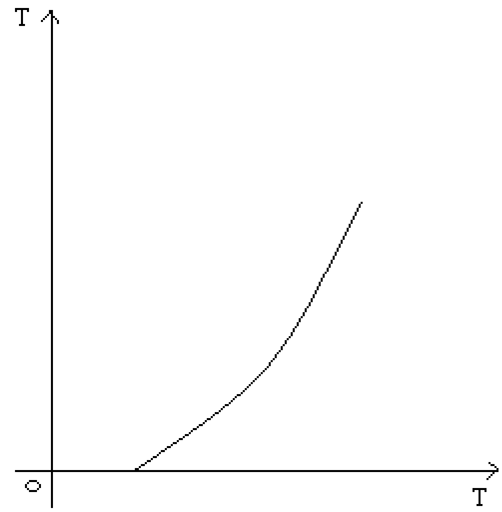
**Graphs :**




**Back emf versus Speed**




**Torque versus Armature current**

1. Determine $Za = \frac{Va}{Ia}$ , Take the average of it
2. Calculate $Xa = \sqrt{Za^1 - Ra^2}$

   $La = Xa / 2\pi f$

**E) DETERMINATION OF La**

3. Conect the circuit as per the circuit diagram
4. Ensure that armature is connected to a.c. supply. Switch ON the main power supply
3. Vary armature voltage in steps and note down armature current.

**RESULT :**

The transferfunction of DC servo motor is thus obtained.

## 6.5 EFFECT OF P, PD, PI, PID CONTROLLER ON A SECOND ORDER SYSTEM

### AIM :

To observe the effect of P,PD,PI,PID Controller on Second Order System.

### APPARATUS:

| S.No | Item | Type | Range | Qty |
|---|---|---|---|---|
| 1 | P,PD,PI,PID Controller Kit | | | 1 |
| 2 | Patch chords | | | As required |
| 3 | C.R.O | | | 1 |

### THEORY :

**INTEGRAL ACTION (I ACTION):**

This is proportional to the integral of error, thus is dependent on the history of the out put and not only the current value. thus, the value of integral action contribution isnot as obvious from the apparent output plot as in case of proportional contribution. The effect of 1 action is to reduce average value of the steady state error. Note that if steady state error is not constant( for example steady state error of sinusoidal + some constant value) then PI controller reduces the dc part ( the average value) to zero and now sinusoidal variation about zero dc value remains. The disadvantage of integral action is that it increases system's setting time. A typical output plot with PI action (proportional+ integral) is shown below. For this Kd is set to zero.

**DERIVATIVE ACTION (D ACTION):**

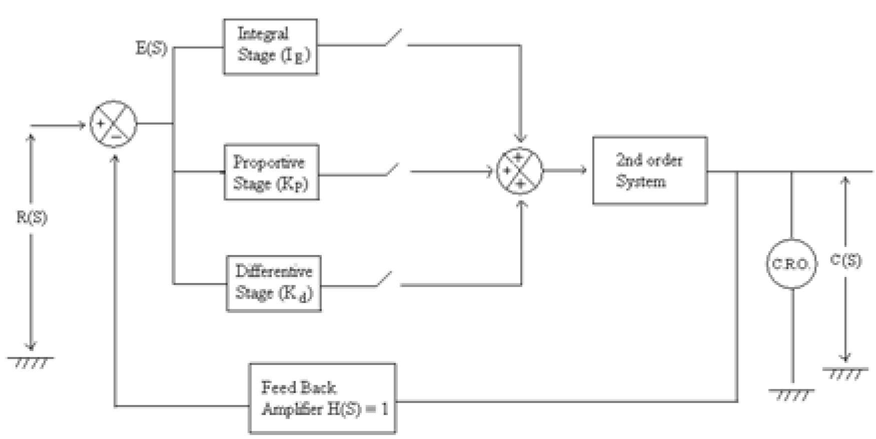
The third term of PID controller transfer equation contributes proportional to the time derivative of error (or rate of change of error). This part is introduced to compensate against the output variations with respect to time.

If steady state error is not constant (for example steady state error of sinusoidal+ some constant value) then PD controller reduces the varying part to zero and the constant steady error of average value remains.

The D action depends on few past and the current error value and not the complete history as in case of integral action. The contribution is high - speed changes in output that may occur because of various reasons. This

also responds to the output variations that may rise due to noise in the sensing, conditioning and feedback network which is unnecessary and hence these parts must be precision type.

**CIRCUTE DIAGRAM :**



**PROCEDURE :**

1. Connect the circuit as per the block diagram shown
2. Switch ON the main power supply and select Input square wave signal of certain amplitude and frequency. Note the input waveform from C.R.o.

**P-Controller:**

3. Switch ON Proportional stage keeping integral, derivative stage in OFF position
4. Vary the proportional gain $K_P$ for 3 to 4 values and note down the Output C(S) waveforms for each value.

**PD Controller:**

5. Switch ON derivative stage keeping integeral stage OFF and fix $K_P$ at certain value.
6. Vary Derivative gain $D_t$ for 3 to 4 values and Note down the Output C(S) waveforms for each value

**PI Controller:**

7. Switch OFF $D_t$ stage, Switch ON Integral stage and Fix $K_P$ at certain value
8. Vary Integral gain Int for 3 to 4 values and note down the output C(S) waveforms for each value.

**PID Controller:**

9. Switch ON all the three controllers fix derivative, Integral controller at certain values.
10. Vary proportional controller gain $K_P$ and note down output C(S) waveforms.
11. Compare the output waveforms for different controller gains and write remarks on the effects of various controller gains on 2$^{nd}$ order system time response specifications.

**RESULT :**

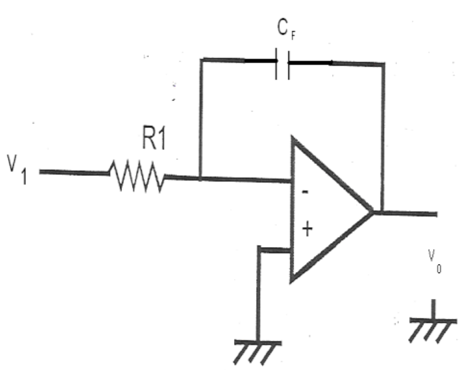
The effect of P, PI, PD, PID controllers are studied

## 6.6. SIMULATION OF OP-AMP BASED INTEGRATOR AND DIFFERENTIATOR CIRCUIT

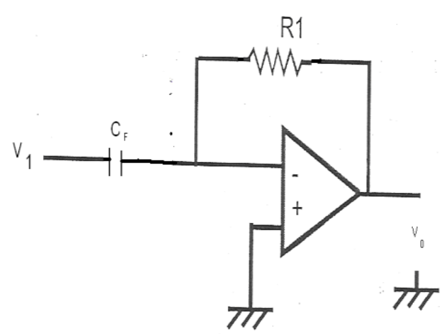
**AIM :** Simulation of Op-amp based differentiator circuit using PSPICE.

**CIRCIUT DIAGRAM:**

INTEGRATOR




DIFFERENTIATOR




**DIFFERENTIATOR**

**PROGRAM:**

.SUBCKT OPAMP 1 2 7 4

EA 4 5 3 4 2E+5

RI 1 2 2E6

GB 4 3 1 2 0.1M

R1 3 4 10K

C1 3 4 1.5619UF

```
R0 5 7 75

.ENDS


Vs 1 0 PWL(0 0 1M 1 2M 0 3M 1 4M 0)

R1 1 2 100

C1 2 3 0.4U

RX 4 0 10K

RL 5 0 100K

RF 3 5 10K

XA1 3 4 5 0 OPAMP

.TRAN 0 4M

.PROBE

.END
```

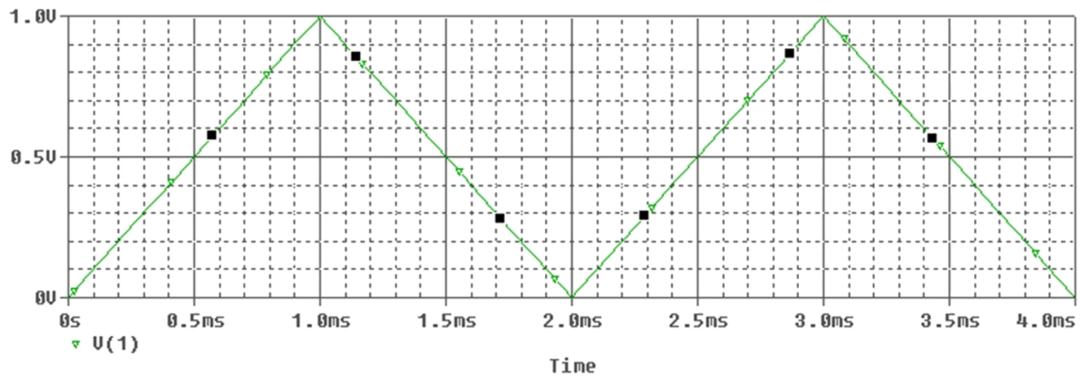
**INTEGRATOR**

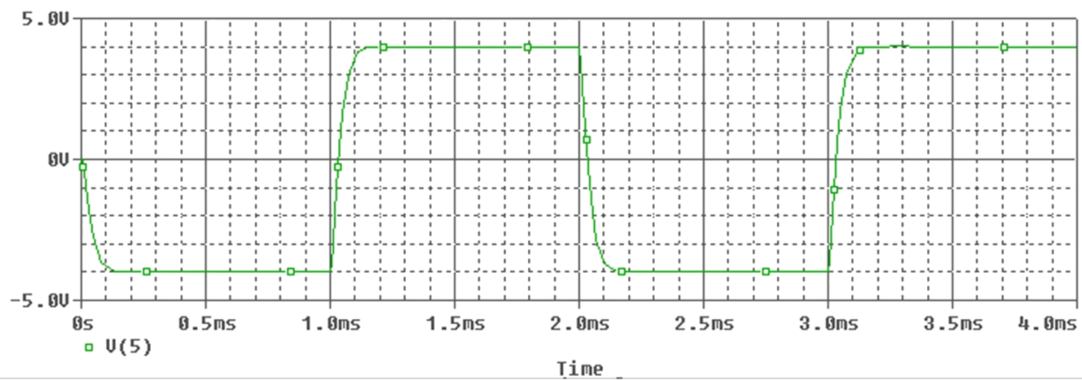
**PROGRAM:**

```
.SUBCKT OPAMP 1 2 7 4

EA 4 5 3 4 2E+5

RI 1 2 2E6

GB 4 3 1 2 0.1M

R1 3 4 10K

C1 3 4 1.5619UF

R0 5 7 75
```

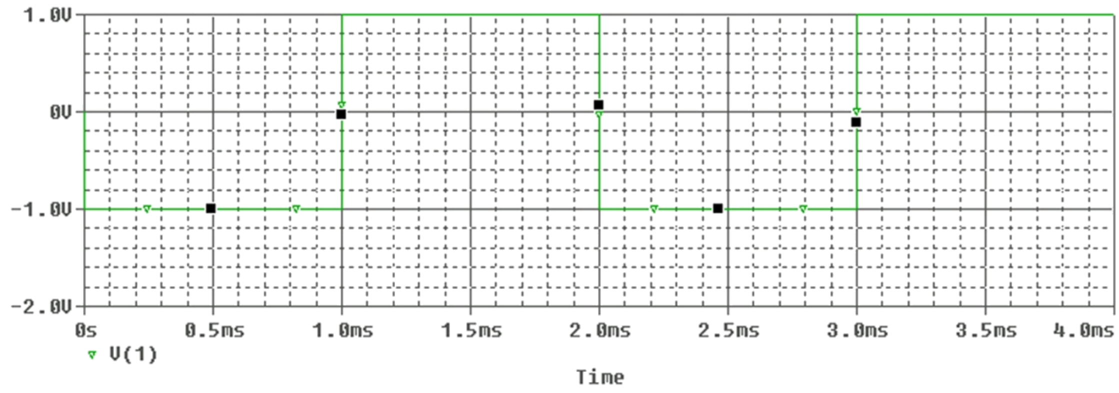
.ENDS

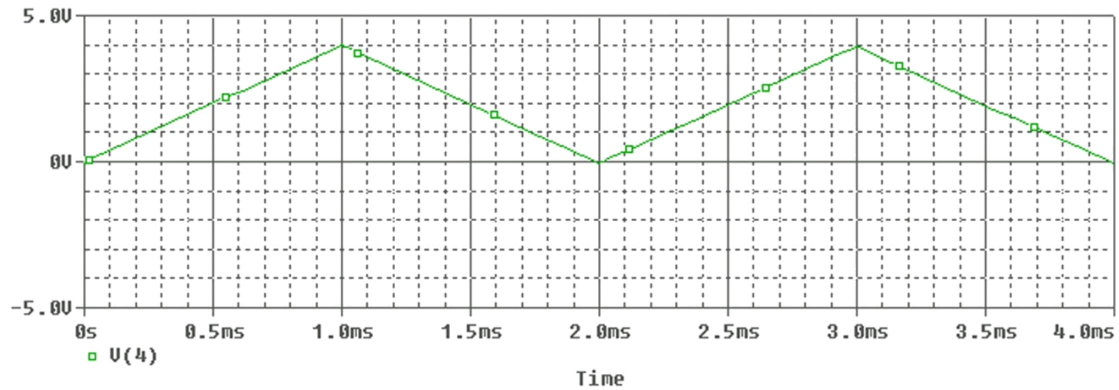
**DIFFERENTIATOR OUT PUT WAVEFORMS:**



**INTEGRATOR OUT PUT WAVEFORMS:**




Vs 1 0 PWL(0 0 1N -1 1M -1 1.0001M 1 2M 1 2.0001M -1 3M -1 3.0001M 1 4M 1)

R1 1 2 2.5K

Rf 2 4 1MEG

Rx 3 0 2.5K

Rl 4 0 100K

C1 2 4 0.1U

XA1 2 3 4 0 OPAMP

.TRAN 0 4M

.PROBE

.END

**Procedure :**

1. Represent nodes for the given circuit
2. Write PSPICE program in the PSPICE text editor and run the program
3. Make the connections if required
4. Observe the output and plot the waveform

**RESULT:**

# 6.7 STUDY OF LAG LEAD COMPENSATION

**AIM :**

To study the characteristics of lag lead compensators

**APPARATUS :**

| S.No | Item | Type | Range | Quantity |
|---|---|---|---|---|
| 1. | LAG LEAD Trainee kit | | | 1 |
| 2 | Patch cords | | | |
| 3 | Multimeter | | | 2 |

**Theory :**

Passive electric components –resistors, capacitors and inductors are used for implementation of a compensator. However the inductor is a very bulky component at low frequencies, passive networks are made up of only resistors and capacitors are used in practice. Condition for reliability of transfer function D(s) with passive resistor capacitor (RC) networks is that all finite poles of D(s) may lie anywhere in s-plane. By taking an operational amplifier to the output of passive RC network, it is possible to realize a specified gain of the compensator.

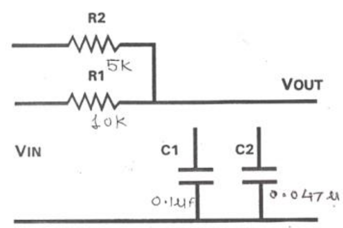
**STUDY OF SIMPLE PHASE LEAD NETWORK:**

Lead compensator has a single pole and a single zero with the pole lying to the left of the zero on the negative real axis of the complex plane. The first order compensator is a lead compensator if $p>z$.

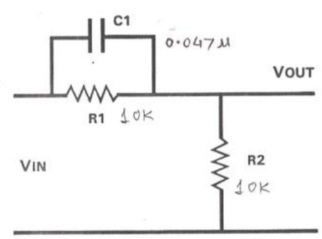
## STUDY OF SIMPLE PHASE LAG NETWOR

A lag compensator has a single pole and a single zero with the pole lying to the right of zero on negative real axis of the complex plane. The first order compensator is therefore a lag compensator if p<z.

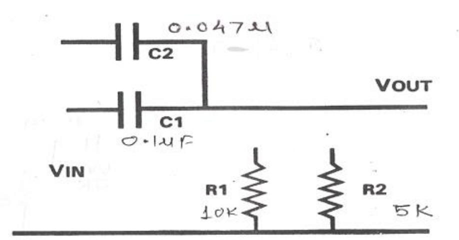
## CIRCUIT DIAGRAM:



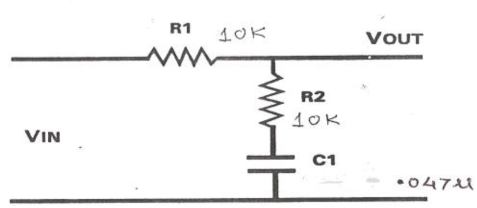

PHASE LAG NETWORK




LEAD COMPENSATOR




PHASE LEAD NETWORK

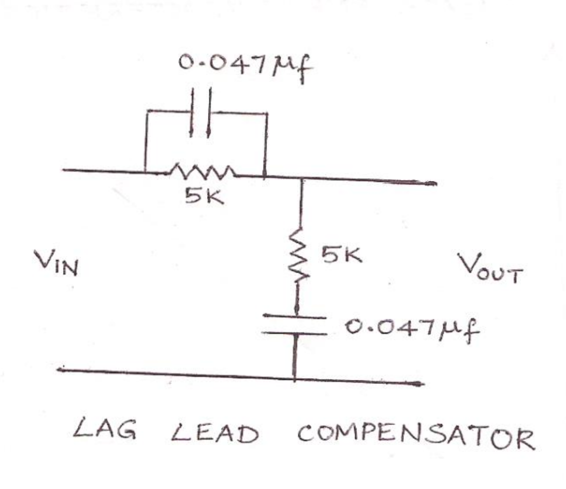



LAG COMPENSATOR

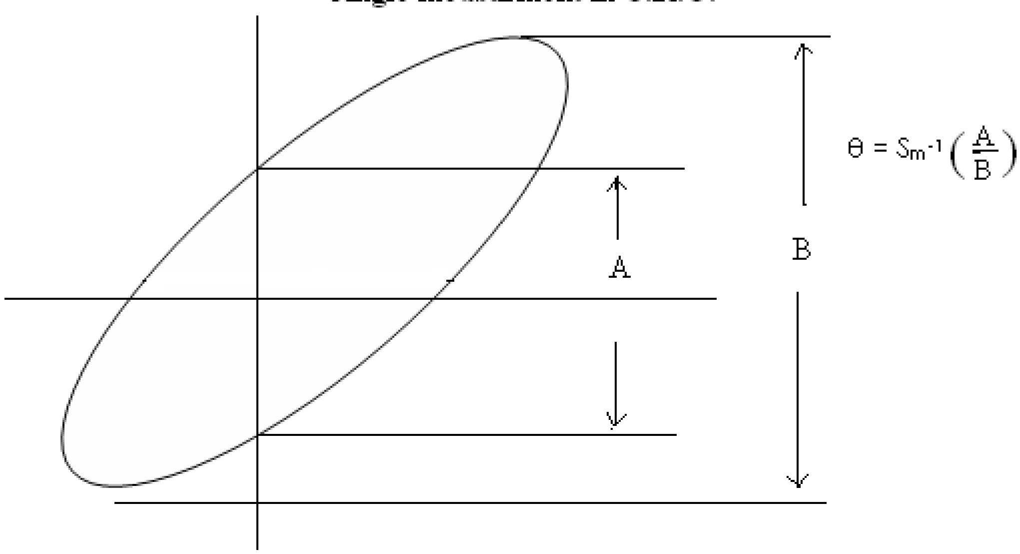
**PROCEDURE:**

1. Connect the circuit as per circuit diagram for phase lag network.

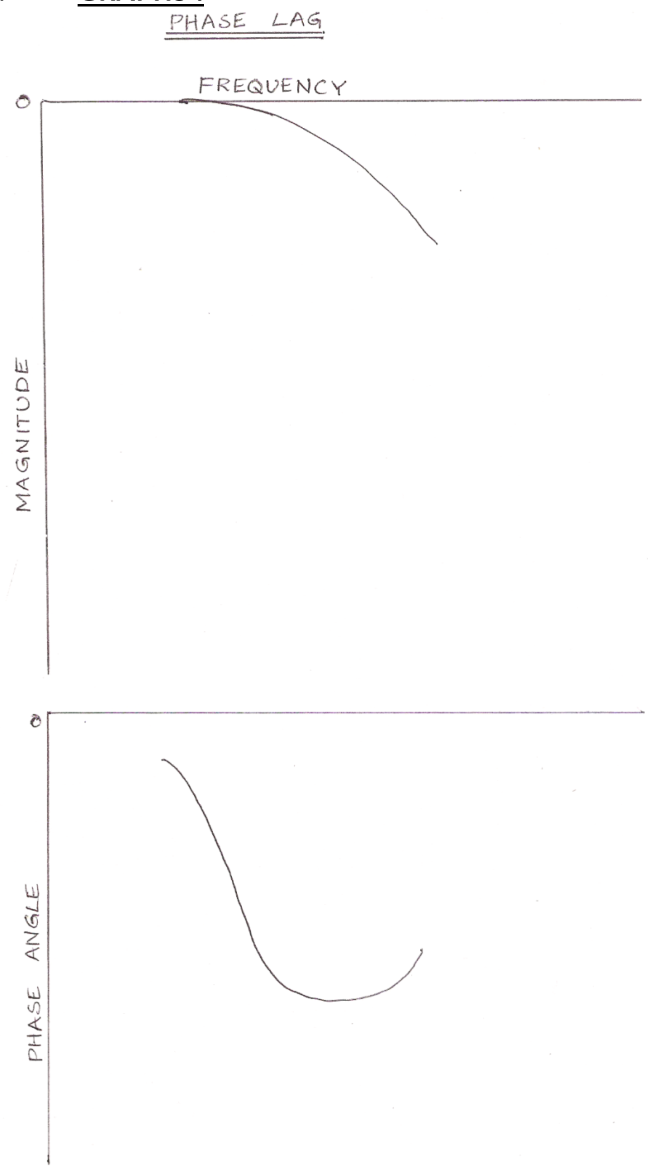
2. Switch ON the power supply to function generator and adjust input sine wave to say 5V.



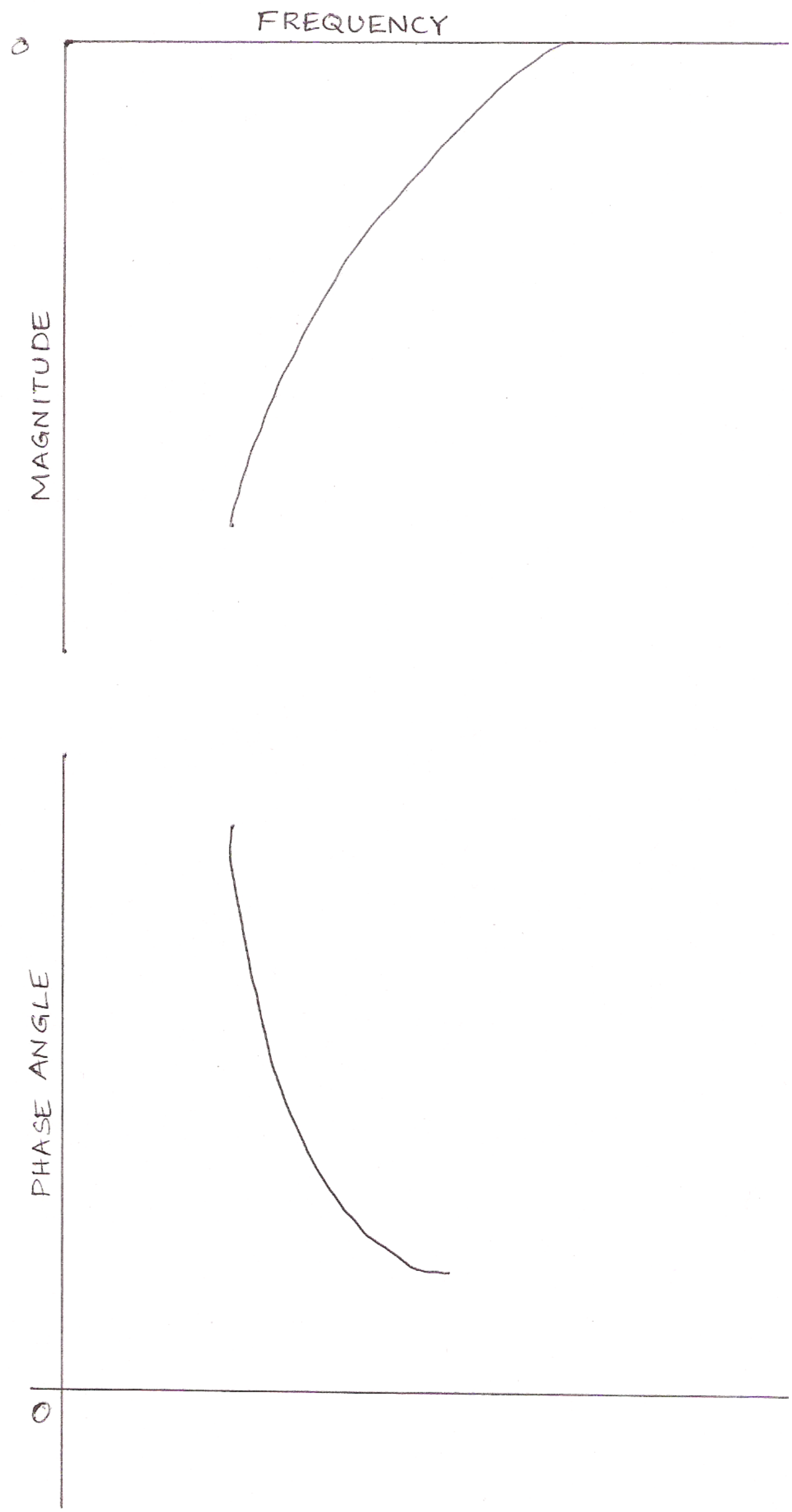

**Angle measurment in C.R.O.**



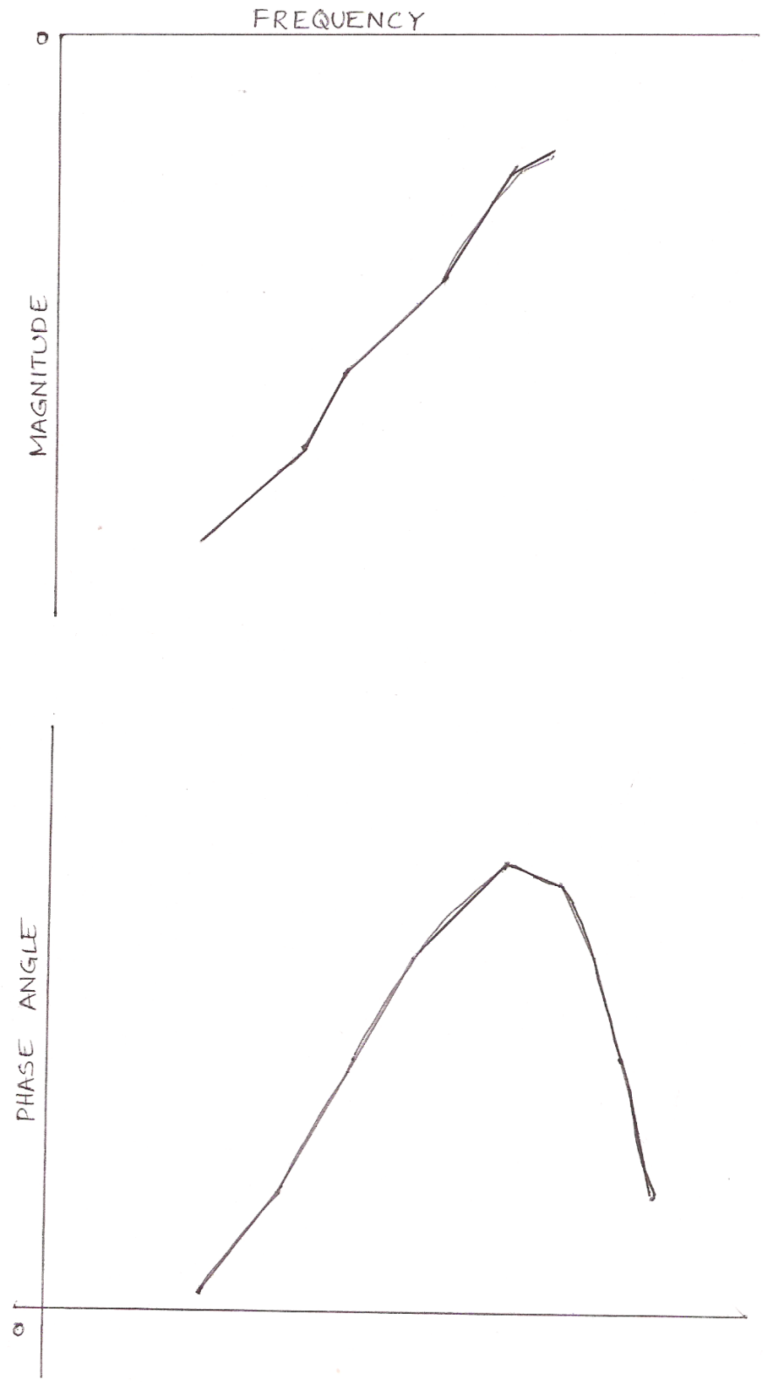
3. C.R.O. is to be connected in X-Y made for phase displacement measurement connect X-input of CRO to input of lag network and Y- input of C.R.O to output of lag network.
4. Slowly vary the input frequency and note down the output magnitude to calculate gain │T (jw)│ and change in phase shift ∟T(jw) using lassjous figures concept
5. Calculate the theoretical values of [T (jw) ] and θ from the formula given above.
6. Plot the graphs of [T(jw) ] and θ adjusting frequency. Find the common frequency.
7. Repeat the above procedure for lead network, lead compensator, lag compensator.
8. Draw bode plot for all the system.
9. **GRAPHS :**



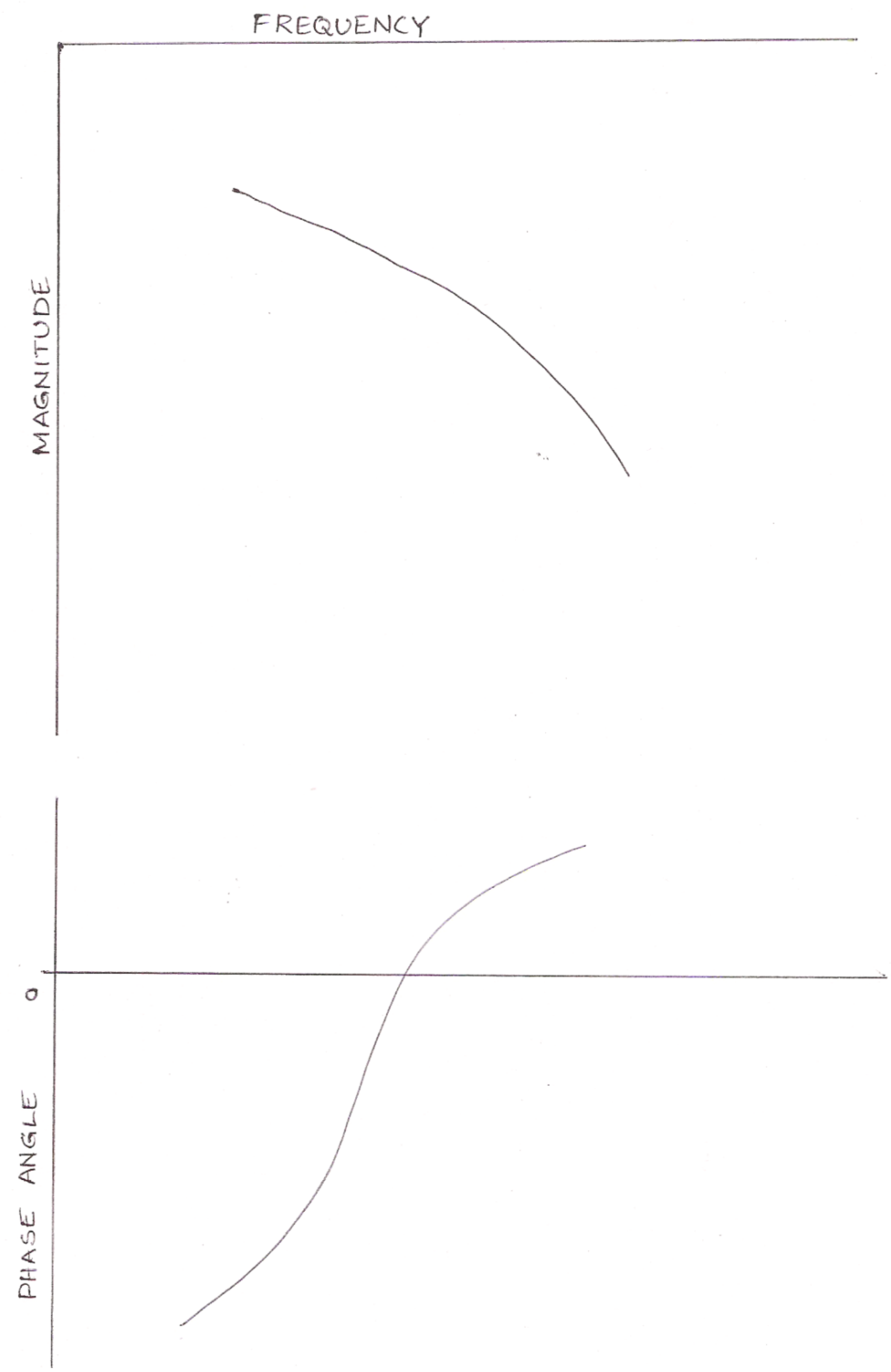
# PHASE LEAD



## LEAD COMPENSATOR



LEAD LAG COMPENSATOR



## OBSERVATIONS:

### LAG NETWORK:

| | | | | Practical | | Theoretical | |
|---|---|---|---|---|---|---|---|
| S. No. | f (Hz) | $V_o$ (V) | $V_i$ (V) | $\|T(j\omega)\|$db 20 log $\|T(jw)\|$ | $\theta$ Degrees | $\|T(j\omega)\|$ | $\theta$ |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |

**LEAD NETWORK:**

| | | | | Practical | | Theoretical | |
|---|---|---|---|---|---|---|---|
| S. No. | f (Hz) | $V_o$ (V) | $V_i$ (V) | \|T(jω)\|20 log \|TLjw\|db | θ Degrees | \|T(jω)\| | θ |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |

**LAG COMPENSATOR:**

| | | | | Practical | | Theoretical | |
|---|---|---|---|---|---|---|---|
| S. No. | f (Hz) | $V_o$ (V) | $V_i$ (V) | IT(jω)\|db 20 log \|T(jw)\|) | θ | \|T(jω)\| | θ |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |

**LEAD COMPEASATOR:**

| Practical Theoretical | | | | | | | |
|---|---|---|---|---|---|---|---|
| S. No. | f (Hz) | $V_o$ (V) | $V_i$ (V) | $\|T(j\omega)\|$ db 20 log $\|T(jw)\|$ | $\theta$ | $\|T(j\omega)\|$ | $\theta$ |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |

**RESULT:** Thus the design of lag lead compensator network has been verified.

## 6.8. CHARACTERISTICS OF MAGNETIC AMPLIFIER

**AIM:**

To study the characteristics of magnetic amplifier.

| S.NO | ITEM | TYPE | RANGE | QUANTITY |
|---|---|---|---|---|
| 1 | Magnetic Amplifier Kit | | | 1 |
| 2 | Patch Cords | | | |
| 3 | Multimeter | | | 1 |

**APPARATUS:**

**THEORY:**Amplification is the control of a larger output quantity by the variation of a small input quantity. Magnetic device used to perform such ctrl is the magnetic amplifier. The combination of saturable reactor with rectifier is called magnetic amplifier.

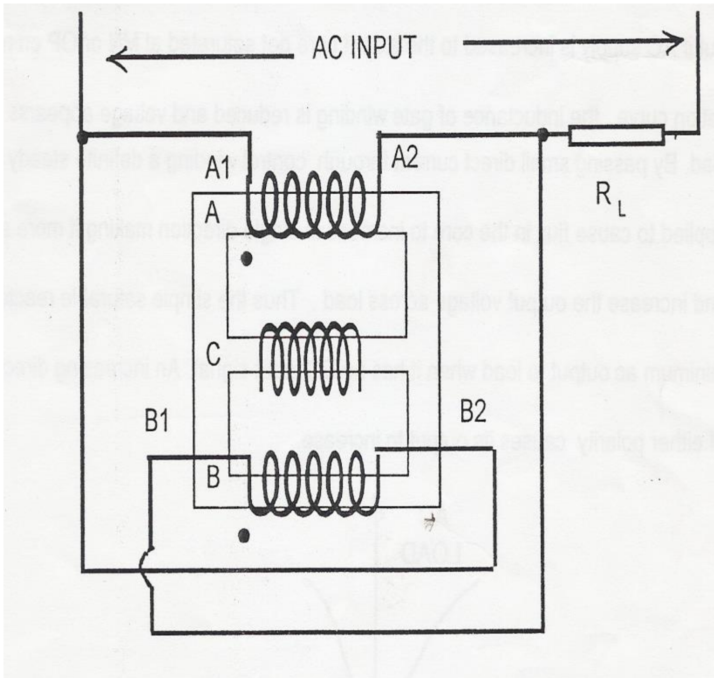
**Saturable reactor:-** This device acts as a variable inductance connected in series with a load across an a c power supply. It is nothing but a transformer, having two or more windings around a core of steel core A&B has it's own ac windings connected her in phase opposition so that when flux moves to the right with in the upper A coil an equal flux moves to the left with in the lower B coil with in the ctrl coil Two flux movements are in opposite direction. There by no objectionable ac voltage is induced in the control winding.

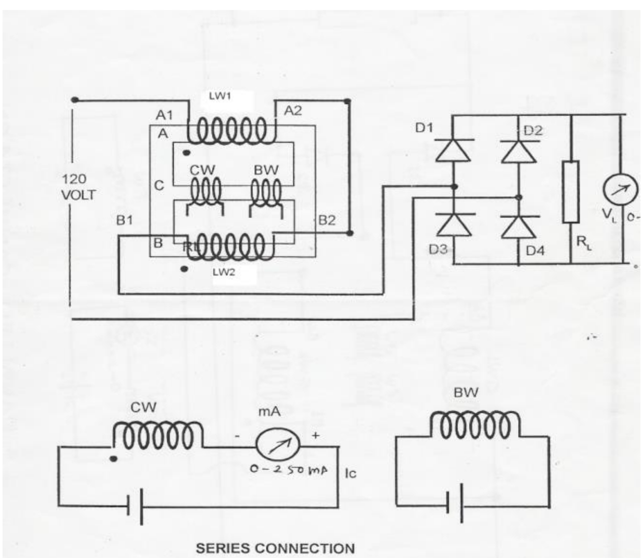
**Operation**:- Gate winding is when operated sin. O&M the voltage across load is very small. But if ac supply is increase to the extent core get saturated at MN or OP on magnetization curve, the inductance of gate winding is reduced & voltage appears across load by passing small dc through control windings .a definite steady MMF is applied to cause flux in the core to increase in single direction making it more saturated and increase the o/p voltage across the load.

**Magnetic Amplifier :-** When Si diode are added in series with each gate winding of the saturable reactor. It becomes self saturated reactor also called as magnetic amplifier.

**Effect of connecting diode:-** When AC power is first applied to the circuit small magnetizing current flown in gate winding and produces initial flux x. during first part of second wave the core flux raises from x to y and during reverse current , the part of y say y flux remains in core. In succeeding cycles, the flux in core is increase to such an extent that the core operate on the flat portion of the curve through out the entire half cycle. Thus although no direct current yet flows in the ctrl

## CIRCUIT DIAGRAM:



**PROCEDURE:**

**a) Parallel connection:-**

1. Make the connections as shown in circuit diagram.
2. Make power on to the circuit .
3. Keep Cw dc supply and Bw dc supply to zero .note load voltage.
4. Adjust Bw dc supply to get minimum load voltage($V_L$).
5. Now slowly increase the Cw dc supply in steps and note the ctrl current and load current .
6. Plot the graph of load current against control current .
7. Calculate the gain of amplifier A= $\frac{\Delta I_L}{\Delta I_c}$ .
8. Calculate power gain = $\frac{V^2{}_L / R_L}{V_{DC} I_{DC}}$

**Observations:**

**Series Connection:-**

| S.NO | $I_C$ (ma) | $V_{DC}$(v) | $V_L$(v) | $I_L = \frac{V_L}{R_L}$ |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**A=** **P=**

**Parallel Connection:-** **$R_{L}$=**156Ω .

| S.NO | $I_C$ (ma) | $V_{DC}$(v) | $V_L$(v) | $I_L = \frac{V_L}{R_L}$ |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Gain A**

windings on the central leg of the core , the reactor has become self saturated, entirely because of the action caused by gate windings combined with diode.

**Bias windings:-** However like Cw if extra winding is provided with fixed dc bias to self saturated reactor, then in power on condition , reactor will be unsaturated and load current is small. If required the dc bias of bias windings can be fixed to get zero current of ctrl winding at any desired it on the curve of load current.

**RESULT:**

**Thus the characteristics of Magnetic Amplifier determined and its gain is calculated.**

| **SERIES** | **PARALLEL** |
|---|---|
| **A=** | **A=** |
| **P=** | **P=** |

## 6.9. ROOT LOCUS AND BODE PLOT USING MAT LAB

**AIM:** To plot root locus and bode plot from the mat lab.

**APPARATUS:** Computer with MATLAB software.

**THEORY:**

COMMAND 1: CLC: It clears the MATLAB command window

COMMAND 2: CLEAR: it clears the MATLAB work shop variables.

COMMAND 3: DISP: Syntax – disp (variable): It displays the variable specified on command window.

COMMAND 4: PAUSE: With this command the execution will be stopped and it waits for the enter key.

COMMAND 5: INPUT: Syntax: Variable = Input ('Comment');

COMMAND 6: PERCENTAGE: It is used at the beginning of any statement to make it as a comment in the program.

COMMAND 7: R-LOCUS: Syntax: r locus (Variable): With this we can plot the root locus of any transfer function. That means in the above syntax the variable is nothing but a transfer function.

COMMAND 8: BODE: Syntax: Bode (Variable): With this command we can get bode plot of the given transfer function.

COMMAND 9: MARGIN: Syntax: Margin (Variable): With this command we can get gain and phase margin of a bode plot of the given transfer function.

COMMAND10: SS: Syntax: Variable1= SS(Variable2): With this command we can get state space model for the given transfer function. Variable 2 is a transfer function and variable 1 holds the SS model.

COMMAND11: SS DATA: Syntax: [a,b,c,d] = Ssdata (Variable):

With this command we can retrieve the a,b,c,d matrices of a state space model. Variable holds the state space model.

**PROCEDURE:**

1. Write the programmme in MATLAB text editor using mat lab instructions for state model of classical transfer function and for transfer function from state model.
2. Run the programs.
3. Note down the outputs.

**PROGRAM:**

```
Num = input (“Enter numerator polynomial values in the form of matrix array” );

num = input (“Enter denominator 1 values” );

den = input (“Enter denominator 2 values” );

den = conv (num,den);

H = tf (num,den);

r locus (H);

pause;

Bode(H);

Pause;

Margin(H);

nyquist (H);

pause;

end
```

**RESULT:**

The root locus, bode plot and nyquist plot of a transfer function were plotted using MATLAB software.

## 6.10. STATE MODEL FOR CLASSICAL TRANSFER FUNCTION & VICE VERSA USING MATLAB

**AIM:**

To find state model for classical transfer function and transfer function from state model using MATLAB.

**APPARATUS:** Computer with MATLAB software

**THEORY:**

COMMAND 1: CLC: It clears the MATLAB command window

COMMAND 2: CLEAR: it clears the MATLAB work shop variables.

COMMAND 3: DISP: Syntax – disp (variable): It displays the variable specified on command window.

COMMAND 4: PAUSE: With this command the execution will be stopped and it waits for the enter key.

COMMAND 5: INPUT: Syntax: Variable = Input (‘Comment’);

COMMAND 6: PERCENTAGE: It is used at the beginning of any statement to make it as a comment in the program.

COMMAND 7: R-LOCUS: Syntax: r locus (Variable): With this we can plot the root locus of any transfer function. That means in the above syntax the variable is nothing but a transfer function.

COMMAND 8: BODE: Syntax: Bode (Variable): With this command we can get bode plot of the given transfer function.

COMMAND 9: MARGIN: Syntax: Margin (Variable): With this command we can get gain and phase margin of a bode plot of the given transfer function.

COMMAND10: SS: Syntax: Variable1= SS(Variable2): With this command we can get state space model for the given transfer function. Variable 2 is a transfer function and variable 1 holds the SS model.

COMMAND11: SS DATA:Syntax: [a,b,c,d]=SSdata (Variable):

With this command we can retrieve the a,b,c,d matrices of a state space model. Variable holds the state space model.

**PROCEDURE:**

1. Write the programme in MATLAB text editor using mat lab instructions for state model of classical transfer function and for transfer function from state model.
2. Run the programs.
3. Note down the outputs.

**PROGRAM 1:**

```
a= input ( "Enter the values of a matrix" );

b= input ( "Enter the values of b matrix" );

c= input ( "Enter the values of c matrix" );

d= input ( "Enter the values of d matrix" );


[num , den] = SS2 tf  (a,b,c,d,1)

S1=tf  (num(1, : ) , den );

S2=tf  (num(2, : ) , den );

 [num1 , den1 ] = SS2 tf  (a,b,c,d,2);

S3=tf  (num1 (1, : ) , den1 );

S4=tf  (num1 (2, : ) , den1 );

DISP [S1,S2,S3,S4 ];
```

**PROGRAM 2:**

```
Num = input ("Enter numerator polynomial values in the form of matrix array" );
den1 = input ("Enter denominator 1 values" );
den2 = input ("Enter denominator 2 values" );
den = conv (den1,den2);
H = tf (num,den);
P = SS(H);
[a,b,c,d] = SS data(P);
```

**RESULT:**

The state model for classical transfer function and transfer function from state model are obtained using MATLAB software.

## 6.11. CHARACTERISTICS OF AC SERVOMOTOR

**AIM:**

To determine the speed torque characteristics of AC Servomotor

**APPARATUS:**

| Sl. No. | Item | Type | Range | Quantity |
|---|---|---|---|---|
| 1 | A.C Servomotor Kit | | | 1 |
| 2 | Multimeter | | | 1 |
| 3 | Patch cords | | | |

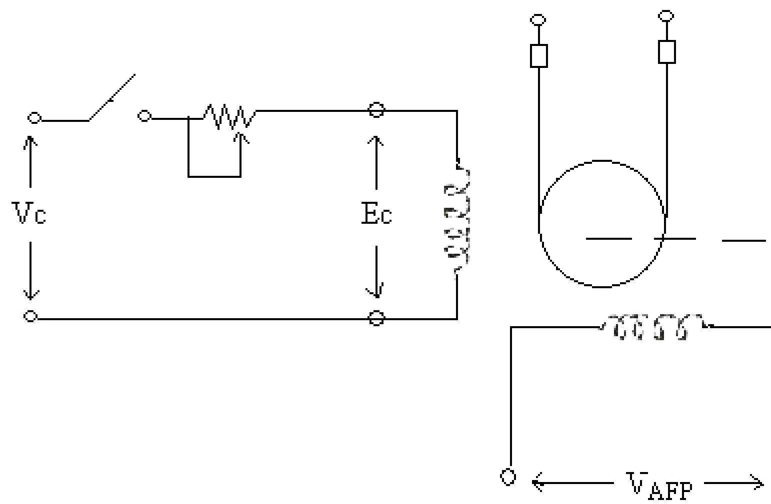
**THEORY:**

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 degrees. Generally voltages of equal magnitude and 90 degrees phase difference are applied to the two stator phases thus making their respective fields 90 degrees apart in both time and space at synchronous speed.

The stator windings are excited by voltages of equal r.m.s magnitude & $90^0$ phase difference these currents give rise to a rotating magnetic field of constant magnitude the direction of rotation depends of on the phase relationship of the two currents (or voltages) the exciting currents produce a clock wise rotating magnetic field & phase shift of $180^0$ in $i_1$ will produce an anti clock wise rotating magnetic field.

Due to the interaction of stator &rotor flux, a mechanical force (or torque) is developed on the rotor & so the rotor starts moving in same direction as that of rotating magnetic field.

**CIRCUIT DIAGRAM:**




**PROCEDURE**

1. Ensure that all control pots are in minimum position and motor brake drum is free to rotate.
2. Switch on the power supply and adjust the control voltage to a certain value and fix it.
3. Note down the No-load speed
4. Now load the motor by tightening the wheels of spring balance. Note down speed, $S_1$, & $S_2$ values.
5. Repeat step 4 by increasing the load for 4 different set of loads.
6. Now remove the brake on the motor by loosening the wheels
7. Fix the control voltage at 4 different values and for each value perform steps 3,4,5.
8. Calculate torque and plot Torque VS speed characteristic for different control voltages.

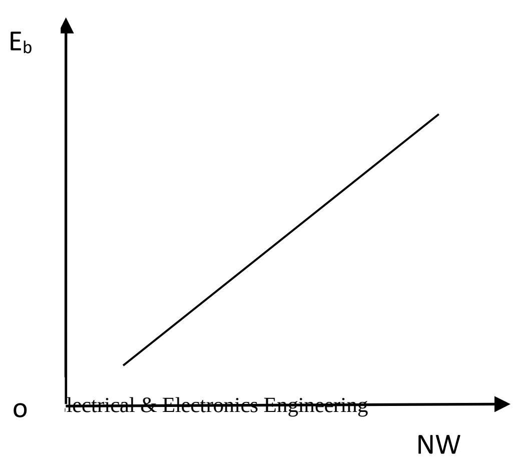
## OBSERVATIONS:

| S.No | SPEED(r.p.m) | $E_b$(Volts) |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

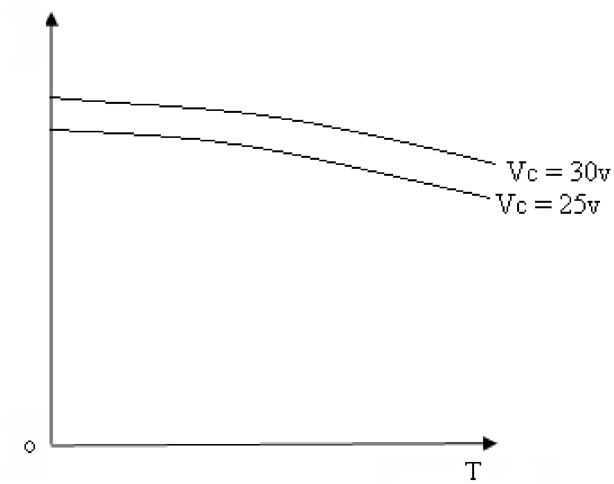
| S.No | $V_C$ (V) | N (r.p.m) | $S_b$ | $S_2$ | Torque |
|---|---|---|---|---|---|
| | | | | | |

## GRAPHS

**BACK EMF CHARACTERISTICS**



SPEED-TORQUE CHAEACTERISTIC




**RESULT:** Speed torque characteristics of AC Servomotor are observed.

## 6.12. PROGRAMMABLE LOGICAL CONTROLLER

**AIM:**

To implement various logics using PLC trainer

**APPARATUS:**

PLC – 51
EPROM Chip
FANMOTOR
COMPUTER
CONNECTING CHORD

**THEORY:**

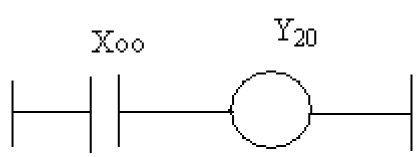
A programmable controller, formerly called as programmable logic controller PLC can be defined as a solid state device member of the computer family. It is capable of strong instructions to implement control function such as servicing timing, counting arithmetic, data manipulation & communication to control industrial machines & processed.

PLC Programming:

Implement the following ladder network (shown in figure)

**1. PROGRAM:**

LD 0 0
OUT 20
END



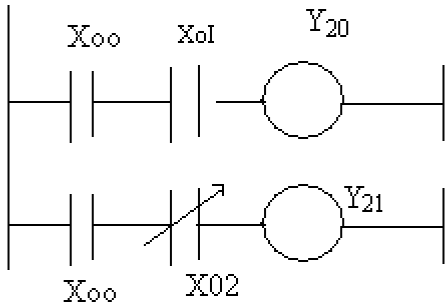

**LADDER NETWORK I**

**2. PROGRAM:**

To implement the following ladder Network.

LD 0 0
AMD 01
OUT 20
LD 00
ANI 02
OUT 21

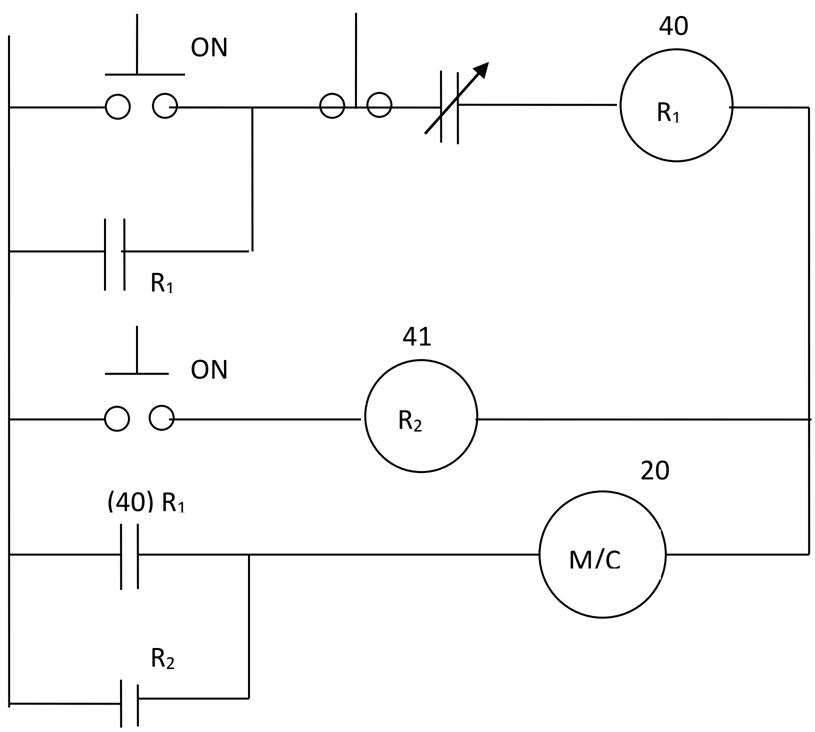
END




**LADDER NETWORK II**

**3. PROGRAM:**

Implement the following mechanical logic using PLC
LD 00
OR 40
ANI 01
ANI 41
OUT 40
LD 01
OUT 41
LD 40
OR 41
OUT 20
END




(41)

**MECHANICAL LOGIC USING PLC**

**LOGIC:**

The above circuit uses internal relays. There are 16 relays M & M & M. Here we use the relays 40 & 41. Once 00 is ON & output 20 is ON permanently. Once 01 is ON, R gets off but N is On. So 20 continues to be ON but when 01 is removed 20 gets OFF because M does not have a feedback as mechanism as M.

**RESULT:**

The above programs

# 7 Content beyond syllabus:

1) Simulation of block diagram
2) Simulation of  practical circuit diagram control system.

## 8 Sample Viva Voce Questions

**Exp 1:**

1. What is delay time?
2. What is rise time?
3. What is peak time?
4. What is peak overshoot?
5. What is settling time?

**Exp 2:**

1. What is a synchro?
2. What is the use of synchro?
3. What is the constructional difference between synchro transmitter & synchro receiver?
4. What is the relation between a synchro & a transformer?
5. Where do we get maximum e m f in a synchro?
6. When we will get maximum e m f in a synchro?
7. What is the phase different between three voltages induced in the stator of synchro and why ?
8. How do you determine zero position of synchro
9. what is the error voltage induced ?

**Exp 3:**

1. What is a servomotor?
2. What are the applications of servomotor?
3. How do you load the D.C Servomotor?
4. Why a servomotor should not be switched on load?
5. What are the elements used as feedback

6. What are the general input and o/p parameters of D.C. servomotor
7. What is the element used as error detector in the given circuit.

**Exp 4:**

What is a servomotor?

2. What are the applications of servomotor?
3. How can we get the feed back characteristics of D.C Servomotor?
4. How do you load the D.C Servomotor?
5. Why a servomotor should not be switched on load?
6. What is a mathematical model ? What is its importance?
7. How do you define transfer function? What is its significance?
8. What are $K_b$, $K_T$

**Exp 5:**

1. What is the use of a controller in control system?
2. What is the use of proportionality controller?
3. Why is integral controller used?
4. Why is differential controller used?
5. How can you rectify an error using controller?
6. What is meant by sampling network?
7. How do you sense the errors in a control system?
8. What do you mean by tuning of controller?
9. Which controller is most commonly used?

**Exp 6:**

1. What is the instruction used for plotting bode plot
2. do we get transfer function of a control system using MATLAB?

3. How do you load the A.C Servomotor?

**Exp 7:**

1. What is the formula for calculating phase angle?
2. What is the formula magnitude of phase lead circuit lag network & loss?
3. What is the difference between lag network & low pass filter?
4. What is meant by compensation?
5. How a lag network can be compensated?

**Exp 8:**

1. What is a magnetic amplifier?
2. What is the difference between magnetic amplifier & electronic amplifier?
3. Which amplifier (series parallel) gives maximum amplification?
4. What is the need of control winding?
5. What is the need of bias winding?

**Exp 9:**

1. What is MATLAB?
2. What are the applications of MATLAB?
3. What is the instruction used for plotting root locus?
4. What is the instruction used for plotting bode plot?
5. How do we get transfer function of a control system using MATLAB?
6. How many windows does it has?

7. How do you differentiate C language programming with MATLAB?

**Exp 10:**

1. What is MATLAB?
2. What are the applications of MATLAB?
3. What is the instruction used for plotting root locus?
4. What is the instruction used for plotting bode plot?
5. How do we get transfer function of a control system using MATLAB?

**Exp 11:**

1. What is a servomotor?
2. What are the applications of servomotor?
3. How can we get the feed back characteristics of A.C Servomotor?
4. How do you load the A.C Servomotor?
5. Why a servomotor should not be switched on load?
6. How can a A.C servomotor be controlled?

9**. Sample Question paper of the lab external**

. 1. plot the wave form Time Response of Second order system

2. Study of characteristics of Synchros

3.studu the Effect of feedback on DC servo motor

4. calculate the Transfer function of DC motor

5. plot the Effect of P, PD, PI, PID controller on a second order systems

6. Simulate the OP – AMP based integrator and differentiator

8. Study the performance of Lag leg compensation

9. draw the Characteristics of magnetic amplifier

10. plot Root locus Bode plot from MATLAB

11. find the State space model for classical transfer function using MATLAB Verification

12. draw the Characteristics of AC servo motor

13 Perform the experiment on Programmable logic controller

14 Study the Stability analysis

15 Find the State space model for classical transfer function .

## *10. Applications of the laboratory*

1) To find the state space model of control system

2) To find the second order system output

3) to know the closed loop system

4) to find the stability of control systems

5) plot the locus diagram for second and higher order system

## 11. Precautions to be taken while conducting the lab

**SAFETY – 1**

Power must be switched-OFF while making any connections.

- Do not come in contact with live supply.
- Power should always be in switch-OFF condition, EXCEPT while you are taking readings.
- The Circuit diagram should be approved by the faculty before making connections.
- Circuit connections should be checked & approved by the faculty before switching on the power.
- Keep your Experimental Set-up neat and tidy.
- Check the polarities of meters and supplies while making connections.
- Always connect the voltmeter after making all other connections.
- Check the Fuse and it's ratify.
- Use right color and gauge of the fuse.
- All terminations should be firm and no exposed wire.
- Do not use joints for connection wire.

**SAFETY – II**

1. The voltage employed in electrical lab are sufficiently high to endanger human life.
2. Compulsorily wear shoes.
3. Don't use metal jewelers on hands.
4. Do not wear loose dress

Don't switch on main power unless the faculty gives the permission

**12. Code of Conduct**

1. Students should report to the labs concerned as per the timetable.

2. Students who turn up late to the labs will in no case be permitted to perform the experiment scheduled for the day.

3. After completion of the experiment, certification of the staff in-charge concerned in the observation book is necessary.

4. Students should bring a notebook of about 100 pages and should enter the readings/observations/results into the notebook while performing the experiment.

5. The record of observations along with the detailed experimental procedure of the experiment performed in the immediate previous session should be submitted and certified by the staff member in-charge.

6. Not more than three students in a group are permitted to perform the experiment on a set up.

7. The group-wise division made in the beginning should be adhered to, and no mix up of student among different groups will be permitted later.

8. The components required pertaining to the experiment should be collected from Lab-in-charge after duly filling in the requisition form.

9. When the experiment is completed, students should disconnect the setup made by them, and should return all the components/instruments taken for the purpose.

10. Any damage of the equipment or burnout of components will be viewed seriously either by putting penalty or by dismissing the total group of students from the lab for the semester/year.

11. Students should be present in the labs for the total scheduled duration.

12. Students are expected to prepare thoroughly to perform the experiment before coming to Laboratory.

13. Procedure sheets/data sheets provided to the students' groups should be maintained neatly and are to be returned after the experiment.

## 13. Graphs if any.