SCHOOL OF ELECTRICAL ENGINEERING
(SELECT)

B.Tech. (Electrical and Electronics Engineering)

ACADEMIC YEAR: WINTER 2015

EEE226 CONTROL SYSTEM LABORATORY MANUAL

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Lab Slot: L3+L4

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INSTRUCTIONS TO STUDENTS

- Control System lab experiments are designed with both software simulation and hardware experiments.
- For each and every lab session, before the lab, the student would be expected to write down the aim, theory etc. of the experiment.
- For software experiments, a basic outline about the necessary algorithm for developing the required program would be given in the lab class. The students after clarifying the necessary doubts should proceed with the execution of the program.
- For the hardware experiments, the students should write the aim, theory of the experiment and the procedure for completing the study.
- Follow the rules and regulations of the laboratory.
- Wear closed shoes while entering the laboratory.
- Maintain discipline inside the laboratory.
- Prepare the observation / record note book neatly. Draw the required diagrams with the aid of scale and pencil.
- Use procircles for drawing measuring instruments.
- Prepare well for answering viva questions.
- Don't switch on the power supply in the absence of Faculty / Staff.
- Get the readings verified by the Faculty before disconnecting the circuit components.

TRANSFER FUNCTION OF SEPERATELY EXCITED DC GENERATOR.

EXPT. NO: H.1 **DATE:**

AIM: To obtain the transfer function of Separately Excited DC generator.

APPARATUS REQUIRED:

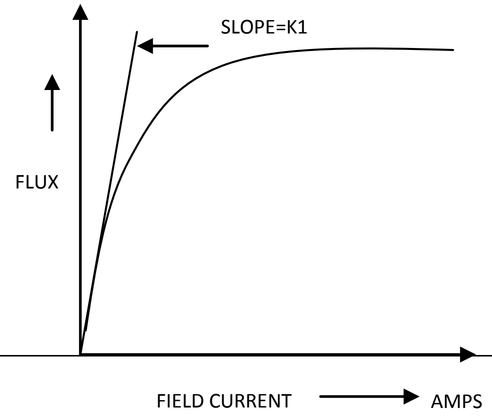
S.No	Item	Specification / Range	Quantity
1.	DC generator trainer kit		
2.	DC motor – Generator set	0.5HP/180V/1500 rpm.	
3.	Patch cords		

THEORY:

A DC generator can be used, as a power amplifier in which the power required to excite the field circuit is lower than the power output rating of the armature circuit. The voltage induced e_g is directly proportional to the product of the magnetic flux, ϕ setup by the field and the speed of rotation, ω of the armature which is expressed as

$$e_g = k_1 \phi \, \omega \qquad \text{..........} \quad (1.1)$$

The flux is a function of field current and the type of iron used in the field. A typical magnetization curve showing flux as a function of field current is shown in figure.



Up to saturation the relation is approximately linear and the flux is directly proportional to field current i.e.

$\phi = k_2 i_f$ ……………… (1.2)

Combining both equations,

$e_g = k_1 k_2 \omega i_f$ ……………….. (1.3)

When used as a power amplifier the armature is driven at a constant speed and the equation becomes

$e_g = k_g i_f$

A generator field winding is represented with L_f and R_f as inductance and resistance of the field circuit. The equation for the generator is,

$$e_f = L_f \frac{di_f}{dt} + R_f i_f \ldots \text{……………………………………………}(1.4)$$

Finding Laplace transform of the equation 1.3 and 1.4,

$$E_f(s) = (sL_f + R_f) I_f s \text{…………………………………………………}(1.5)$$

$$E_g(s) = k_g I_f(s) \text{………………………………………………………}(1.6)$$

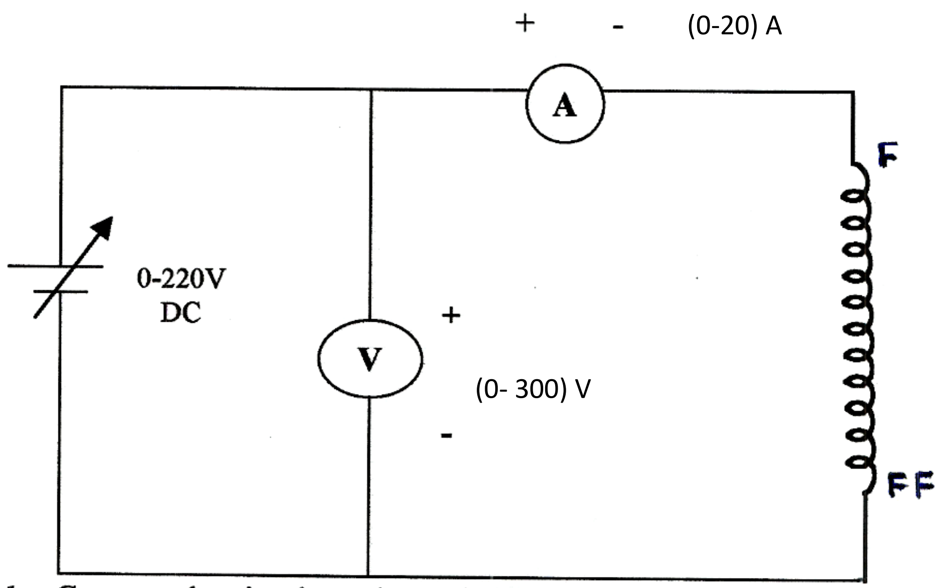
Combining the above two equations, Then the transfer function of a DC generator is given as,

$$\frac{E_g(S)}{E_f(S)} = \frac{k_g}{SL_f + R_f}$$

PRECAUTIONS:

1. At the time of starting the motor field rheostat should be in minimum resistance position and generator field rheostat should be in maximum resistance position.
2. There should not be any load connected to the generator terminals.

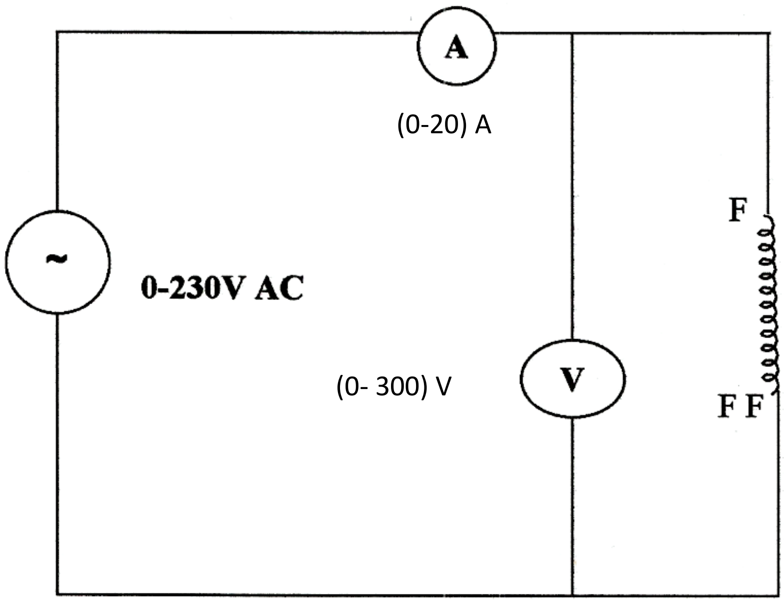
MEASUREMENT OF FIELD RESISTANCE



1. Connect the circuit as shown in figure.
2. Keep the armature winding open
3. Vary the input DC Supply from the controller and note down voltmeter and ammeter readings. V/I ratio will give the field Resistance
4. Repeat the same for different input voltage and find out R_F.
5. The average value gives R_F.

Sl. No.	*Vf Volts*	*If Amps*	*Rf=Vf/If ohms*

MEASUREMENT OF FIELD INDUCTANCE



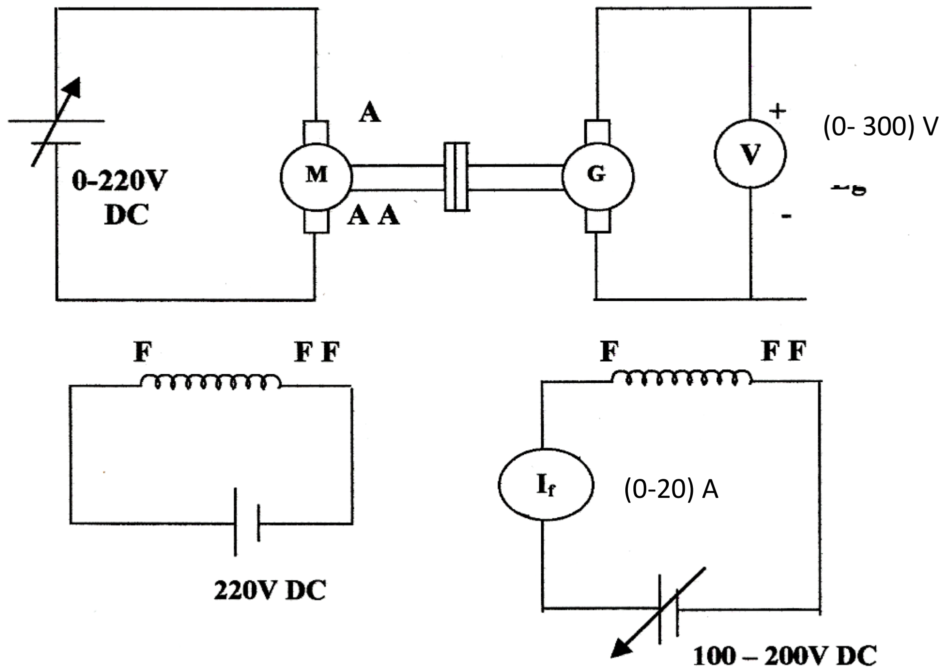
1. Connect the circuit as shown in the figure
2. Keep the armature winding open
3. Vary the input AC supply from the controller and note down voltmeter and ammeter readings and enter in the tabular column.
4. Calculate Z_f, Xf and Lf
5. Repeat the same for different input voltages.

TABLE

Sl. No.	V_f	I_f	$Z_f = \frac{V_f}{I_f}$	$X_f = \sqrt{Z_f^2 - R_f^2}$	$L_f = \frac{X_f}{2\Pi f}$

TRANSFER FUNCTION OF DC GENERATOR

(Separately Excited)



1. Make the connections as given in the circuit diagram
2. Connect 220V fixed DC supply to the Motor field
3. Connect 100-220V Variable DC supply to the Generator field
4. Connect 0-220V Variable DC supply to the armature.
5. Switch on the MCB keeping armature voltage control pot at its minimum position & ON/OFF switch at OFF position and also variable field voltage pot at its maximum position
6. Now switch ON the Armature control switch and vary the armature control potentiometer till the motor rotates at its rated speed.

7. Note down If and Eg and entered in the tabular column.

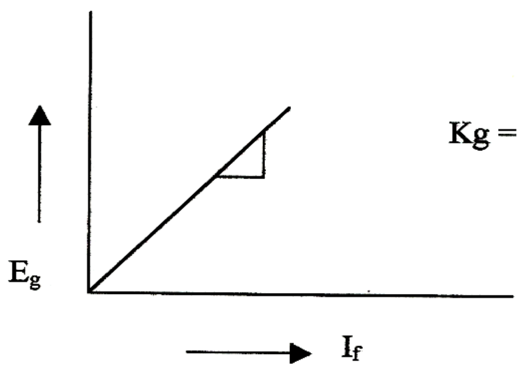
8. Now vary the generator field supply and note down Eg for different Igs and entered in the tabular column.

9. Draw the graph of Eg volts v/s I_f.

Sl. No.	If Amps	Eg Volts

$$\text{Transfer function} = \frac{K_g / L_f}{S_f R_f / L_f}$$

$$= \frac{K_g / L_f}{S + \frac{R_f}{L_f}}$$



$$Kg = \frac{\Delta \; Eg}{\Delta \; I_f}$$

RESULT:

TYPICAL PROBING QUESTIONS:

- Define transfer function?
- What is the importance of transfer function?
- What assumption is made concerning initial conditions when dealing with transfer functions?
- Why do transfer functions for mechanical networks look identical to transfer functions for electrical networks?
- To what classifications of systems can be transfer function be best applied?
- Do the zeros of a system change with a change in gain?
- Where are the zeros of the closed loop transfer function?

TRANSFER FUNCTION OF ARMATURE CONTROLLED DC MOTOR.

EXPT.NO: H.2 **DATE:**

AIM: To obtain the transfer function of an armature controlled dc shunt motor.

APPARATUS REQUIRED:

S. No	Name of the Apparatus	Range	Type
1.	DC servo motor trainer kit	-	
2.	DC servo motor		

THEORY:

The DC motor is basically a torque transducer that converts electrical energy into mechanical energy. DC motors used in control systems also called "servo motors" are characterized by large torque to inertia ratios, small size and better linear characteristics.

Most of the DC motor used in control systems can be modeled as shown in Figure 1. There are two circuits called the field circuit and armature circuit. Let i_f and i_a be the field and armature current respectively. The torque T generated by the motor is given by

$$T(t) = k\, i_a(t)\, i_f(t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where k is a constant. The generated torque is used to drive a load through a shaft. Let 'J' be the total moment of the motor, 'θ' be the angular displacement of the load and 'f' be the viscous frictional coefficient of the bearing then we have,

$$T(t) = J\frac{d^2\theta}{dt^2} + f\frac{d\theta}{dt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This describes the relationship between the motor torque and load's angular displacement.

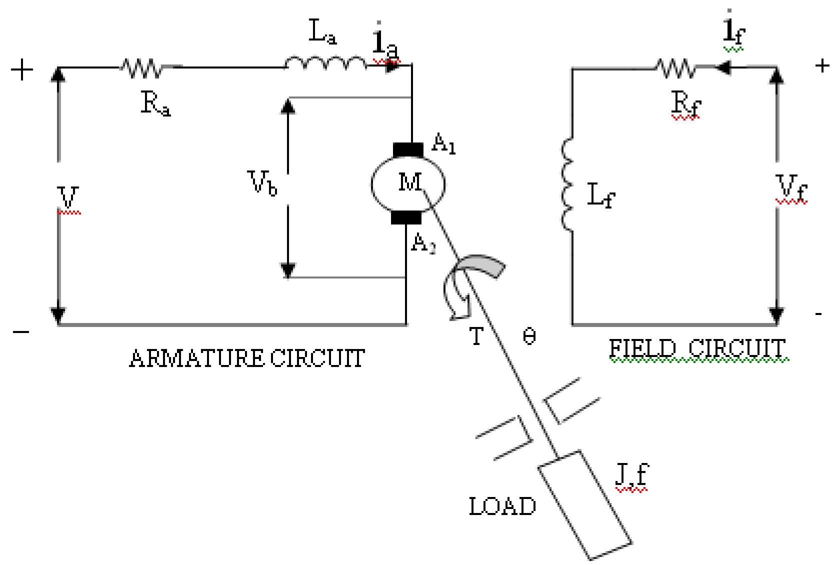


Figure 1
DC Motor Model

There are basically two ways of controlling the DC motor. If the field current is kept constant and if the input voltage is applied to the armature circuit then the motor is called an "armature controlled" DC motor. If the armature current is kept constant and the input voltage is applied to the field circuit, the motor is called a "field controlled" DC motor

Consider the dc motor shown in Figure 1. If the field current i_f is kept constant and the input voltage is applied to the armature circuit then the motor is an armature controlled dc motor. If i_f is constant equation (1) can be written as,

$T(t) = k_t\ i_a(t).$ ------------------------------- (3)

Where kt = k if(t) is a constant. When the motor is driving a load, a back electromotive force (back emf) voltage V_b, will develop in the armature circuit to resist the applied voltage. The voltage V_b (t) is linearly proportional to the angular velocity ω (t) of the motor shaft

$V_b(t) = k_b\ \omega(t)$ ----------------------------------- (4)

$$= k_b \frac{d\theta(t)}{dt} \text{...}(5)$$

Thus the armature circuit in the Figure 1 is described by substitution of equation (3) in (2) and the application of laplace transform to(2) and (6) give, assuming zero initial conditions,

$$R_a i_a(t) + L_a \frac{di_a(t)}{dt} + V_b(t) = V_a(t) = u(t) \text{...}(6)$$

$$k_t i_a(s) = Js^2\theta(s) + fs\theta(s) \text{..}(7)$$

$$R_a i_a(s) + L_a s i_a(s) + k_b s\theta(s) = V_a(s) \text{...}(8)$$

Eliminating i_a, we get the transfer function,

$$G(s) = \frac{\theta(s)}{V_a(s)} = \frac{k_t}{s[(Js+f)(R_a + i_a s) + k_t k_b]} \text{...}(9)$$

Block diagram of armature controlled dc motor is shown in Figure 2.

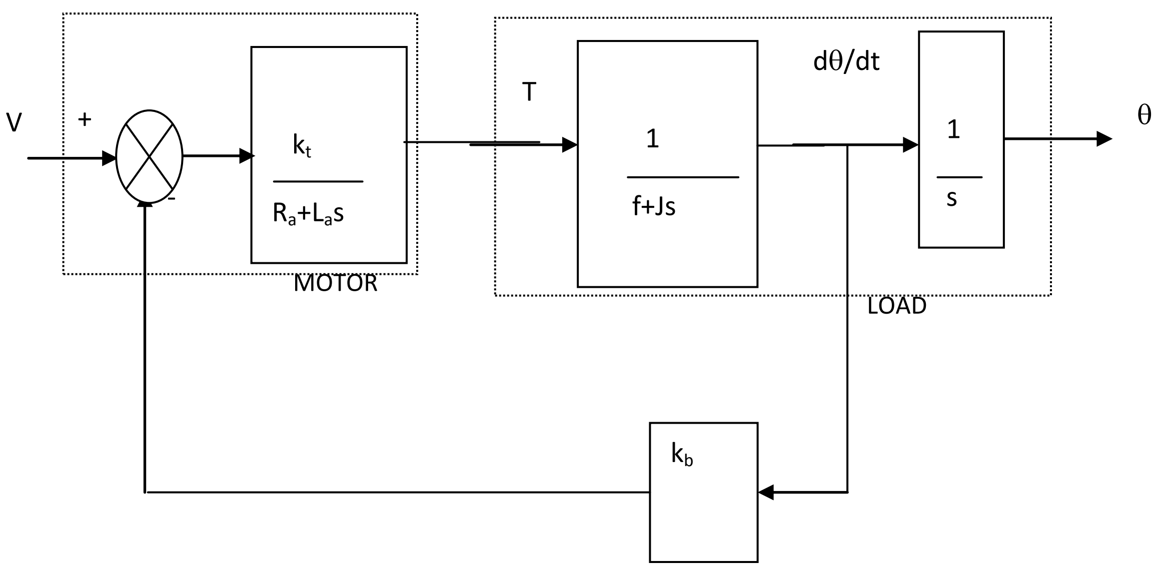


Figure 2 Block diagram of armature controlled dc motor

The equation (9) can be rewritten as,

$$\frac{\theta(s)}{V_a(s)} = \frac{K}{s\left[(1+s\tau_a)(1+s\tau_m) + \dfrac{k_t k_b}{R_a f}\right]} \text{..}(10)$$

where

$$\tau_a = \frac{L_a}{R_a} \qquad \tau_m = \frac{J}{f} \qquad K = \frac{K_t}{R_a f}$$

PRECAUTIONS:

1. Initially keep all switches in OFF Position.

2. Initially keep voltage adjustment POT (VARIAC) in minimum position.

3. Initially keep Armature and field voltage adjustment POT in minimum position.

PROCEDURE:

To find armature resistance R_a

1. Connect VPET-300(A) module Armature output A and AA to motor Armature terminal A and AA respectively.

2. Switch ON the power switch and SPST Switch 'S1'.

3. Shaft should not rotate, when applying the DC input voltage.

4. Now note down the Armature current for various Armature voltage in the table. Armature current should not exceed rated current value (2.5A).

5. Calculate the Resistance value Ra = Va / Ia.

6. The average resistance value gives the armature resistance.

Sl No	Armature Voltage Va (Volts)	Armature Current Ia(A)	Ra= Va/ Ia (Ω)

To find La:

1. Connect VPET-300(A) module variac output P and N to motor Armature terminal A and AA respectively.
2. Switch ON the power.
3. Shaft should not rotate, when applying the AC input voltage.
4. Now note down the AC current for various AC voltage in the table
5. Calculate the Inductance value La = Va / Ia.
6. The average Inductance value gives the armature Inductance.

S No	Armature Voltage(Va)	Armature Current(A)	Za= Va/Ia (Ω)	**Xa = √Za2 - Ra2** (Ω)	La=Xa/2∏f (H)

To Find Back Emf Constant:

1. Connect VPET -300(A) module, armature output A and AA to motor Armature terminal A and AA respectively.
2. Connect VPET -300(A) module, field output F and FF to motor Field terminal F and FF respectively.
3. Switch on the power and SPST Switch 'S1' and ‘S2'.
4. Set the field Voltage at rated value (48V).
5. Adjust the Armature voltage by using Armature POT. Now note down the Armature current and speed for various Armature Voltage (up to Motor rated Speed).
6. Plot the graph Eb versus T, model graph is as shown in Fig.3 and calculate the back emf.

S No	**Armature Voltage(Va)**	**Armature Current (A)**	**E_b= V – IaRa (V)**	**Speed NRPM**	**ω =Rad/sec.**

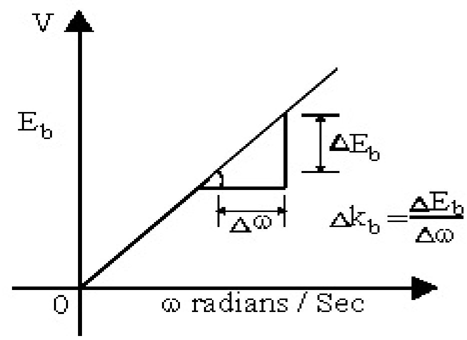


Figure 3

To Find Armature torque constant:

1. Connect VPET -300(A) module armature output A and AA to motor Armature terminal A and AA respectively.

2. Connect VPET - 300(A) field output F and FF to motor Field terminals F and FF respectively.

3. Switch ON the power and SPST switches ‘S1' and ‘S2'.

4. Adjust the Field voltage to rated value.

5. Apply the Armature voltage till the Motor run at rated speed.

6. Apply load by tightening.

7. Now, note down the armature voltage, current and spring balance reading in the table.

8. Plot the graph Torque Vs Armature current (Ia) model graph is shown figure-4.

9. Calculate the Torque constant from graph as shown below

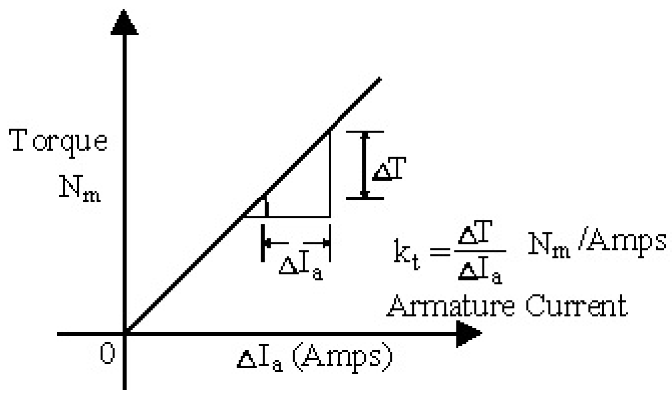
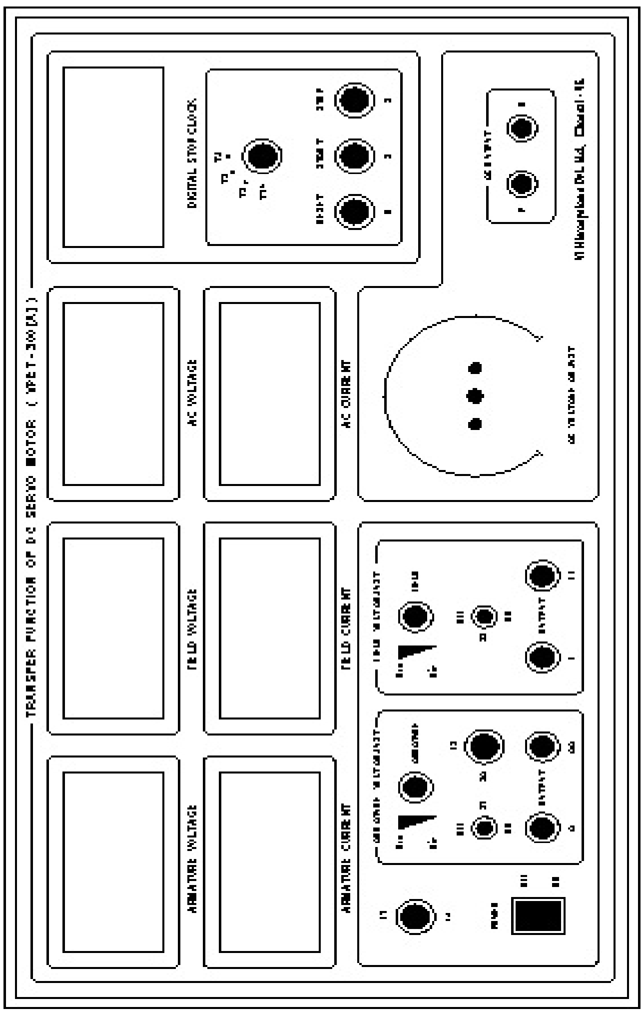


Figure 4 Torque Vs Armature Current (Ia)

S No	Armature Voltage(V)	Armature Current (A)	**S1 Kg.**	**S2 Kg.**	**S_1~ S2 Kg.**	**T =(S1~S2)×9.81 x r N-m**

Front Panel View



RESULT:

TYPICAL PROBING QUESTIONS:

- Illustrate the meaning of each of the following : Direct transfer function, Loop transfer function and closed loop transfer function
- State an advantage of the transfer function approach over the state space approach.
- Since the motor's transfer function relates armature displacement to armature voltage, how can the transfer function that relates load displacement and armature voltage be determined?
- What do you mean by control system?
- Define transfer function?
- What is DC servo motor? What are the main parts?
- What is servo mechanism?
- Is this a closed loop or open loop system .Explain?
- What is back EMF?

TRANSFER FUNCTION OF AC SERVO MOTOR

EXPT.NO: H.3 **DATE:**

AIM: To derive the transfer function of the given AC Servomotor.

APPARATUS REQUIRED:

S. No	Name of the Apparatus	Range	Type	Quantity
1.	AC servo motor trainer kit	-		1
2.	AC servo motor			1
3.	Patch cords	-		As required
4.	Loads			As required

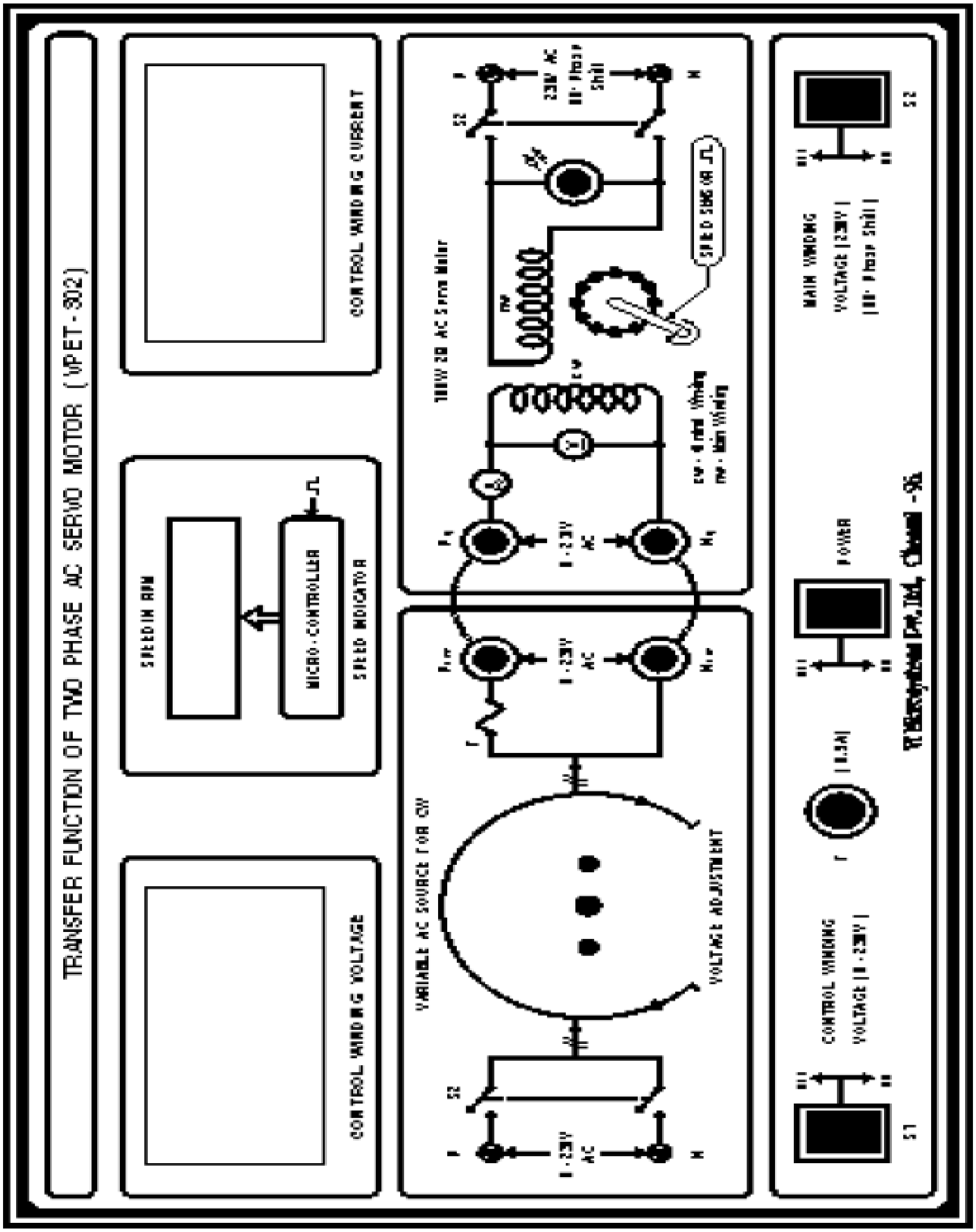
THEORY

The AC servo motor is basically a two phase induction motor with some special design features. The stator consists of two pole pairs (A-B and C-D) mounted on the inner periphery of the stator, such that their axes are at an angle of 90^o in space. Each pole pair carries a winding, one winding is called reference winding and other is called a control winding. The exciting current in the winding should have a phase displacement of 90^o. The supply used to drive the motor is single phase and so a phase advancing capacitor is connected to one of the phase to produce a phase difference of 90^o.The rotor construction is usually squirrel cage or drag-cup type. The rotor bars are placed on the slots and short-circuited at both ends by end rings. The diameter of the rotor is kept small in order to reduce inertia and to obtain good accelerating characteristics. The drag cup construction is employed for very low inertia applications. In this type of construction the rotor will be in the form of hollow cylinder made of aluminum. The aluminum cylinder itself acts as short-circuited rotor conductors. Electrically both the types of rotor are identical.

WORKING PRINCIPLE AS AN ORDINARY INDUCTION MOTOR

The stator windings are excited by voltages of equal magnitude and 90^o phase difference. These results in exciting currents i_1 and i_2 that are phase displaced by 90^o and have equal values. These currents give rise to a rotating magnetic field of constant magnitude. The direction of rotation depends on the phase relationship of the two currents (or voltages). This rotating magnetic field sweeps over the rotor conductors. The rotor conductor experience a change in flux and so voltages are induced rotor conductors. This voltage circulates currents in the short-circuited rotor conductors and currents create rotor flux. Due to the interaction of stator & rotor flux, a mechanical force (or torque) is developed on the rotor and so the rotor starts moving in the same direction as that of rotating magnetic field.

Front Panel diagram:



Transfer Function:

The transfer function of the AC servomotor is obtained using the torque equation. The developed torque is given by

$$T_c = k_1 \ e_c(t) - k_2 \ \omega(t)$$

Where k_1 and k_2 are motor parameters which depend on the control voltage e_e (t).

k_1 is expressed in Nm / Volt

k_2 is expressed in Nm / rad / sec

Mechanical system consisting of the rotor, is described by the dynamic equation

$$T_e = J\frac{d\omega}{dt} + B\omega$$

Where J - moment of inertia kg.cm_2

B - viscous friction co-efficient

T - speed in rad/sec

At equilibrium the motor torque is equal load/mechanical system torque

$$k_1 \ e_c(t) - k_2 \ \omega(t) = J \times \frac{d\omega(t)}{dt} + B\omega(t)$$

Taking Laplace transform

$$k_1 \ E_c(s) - k_2.\omega(s) = J \ s \ \omega(s) + B \ \omega \ (s)$$

$$k_1 \ E_c(s) = (s \ J + k_2 + B) \ \omega(s)$$

$$\frac{\omega(s)}{E(s)} = \frac{k_1}{sJ + k_2 + B}$$

$$= \frac{k_m}{1 + s\tau m}$$

where

$$K_m = \frac{K_1}{(K_2 + B)} - \textit{Motor gain constant}$$

$$\textit{and} \quad \tau_m = \frac{J}{(k_2 + B)} = \textit{motor time constant}$$

Procedure:

To Find the motor constant K2:

i. Initially keep variac is minimum position.
ii. Connect banana connectors "P_{OUT}" to "P_{IN}" and "N_{OUT}" to N_{IN} (VARIAC output terminal

is connected to input of control winding)

iii. Connect 9 pin D-connector from motor feed back into input of, VPET-302 module.

iv. Switch ON the 230V AC supply to the motor setup.

vi. Switch ON the power ON/OFF switch.

vi. Switch ON the S2 (main winding) and S1 (control winding).

vii. Vary the control voltage by using VARIAC and set the rated voltage (60V) to control phase winding.

viii. Apply the load on the motor step by step up to motor will run at 0 rpm.

ix. For each step note the readings (Load and Speed) as shown in the table 1. Speed is measured from LCD display.

x. To calculate the torque value.

xi. Plot the graph Speed Vs Torque.

xii. The slope of speed - torque curve given the motor constant K_2.

FORMULA TO BE USED

Torque (T) = 9.81 × r × s NM.

S = Applied Load in Kg.

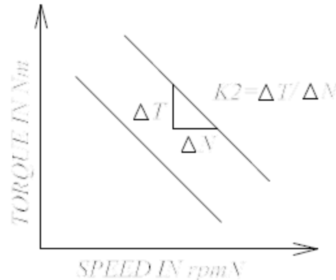
r = Radius of shaft in m. = 0.068 meter

TABLE - 1

Control Voltage = Rated Voltage (60V)

S.No.	Speed (rpm)	Load (kg)	Torque (Nm)

MODEL GRAPH:



ii) To determine the motor constant K1:

i. Initially keep variac is minimum position of VPET - 302 module.

ii. Connect banana connectors "P_{OUT}" to "P_{IN}" and "N_{OUT}" to N_{IN} (VARIAC output terminal is connected to input of control winding).

iii. Connect 9 pin D-connector from motor feed back into input of VPET-302 module.

iv. Switch ON the 230V AC supply to the motor setup.

v. Switch ON the power ON/OFF switch.

vi. Switch ON the S2 (main winding) and S1 (control windings).

vii. Vary the control voltage by using VARIAC and set the rated voltage (230V) to control phase winding.

viii. Apply the load on the motor step by step up to motor will run at 0 rpm

ix. For each step note the load and control winding voltage is shown in the table 2.

x. To calculate the torque value.

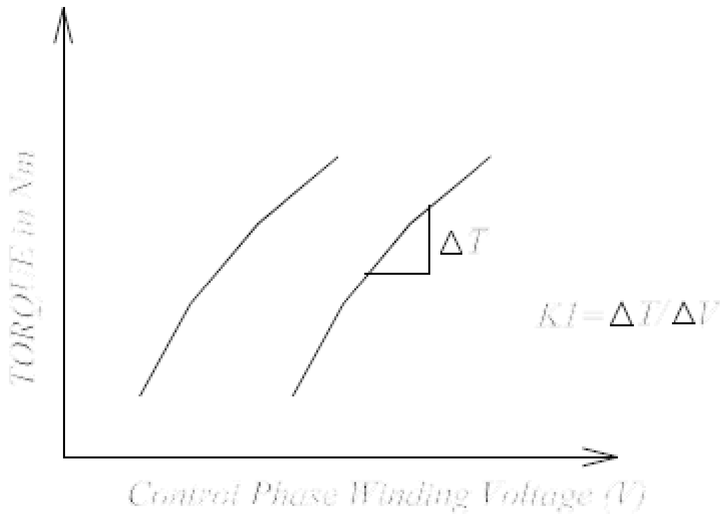
xi. Plot the graph Torque Vs Control voltage.

xii. The slope of torque - control voltage curve gives the motor constant K1

Table 2 Rated speed 200rpm

SNo	Load (kg)	Control voltage Ec	Torque (Nm)

MODEL GRAPH



RESULT:

TYPICAL PROBING QUESTIONS:

1. What are the main parts of an AC servomotor?
2. What are the advantages and disadvantages of an AC servo motor?
3. Give the applications of AC servomotor?
4. What do you mean by servo mechanism?
5. What are the characteristics of an AC servomotor?

STUDY OF SYNCHROS

EXPT NO: H.4.a **DATE:**

AIM: To study the characteristics of magnetic amplifier and SYNCHRO Transmitter & Receiver.

APPARATUS RECEIVED:

S.No:	Item	Specification / Range	Quantity
1.	Synchro transmitter and receiver kit	-----	1
2.	Patch chords	-----	1

THEORY:

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

Basic synchro is usually called as synchro transmitter. Its construction is similar to that of a three phase alternator. The stator is of laminated silicon steel and is slotted to accommodate a balanced three phase winding. The rotor is of dump-bell construction and wound with a concentric coil. An a. c. voltage is applied to the rotor winding through slip rings.

Let the a. c. voltage applied be

$$V_{r(t)} = V_m \sin \omega t$$

This voltage applied to the rotor of the synchro transmitter cause a flow of magnetizing current in the rotor coil which produces a sinusoidal time varying flux directed along its axis and distributed nearly sinusoidal in the air-gap along stator periphery. Due to transformer action voltages are induced in each of the stator coils. The flux linking with the stator coil is proportional to the cosine of the angle between rotor and stator coil axis and so is the voltage induced in each stator coil.

The induced voltages in the stator coils s_1,s_2 and s_3 with respect to neutral are given as,

$Vs_{1N}=KV_m \cos(\theta+120)$

$Vs_{2N}=KV_m \sin\omega t \cos\theta$

$Vs_{3N}=KV_m \sin\omega t \cos(\theta+240)$

where θ is the angle between the rotor coil axis and stator coil s_2 axis.

The terminal voltages of the stator are,

$Vs_1s_2=3KV_m \sin(\theta+240) \sin\omega t$

$Vs_2s_3=3KV_m \sin(\theta+120) \sin\omega t$

$Vs_3s_1=3KV_m \sin\theta \sin\omega t$

Thus the input angular position to the synchro transmitter results in an output of three single phase voltages and the magnitude of the voltages are functions of shaft position.

A synchro system consists of two units namely,

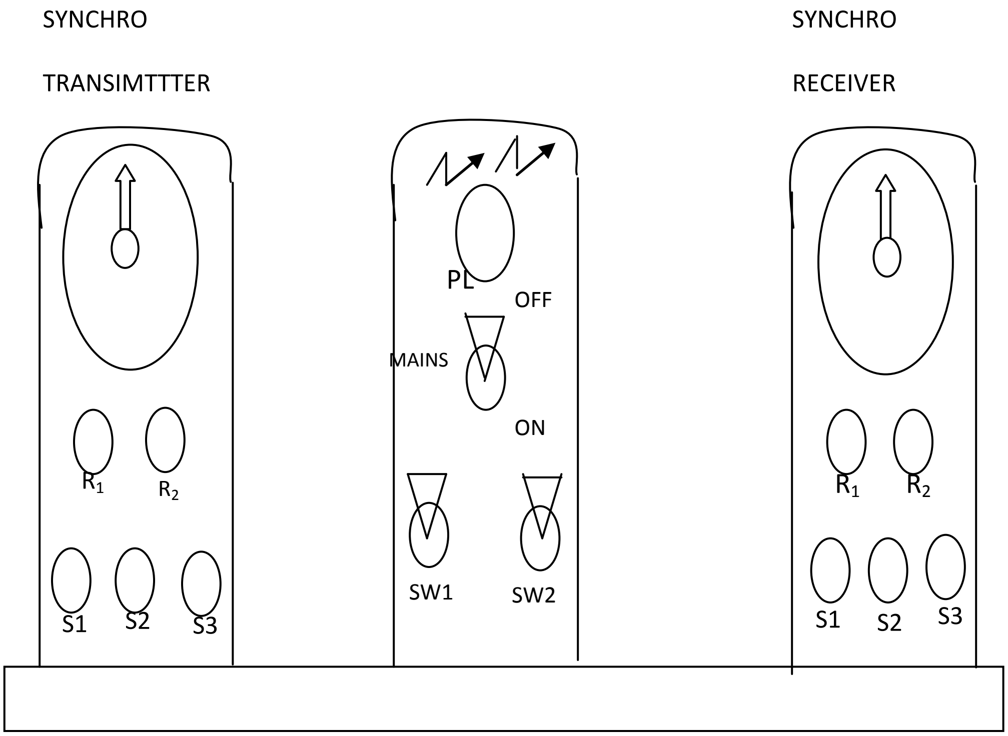
1) Synchro transmitter

2) Synchro receiver.

Synchro receiver has almost the same constructional features as transmitter. Initially the winding s2 of the stator of transmitter is positioned for maximum coupling with rotor winding. If V is the voltage in the coil s_2, the coupling between s_1 and s_3 of the stator and rotor winding is a cosine function. Therefore the effective voltages in these windings are proportional to cos 60 or they are v/2 each. So long as the rotor of the transmitter and receivers remain in this position no current will flow between windings because of the voltage balance.

When the rotor of the transmitter is moved to a new position, the voltage balance is disturbed. This voltage imbalance between the stator winding of transmitter and receiver causes currents to flow 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 same as that of the transmitter.

FRONT PANEL VIEW:



PROCEDURE:

To Find the Stator output voltage with respect to the rotor position:

i. Connect Digital Voltmeter across the any two Stator output of Synchro transmitter.

ii. Connect Synchro transmitter stator outputs to corresponding Stator terminals of Synchro receiver.

iii. Power ‘ON’ the all ON/OFF Switches

iv. Verify the Stator output voltage of 0V at 0 degree, if it is not make 0V at 0 degree; try to adjust the pointer of both transmitter and Receiver.

v. Adjust the transmitter rotor position Step by Step.

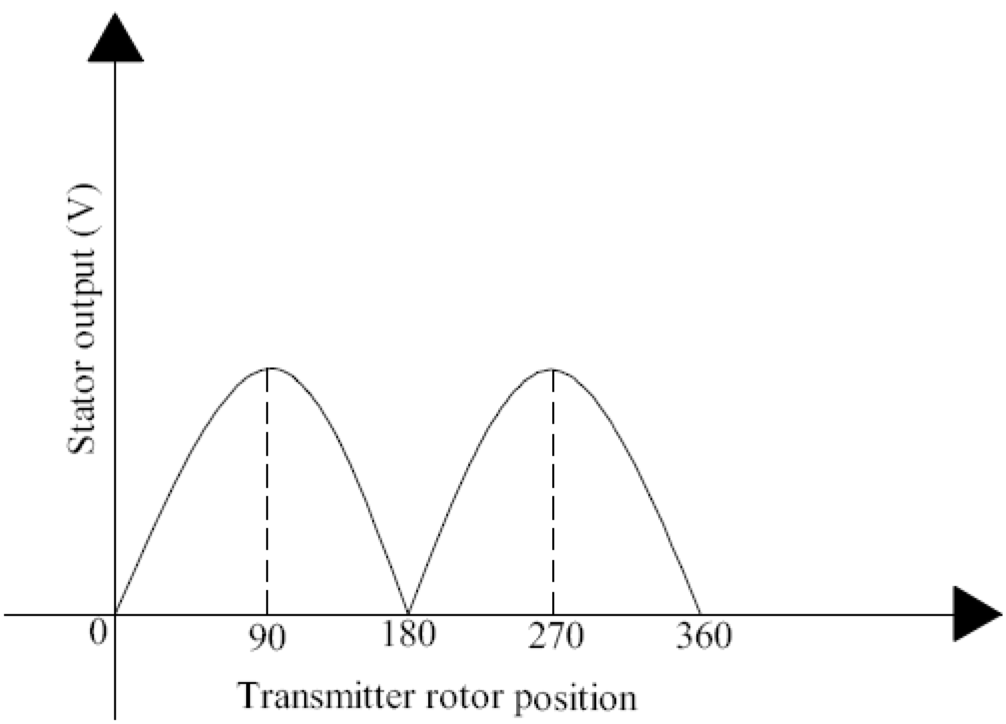
vi. Now note down the output voltage for various rotor position in the table 1.

vii. Repeat the Same procedure for other pair of Synchro transmitter coils.

Table-1

Sl No	Synchro transmitter			
	Rotor Position (degree)	Stator Output (1-2)(V)	Stator Output (2-3)(V)	Stator Output (1-3)(V)

Model Graph:



To Study the Rotor position of Synchro transmitter and Receiver:

i. Connect Digital Voltmeter across to the any two Stator output of Synchro transmitter.

ii. Connect Synchro transmitter stator outputs to corresponding Stator terminals of Synchro receiver.

iii. Power 'ON' the all ON/OFF Switches

iv. Verify the Stator output voltage 0V at 0 degree, if it is not make 0V at 0 degree to adjust the pointer of both transmitter and Receiver.

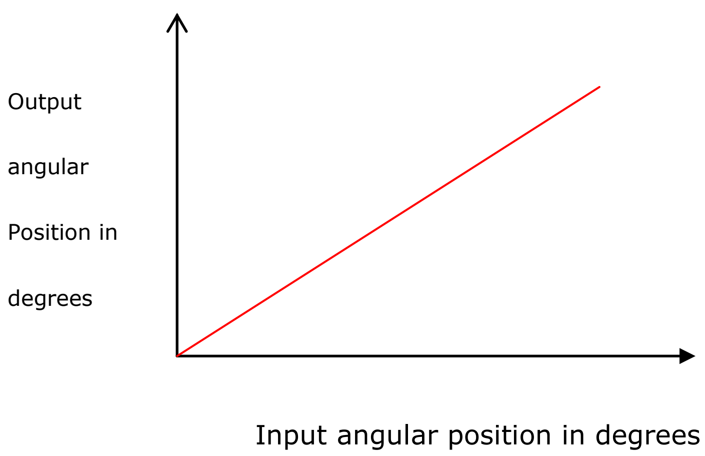
v. Adjust the transmitter rotor position step by step by using knob

vi. Now note down the rotor position of transmitter and receiver in the table-2.

Table 2

SL.No	Synchro Transmitter Rotor Position(degree)	Synchro Receiver Rotor position (degree)	Error=Rotor position (Transmitter-Receiver)

Model Graph:



RESULT:

TYPICAL PROBING QUESTIONS:

- What are the advantages of synchros?
- Define angular displacement?
- For what purpose synchros are used?
- On what principle synchros work?
- What is synchro transmitter?
- What is synchro control transformer?
- Synchro, what type of transducer?

STUDY OF MAGNETIC AMPLIFIER

EXPT.NO: H.4.b **DATE:**

AIM:

To study the characteristics of magnetic amplifier

APPARATUS:

S.No:	Item	Specification / Range	Quantity
1.	Magnetic Amplifier Kit	----	1
2.	RPS	(0-30)V	1
3.	Ammeter	(0 – 1)A MI, (0-1)A MC	1
4.	Rheostat	270 Ω, 1A	
5.	Patch chords	-----	1

THEORY:

Magnetic Amplifier:

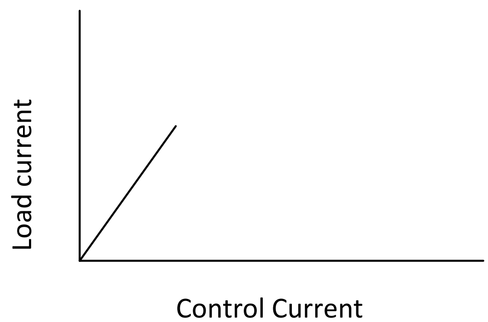
Magnetic Amplifier is a device consisting of combination of saturable reactors, rectifiers and conventional transformers used to secure control or amplification. In magnetic amplifiers the load Current in the circuit is controlled by a D.C magnetizing current, which is comparatively very low as compared with load current. A large current valve is controlled by a small current valve. Hence such types of circuits are termed current amplifiers. To control the load current a saturable reactor is used. The reactance of the reactor depends upon magnetic coupling and magnetism included depends upon the D.C control current. Thus the load current is controlled by using magnetic property and hence the term magnetic amplifier.

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 limb is called as control winding and coils wound on outer 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 circuits can be used in different ways.

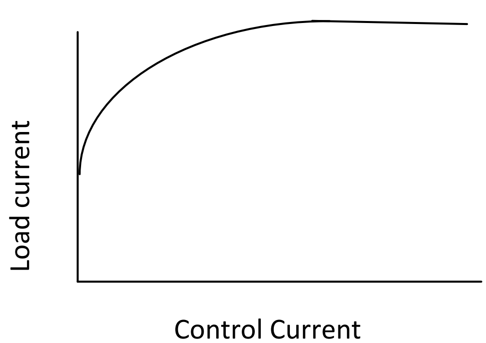
In series connected magnetic amplifier, the two reactors (Load windings) are connected in series. The total reactance is twice and control winding controls it. In such type of magnetic amplifiers, the current can be controlled right from near zero current. By increasing the control current the reactance is slowly decreased and hence load current is increased. Two meters are provided to measure control current (DC 0 – 10 mA) and load current (AC 0 –1A)

By plotting a graph of control current against load current nature of amplification can be observed.



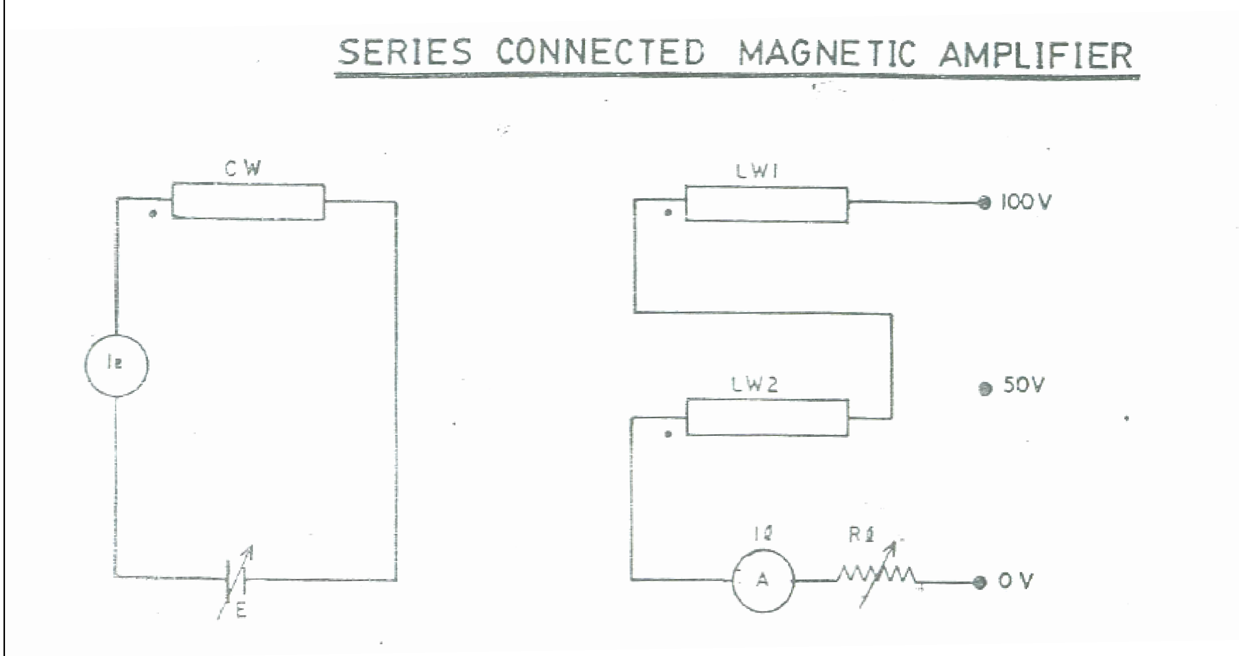
Initially at zero control current, Load current will be very low, as the reactance is maximum. As the Control current is increased load current will also increase with a constant slope (Amplification) .After certain level of control current the slope will go on decreasing and finally load current will reach saturation due to saturation of reactance.

In parallel connected magnetic amplifier the two reactors are connected in parallel. 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 initial load current At zero control current will be more in case of parallel-connected magnetic amplifier. Secondly Saturation level of load current is more as that of series connected version.

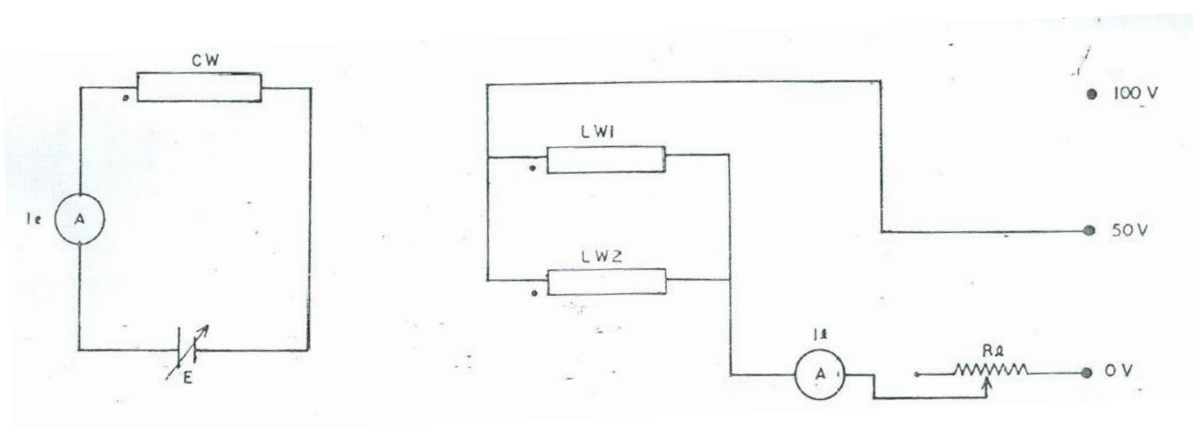


At zero control current there will be some load current flowing in the circuit As the control current is increased load current will also increase with a constant slope (Amplification) as in series connection and will reach a saturation current. But this valve of saturation current will be much more than that in series connected. We can control more load current with nearly same amplification factor.

CIRCUIT DIAGRAM



Parallel Connected Magnetic Amplifier



PROCEDURE:

i) Give the connections as per the circuit diagram.
ii) Keep the rheostat the minimum position.
iii) Switch on the RPS and vary the supply voltage and measure the control winding current.
iv) Note down the load current for every control winding current.
v) Plot the graph.

Tabular column:

Series Connected Magnetic Amplifier:

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

Parallel Connected Magnetic Amplifier:

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

RESULT:

STUDY OF FIRST ORDER AND SECOND ORDER SYSTEM

EXPT.NO: H.5 **DATE:**

AIM:

To obtain the step response and frequency response of both first order and second order electrical system

APPARATUS:

S.No:	Item	Specification / Range	Quantity
1.	Decade Resistance box	-	1
2.	Decade Inductance box	-	1
3.	Decade capacitance box	-	1
4.	Function generator	-	1
5.	CRO	-	1
6.	Breadboard	-	1

THEORY:

Overview First Order Systems:

An electrical RC-circuit is the simplest example of a first order system. It comprises of a resistor and capacitor connected in series to a voltage supply. If the capacitor is initially uncharged at zero voltage when the circuit is switched on, it starts to charge due to the current 'i' through the resistor until the voltage across it reaches the supply voltage. As soon as this happens, the current stops flowing or decays to zero, and the circuit becomes like an open circuit. However, if the supply voltage is removed, and the circuit is closed, the capacitor will discharge the energy it stored again through the resistor. The time it takes the capacitor to charge depends on the time constant of the system, which is defined as the time taken by the voltage across the capacitor to rise to approximately 63% of the supply voltage. For a given RC-circuit, this time constant is $\tau = RC$. Hence its magnitude depends on the values of the circuit components.

The RC circuit will always behave in this way, no matter what the values of the components. That is, the voltage across the capacitor will never increase indefinitely. In this respect we will say that the system is passive and because of this property it is stable.

For the RC-circuit as shown in Fig. 1, the equation governing its behavior is given by

$$\frac{dv_c(t)}{dt} + \frac{1}{RC}v_c(t) = \frac{1}{RC}E \quad \text{where } v_c(0) = v_0 \tag{1}$$

where $v_c(t)$ is the voltage across the capacitor, R is the resistance and C is the capacitance. The constant $\tau = RC$ is the time constant of the system and is defined as the time required by the system output i.e. $v_c(t)$ to rise to 63% of its final value (which is E). Hence the above equation (1) can be expressed in terms of the time constant as:

$$\tau\frac{dv_c(t)}{dt} + v_c(t) = E \quad \text{where } v_c(0) = v_0 \tag{1}$$

Obtaining the transfer function of the above differential equation, we get

$$\frac{V_c(s)}{E(s)} = \frac{1}{\tau s+1} \tag{2}$$

where τ is time constant of the system and the system is known as the first order system. The performance measures of a first order system are its time constant and its steady state.

Overview Second Order Systems:

The generalized notation for a second order system described above can be written as

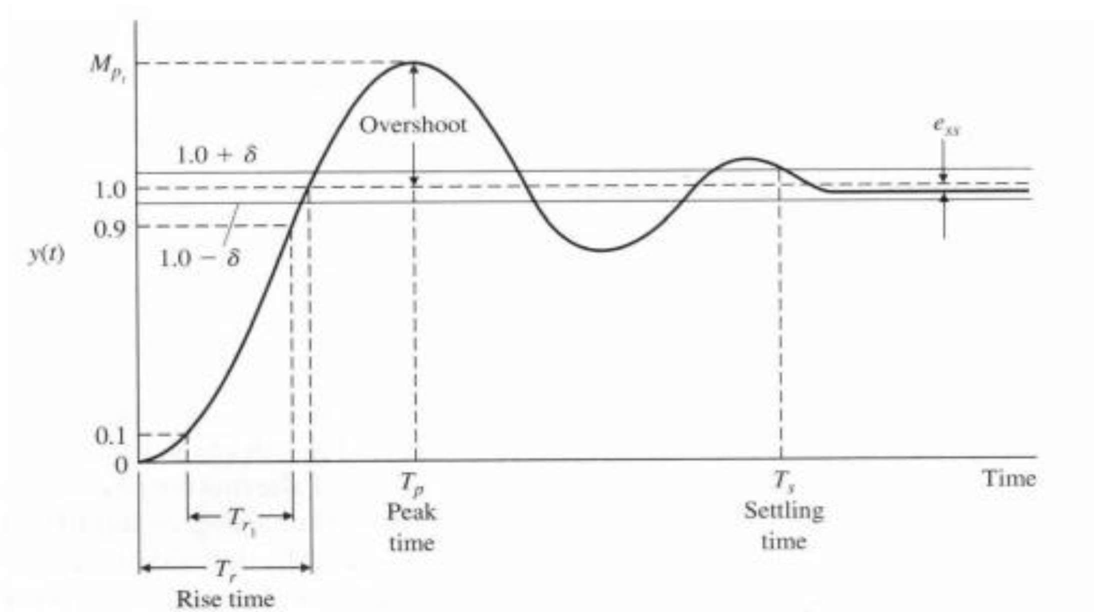
$$Y(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}R(s)$$

With the step input applied to the system, we obtain

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

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

where $0 < \zeta < 1$. The transient response of the system changes for different values of damping ratio, ζ. Standard performance measures for a second order feedback system are defined in terms of step response of a system. Where, the response of the second order system is shown below.



The performance measures could be described as follows:

Rise Time: The time for a system to respond to a step input and attains a response equal to a percentage of the magnitude of the input. The 0-100% rise time, T_r, measures the time to 100% of the magnitude of the input. Alternatively, T_{r1}, measures the time from 10% to 90% of the response to the step input.

Peak Time: The time for a system to respond to a step input and rise to peak response.

Overshoot: The amount by which the system output response proceeds beyond the desired response. It is calculated as

$$\text{P.O.} = \frac{M_{P_t} - f\upsilon}{f\upsilon} \times 100\%$$

where M_{Pt} is the peak value of the time response, and fv is the final value of the response.
Settling Time: The time required for the system's output to settle within a certain percentage of the input amplitude (which is usually taken as 2%). Then, settling time, T_s, is calculated as

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

PROCEDURE:

1. Connections are made as per the circuit diagram.

2. Keep the appropriate values for resistance using decade resistance box.

3. A square pulse of very low frequency is given at the input and output is noted.

4. A graph is plotted showing the variation of output voltage with time.

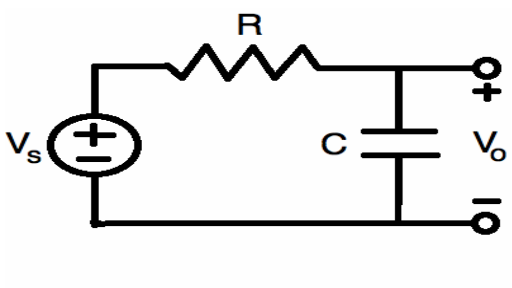
5. To get frequency response, a sinusoidal signal is given as input and output (peak to peak) is noted.

6. The input voltage is kept constant and output is noted for different frequencies. Also the phase angle is noted.

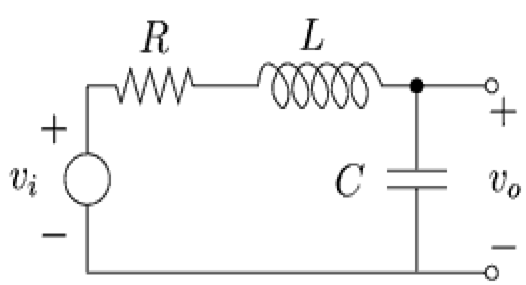
7. The magnitude in decibel and phase angle in degrees is plotted as a function of frequency, ω (rad/sec) in a semi log graph sheet.

CIRCUIT DIAGRAM

FIRST ORDER SYSTEM



SECOND ORDER SYSTEM



TABULAR COLUMN

FIRST ORDER SYSTEM

Sl. No.	Time	Output Voltage (V)

Sl. No	Frequency (rad/sec)	Output Voltage (peak to peak)	Input Voltage (peak to peak)	Gain in db (20 log (V_0/V_i)

SECOND ORDER SYSTEM

Sl. No.	Time	Output Voltage (V)

Sl. No	Frequency (rad/sec)	Output Voltage (peak to peak)	Input Voltage (peak to peak)	Gain in db (20 log (V_0/V_i)

RESULT:

STUDY OF OPEN LOOP AND CLOSED LOOP SYSTEM

EXPT. NO: H.6 **DATE:**

AIM:

To study open loop response and closed loop response of a simple process.

APPARATUS:

Process Control Simulator (PCS-01)

PROCEDURE:

1. Patch the front panel of the PCS-01 as given below in Figure 1 for open loop system and Figure 2 for closed loop system.

2. Keep the process fast /slow switch (SW4) in slow position.

3. Using this set value control, attempt to make measured value meter to indicate any desired value.

4. Note down the relative readings of both measured value and set value meters.

5. Then apply a small disturbing voltage of 1V DC to the load disturbance socket from DC voltage source.

6. Note down the changes in measured value.

TABULAR COLUMN:

OPEN LOOP SYSTEM

Sl. No.	Set Value	Measured Value (No load)	Measured Value (with load)

CLOSED LOOP SYSTEM

Sl. No.	Set Value	No load		With load	
		Measured Value	Deviation	Measured Value	Deviation

Deviation = Set Value – Measured value

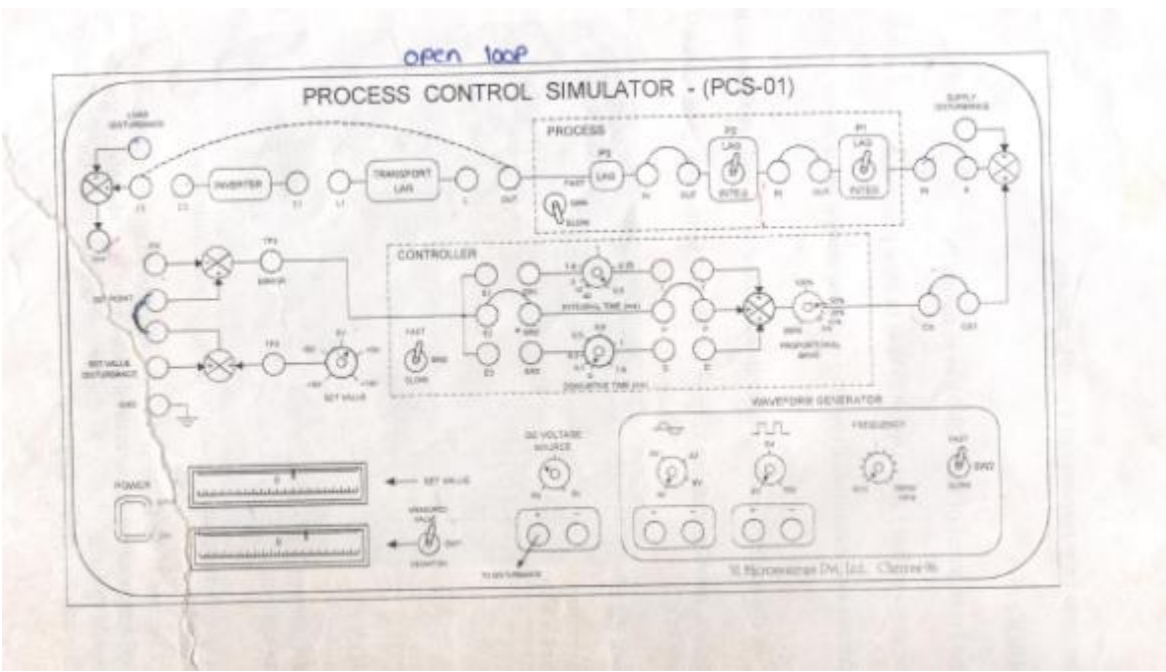


Figure 1 (Open loop system)

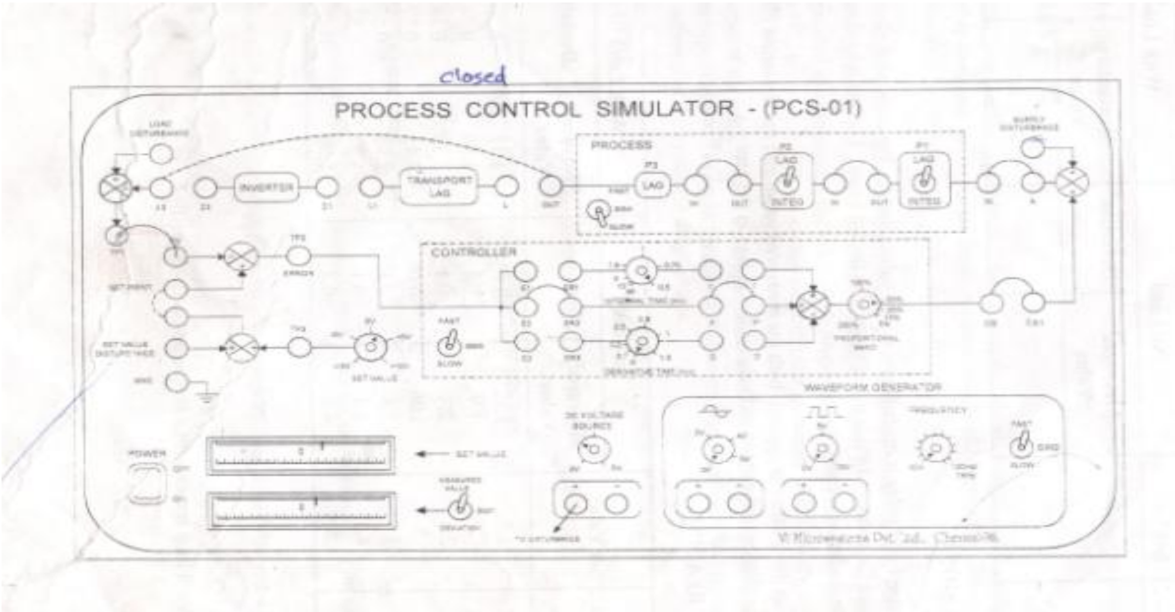


Figure 2 (Closed loop system)

RESULT: