CONTROL SYSTEMS LABORATORY

B.TECH, EE
III YEAR,
Vth SEM
2026-27

Department of Electrical Engineering

STATE INTITUTE OF ENGINEERING & TECHNLOGY, NILOKHERI

DEPARTMENT OF ELECTRICAL ENGINEERING

GENERAL LABORATORY INSTRUCTIONS

- Before entering the lab the student should carry the following things.
  - Identity card issued by the college.
  - Class notes
  - Lab observation book
  - Lab Manual
  - Lab Record
- Student must sign in and sign out in the register provided when attending the lab session without fail.
- Come to the laboratory in time. Students, who are late more than 15 min., will not be allowed to attend the lab.
- Students need to maintain 100% attendance in lab if not a strict action will be taken.
- All students must follow a Dress Code while in the laboratory
- Foods, drinks are NOT allowed.
- All bags must be left at the indicated place.
- The objective of the laboratory is learning. The experiments are designed to illustrate phenomena in different areas of Physics and to expose you to measuring instruments, conduct the experiments with interest and an attitude of learning
- You need to come well prepared for the experiment.
- Work quietly and carefully
- Be honest in recording and representing your data.
- If a particular reading appears wrong repeat the measurement carefully, to get a better fit for a graph
- All presentations of data, tables and graphs calculations should be neatly and carefully done
- Graphs should be neatly drawn with pencil. Always label graphs and the axes and display units.
- If you finish early, spend the remaining time to complete the calculations and drawing graphs. Come equipped with calculator, scales, pencils etc.
- Do not fiddle with apparatus. Handle instruments with care. Report any breakage to the Instructor. Return all the equipment you have signed out for the purpose of your experiment.

HEAD OF THE DEPARTMENT **DIRECTOR-PRINCIPAL**

STATE INTITUTE OF ENGINEERING & TECHNLOGY, NILOKHERI

III YEAR B.Tech EE **L/T/P/C**

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(B24-EE-313) CONTROL SYSTEMS LAB

COURSE OBJECTIVES:

1. To understand the various simulator
2. To study the various compensation technique
3. To study the speed control of dc motor
4. To study the various error detector.

LIST OF EXPERIMENTS

1. Experiment to study linear system simulator.

2. To study the stroboscope & measure the shaft speed

3. Experiment to study light intensity control using P & PI controller with provision for and transient speed control.

4. Experiment to study D.C motor speed control.

5. Experiment to study the stepper motor characteristics and its control through microprocessor kit.

6. Experiment to study Temperature control system.

7. Experiment to study Compensation design.

8. Experiment to study Potential Metric Error detector.

9. Experiment to study Synchros.

10. Experiment to study AC Position control system.

EXPERIMENT NO: 1

LINEAR SYSTEM SIMULATOR

AIM:

To study linear system simulator.

THEORY:

Introduction: - This set up is designed to study the time response of simulated linear systems. The present set up has straightforward building blocks of simulated process & signal sources. A cathode ray oscilloscope (dual trace is best option) is the only other apparatus required to carried out the most experiments. The set up consists following features:

Basic building blocks: - There are some basic building blocks are given upon the panel. A dynamic system can be configured connecting them in suitable manners. All blocks have input / output sockets with arrowhead mark and common of them is connected internally with common ground.

1. *Error detector with gain:* - This block has three inputs marked as Disturbance, reference and feedback. It has one output shown by arrowhead mark. The input error signals referred as e1, e2, e3 are added and the output could be written as: {e o = K (e 1 + e 2 + e 3)}

No - sign indicate the output has same phase with the inputs.

K is the gain factor (0 - 10) which can be adjusted with calibrated 10 turn potentiometer provided upon the panel.

2. **Integrators:** - *These blocks have a pole at the origin and simulates type - 1, system. It has a transfer function in form of {-K / s}, - means introduce a phase shift between input / output.*
3. **Time constants:** - *Next to integrate these blocks simulates type 0, system and its transfer function is in the form of {-K1 / (sT + 1)}. The next time constant block is similar to the first except it has one other input* x10, which results in 10 times higher gains necessary to form second order system

simulating. Its transfer function is in the form of {- K2 / (sT + 1)}.

4. ***The disturbance adder:*** **-** It is an inverting two input and one output adder. The inputs can be written as e 1, e 2 and the output can be defined as:
   {eo = -e1 + e2} (The gain factor of this block is 1).

5. ***Amplifier:*** **-** It is a unity gain inverting amplifier and used to invert the phase of input signal, which is necessary for negative feedback applied to form close loop configuration. Its transfer function is, {eo = - ein}

The signal sources: **-** The setup has necessary built in signal sources to conduct the experiments. The only other external source required in the form of low frequency sine wave oscillator as a disturbance signal. The provided signal sources are as below.

1. ***Square wave:*** It has variable frequency which can be adjusted from frequency control provided upon the panel. The output amplitude is also variable and can be controlled independently with the help of control provided just under the output socket.
2. ***Triangular wave:*** It has same frequency as square wave with independent amplitude control situated just below the output socket.
3. ***Sine (par) wave:*** To observe the time respond signal an integrated triangle wave of fixed amplitude is provided. Its amplitude is 1 - 3Vpp (frequency depended) and it is also frequency related with other two signals.
4. ***Trigger:*** A constant amplitude (1Vpp) signal provided to trigger CRO in external mode.

The frequency of all four signals is controlled with the help of frequency control simultaneously has range from

< 20 Hz to > 50 Hz. The amplitudes of square and triangular wave are variable between 0 to 2 Vpp while trigger output has constant 1V and integrated triangle wave 1 - 3Vpp (freq depend). All the basic building blocks and signal sources based upon op - amps, has powered from internal dc symmetrical regulated power supply.

Some basics

a. First order systems: The first order systems are characterized by one pole and (or)a zero. An integrator with time constant have transfer functions in the form of {K / s} and {K / (sT + 1)}, respectively are common. The input / output characteristics of such systems for unit step input can be written for Fig. 1, if

$$\frac{C(s)}{R(s)} = \frac{K}{(sT + 1)} \qquad \text{subsituting} \qquad R(s) = \frac{1}{s}$$

by expending partial fraction

$$C(s) = \frac{1}{s} - \frac{T}{1+st}$$

Taking inverse Laplace transform

$$C(s) = (1 - e^{-t/T}) \qquad \text{for } t = 0$$

$$\& \qquad c(t) = \{K / (1 - e^{-t/T})$$

The time constant of the system is defined in above Eq. is equal to t = T, which gives an exponential rising curve c(t), then for Fig. 1b, T = $(1 - e^{-1})$ = 0.632K where K is final value. The smaller the time constant T, the faster will be response of the system.

For Fig. 2

$$\frac{C(s)}{R(s)} = \frac{K}{(s)}, \quad \text{subsituting} \quad R(s) = \frac{1}{s}, \quad \& \quad C(s) = \frac{K}{(1/s^2)}$$

Then $c(t) = Kt$

The output is a linear ramp with constant K/s. Higher the value of it lower the steady state error.

b. Second order systems: The second order systems are characterized by two poles and up to two zeros. In view of study transient response, the zeros are not considered for simplification and since they do not affect the results. The transfer function of such system as shown in Fig. 3 can be written

$$G(s) = \frac{\omega^2_n}{s2 + 2\zeta\omega_n s + \omega^2 n}$$

as:

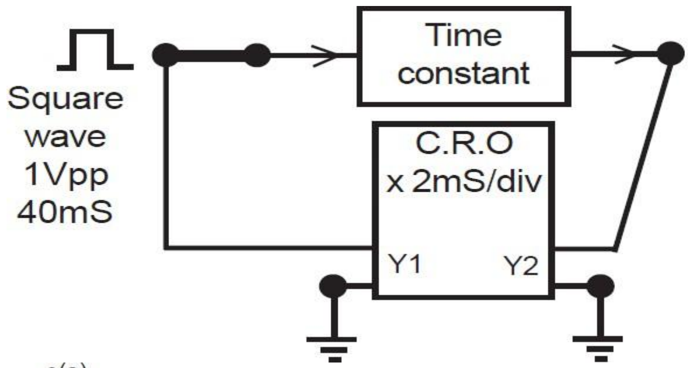


Fig 1a.
Connection for evaluation
Time constant response.

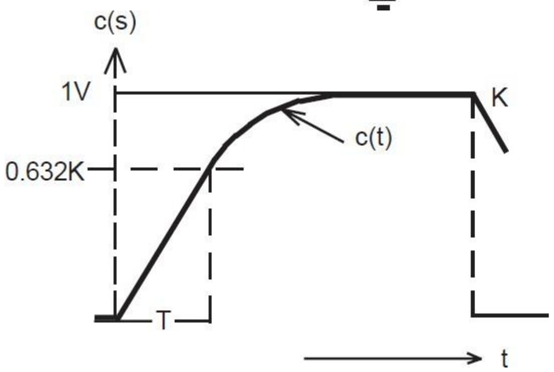


Fig 1b.
Time constant response.
1/ (1 + sT)

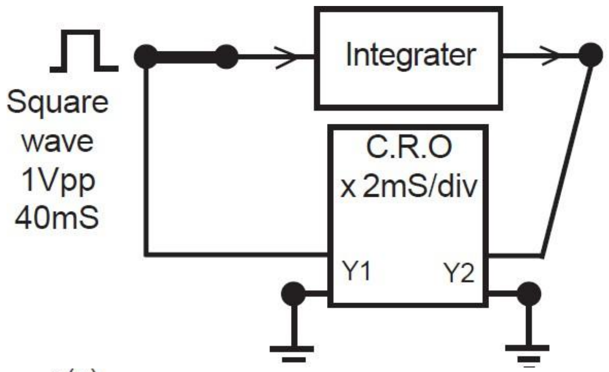


Fig 2a.
Connection for evaluation
integrater response.

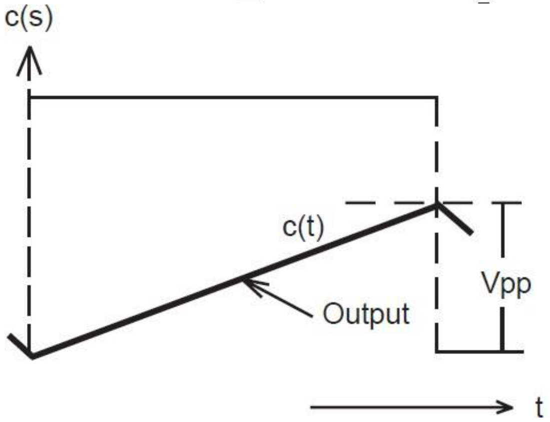


Fig 2b.
Time response
K/s

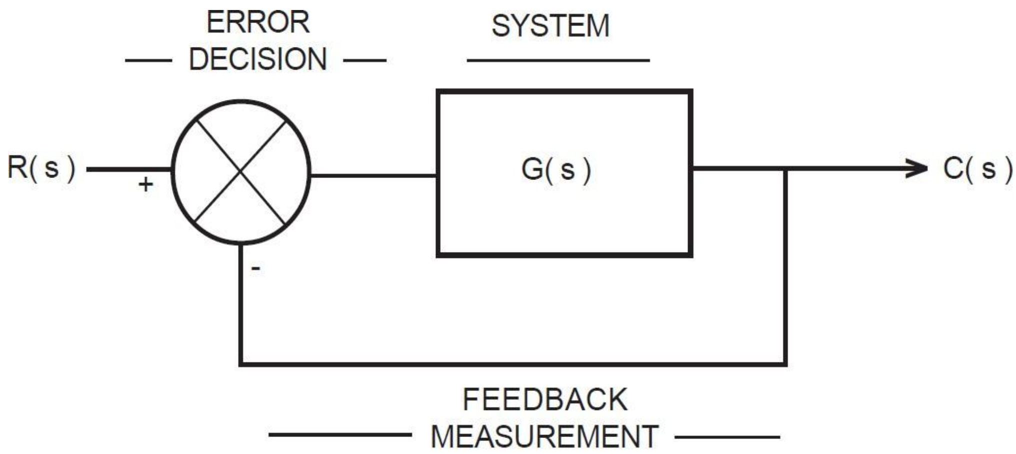


Fig -3a. Block diagram of a close loop system.

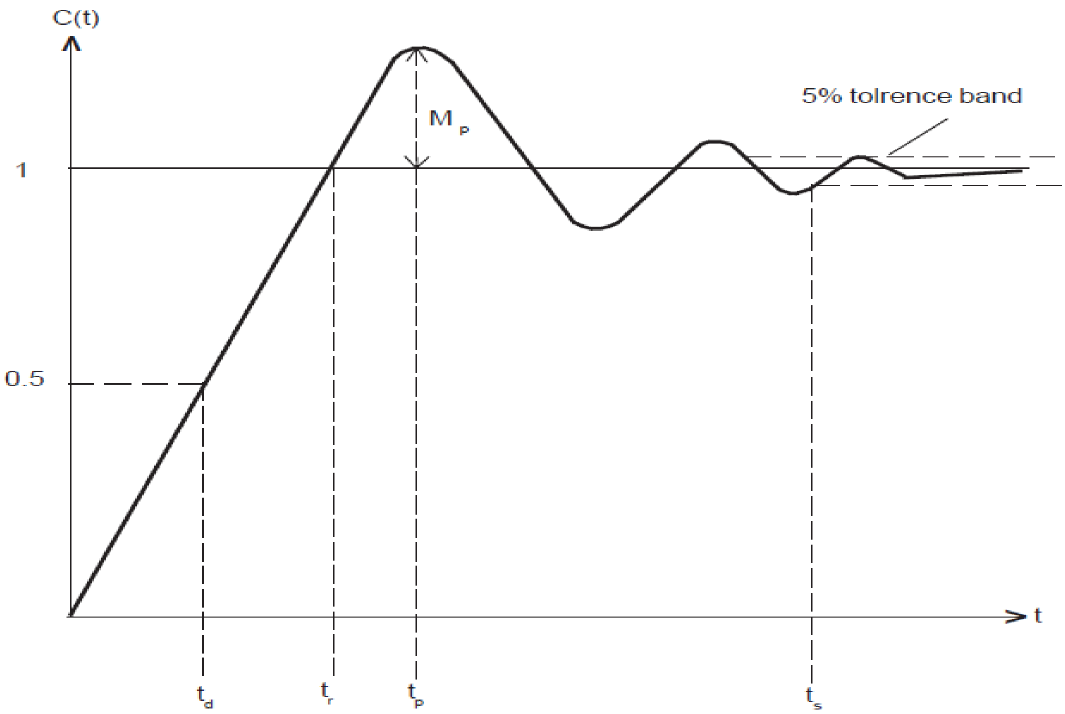


Fig. 3b. Step response of an underdamped 2nd order system.

Experiment procedure

In first step open loop response (page 8) should be carried out. For the purpose one dual trace CRO will be required.

Open loop response.

a. Error detector with gain

1. Set gain pot to 10.0.
2. Apply a 100 mVpp square wave of 25 Hz (40 mS) to any of the three inputs.

Measure the pp amplitude form CRO. Note the phase relation between input / output.

3. Decrease gain to 9, 8, 5 and verify the gain decrease in multiple, e.g. for 5 it should be equal to 500 mVpp.
4. Change the input to other one and observe that gain remain same.
5. Write an equation for the output as described earlier.

b. Time constant 1.

1. Apply 1 Vpp 25 Hz square wave signal to the input of first time constant block (with single input).

2. Find the time T from the trace at which the response approaches to 63% its value. Use X - expansion facility of CRO for the purpose to evaluate T.

3. Coincide the input / output traces and note the input / output amplitudes with their phase relations.
4. Write an equation for the transfer function from the observation.

* At works it is measured as T = 1 msec.

c. Time constant 2.

1. Apply 100 mVpp 25 Hz square wave and repeat the steps as taken for Exp. - b, for both inputs one by one.

2. Write two equations for the transfer functions of the block.

d. Integrater.

1. Apply 1 Vpp 25 Hz square wav
2. e signal to the input of the integrator block.
3. Measure the pp output of the triangle wave and note its phase relation.
4. Write the transfer function of the block calculating the equation Ki = 4 Vopp / τ (Valid if input is 1Vpp, the charge rate is 0.5/ R. l / 2C)

Otherwise calculate as: 4 Vopp / Vin.τ. Where Vin is in volts and Vo in mV and τ in millisecond or = 1 / f.

c. Time constant 2.

1. Apply 100 mVpp 25 Hz square wave and repeat the steps as taken for Exp. - b, for both inputs one by one.
2. Write two equations for the transfer functions of the block.
The time constant is T = 1 msec and K = 1 and 10 for respective inputs.

d. Integrator 1.

1. Apply 1 Vpp 25 Hz square wave signal to the input of the integrater1.
2. Measure the pp output of the triangle wave and note its phase relation.
3. Write the transfer function of the block calculating the equation

Ki = 4 Vopp / Vin τ Where Vin is in volts and τ in second (given 40msec).

The same procedure for integrator 2.
*At works it is measured about, 9.6 for integer 1&, 13.8 for integer 2.

e. The uncommitted Amplifier

Feed 25 Hz square wave signal to the input of the amplifier block and note its output voltage and its phase between input / output.

f. The disturbance adder

1. Feed 1 Vpp 25 Hz square wave signal to the one input of disturbance adder block and note its input / output phase and gain.
2. Change the input and note the gain and phase.

Close loop system

a. First order systems

Two types of first order systems can be configured as shown in Fig. 4. Make connections as shown and proceed as follows.

1. Apply 1 Vpp 25 Hz square wave signal to the input and note the response curve on tracing papers setting gains at 1, 2, 3 and so.

2. Calculate the time constants (for type 0 system) in each case and verify the results.

3. Calculate the steady state error from above cases. In case of type - 1, system particularly it is difficult to find out the steady state error. Switch CRO to XY mode and connect its X input with the triangular wave input, keeping triangular output equal to square.

4. Find the ess from the loop as shown in Fig. 6

5. Write the results from the experiments and compare it with the theory*. * There may some imperfection since there is a tolerance between practical and theory.

b. The second order system.

The Fig. 5 shows the configurations can be made for 2nd order systems. Select one and then other for experiment. Connect the circuit in proper manner and proceed as

1. Apply 1 Vpp 25 Hz square wave signal to the input and trace the output waveforms for different settings of error detector gain K* upon paper.
2. From the traces find out the value of td, tr, tp, Mp, ts and ess. Calculate the theoretical values and compare it with practical results.
3. In case of type - 1, system use XY mode stated as before for ess evaluations.

* For type one system start K from 10.0 and then decrease it. For type 0, start from lower side settings and then increase.

c. Disturbance rejection.

Other apparatus required, low freq. sine wave signal (shown in Fig. 7), otherwise inject the given sine (PAR) signal.

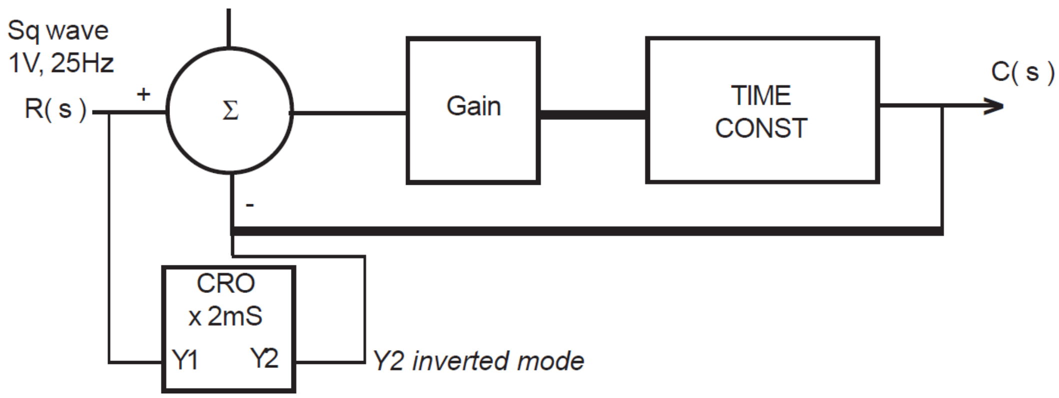
1. Connect the circuit as shown in fig 7b.
2. Feed low frequency sine wave signal (10 Hz) of 0.5Vpp or PAR signal at input of error detector. Observe the effect of disturbance upon the system.
3. Disconnect the sine wave signal from the input and connect it with output disturbance adder (Fig. 7a). Observe the effect.

* It is observed that when the disturbance signal added at input it becomes a part of command signal. When it is added at output the error detector reject it effectively.

d. Type 1, third order system (introductory).

Although it is not included in syllabi and practical approach but it can be configured as shown in Fig. 8.

1. Connect the circuit as shown in fig 8.
2. Feed 1 Vpp of 25 Hz square wave to the input and observe the output signal for gain K adjusted to 4,5, 6 alternately.
3. From the traces find out the value of td, tr, tp, Mp, ts and ess. Calculate the theoretical values and compare it with practical results.
4. In case of type - 1, system use XY mode stated as before for ess evaluations.



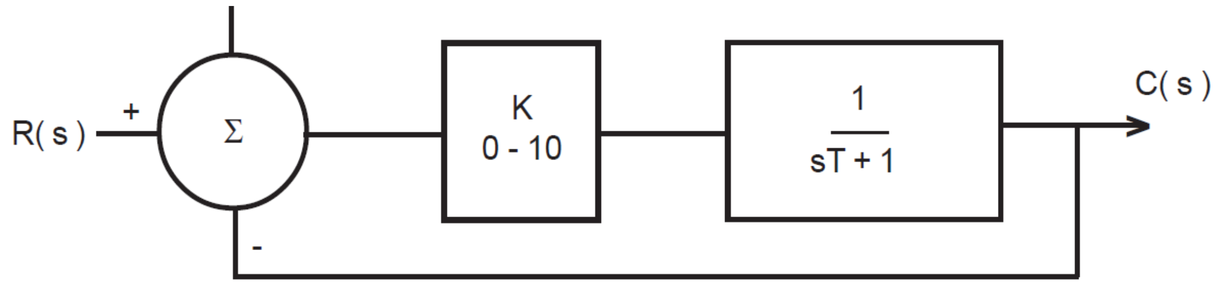


Fig 4a. First order type 0 system.

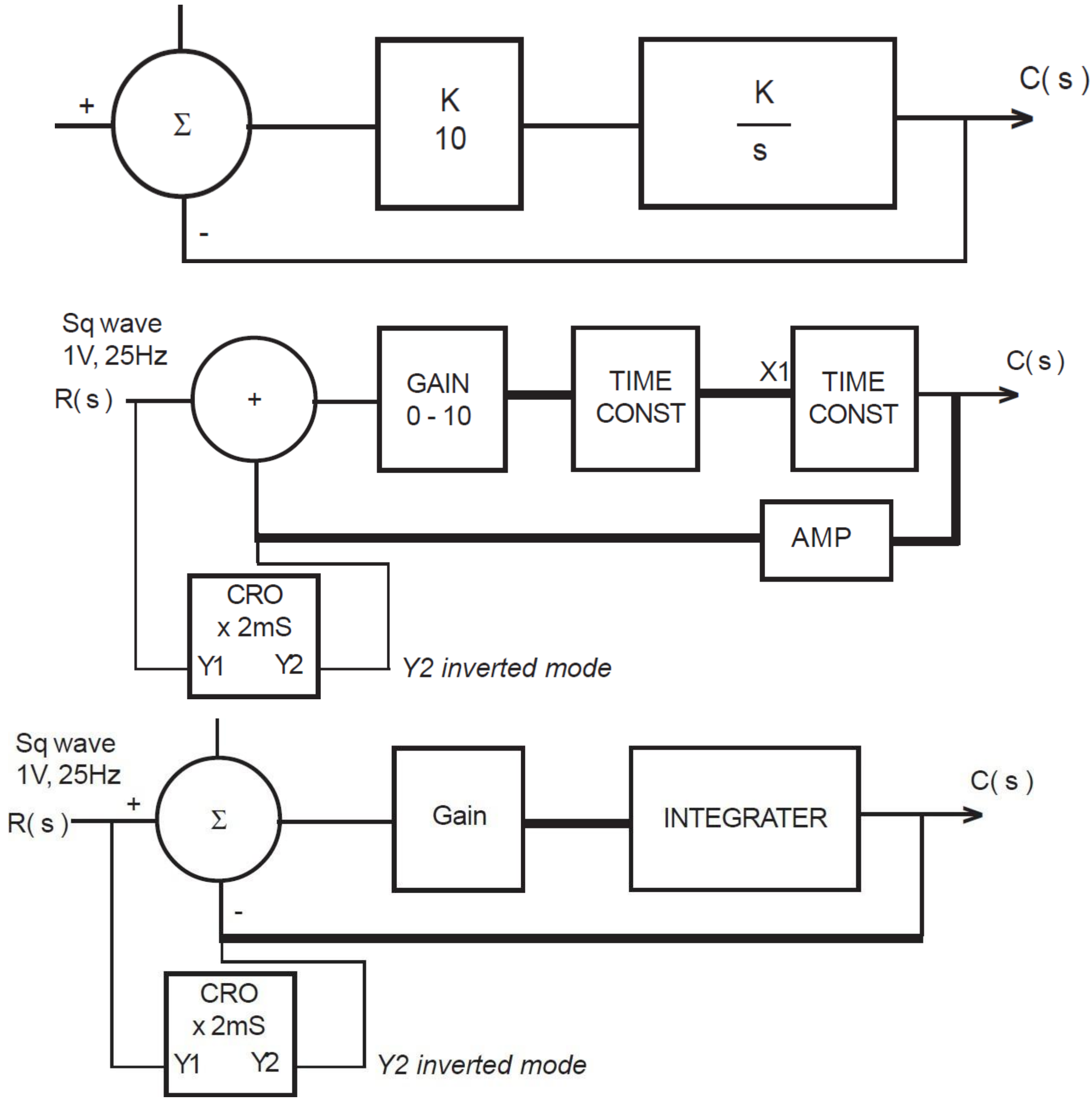


Fig. 4b. First order type 1 system.

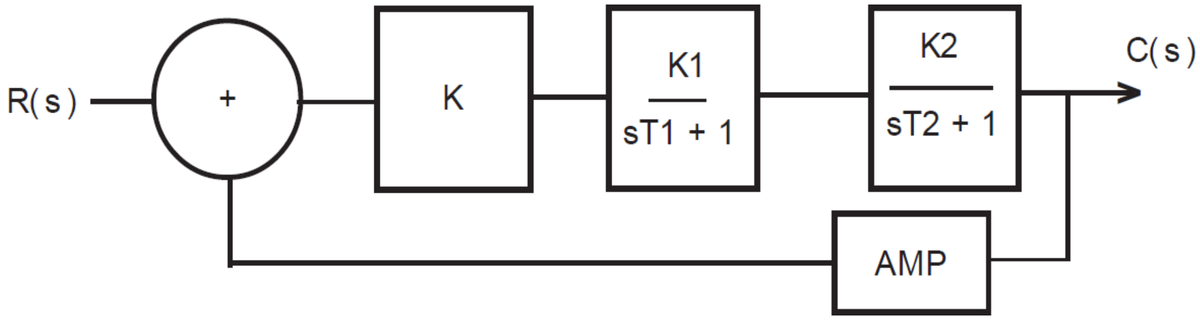
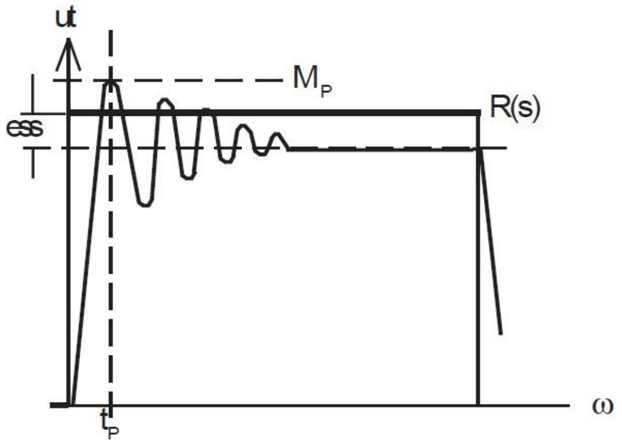
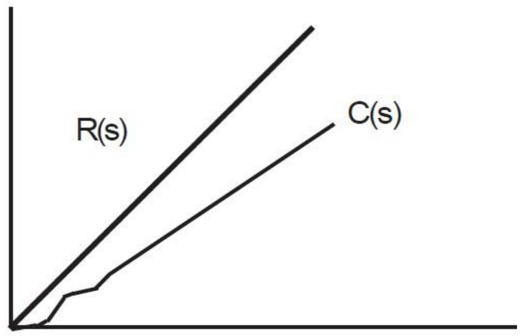


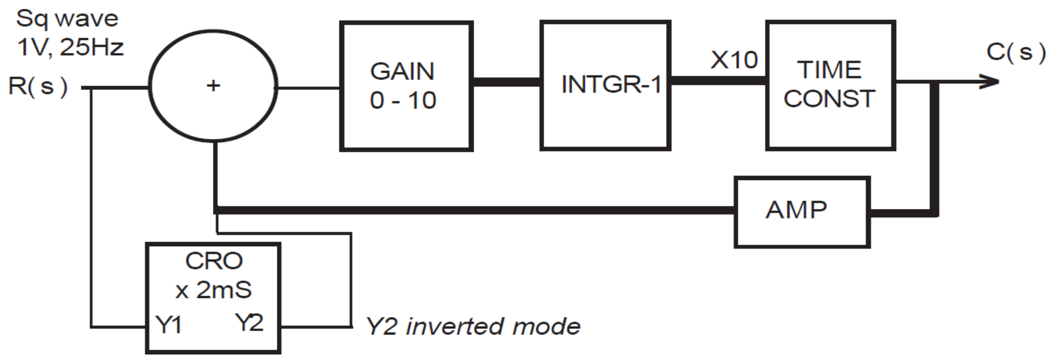
Fig. 5a. Type 0. 2nd order.



Typical response curve shown. R(s) is in form of square wave. System type 0, 2nd order.



Typical response curve shown. R(s) is in form of triangle wave. System type 0, 2nd order



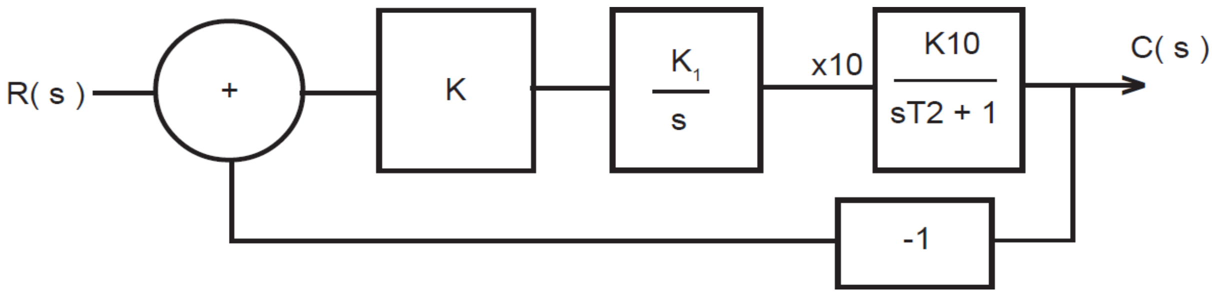
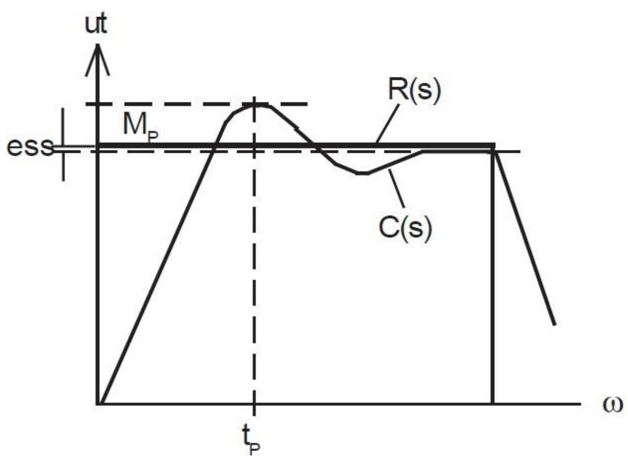
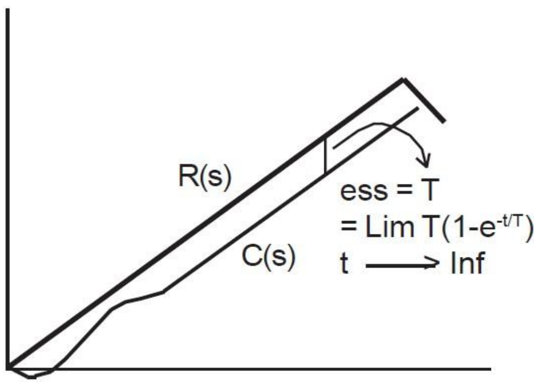


Fig. 5b. Type 1, 2nd order.



Typical response curve shown. R(s) is in form of square wave. System type 1. 2nd order



Typical response curve shown. R(s) is in form of triangle wave. System type 1. 2nd order

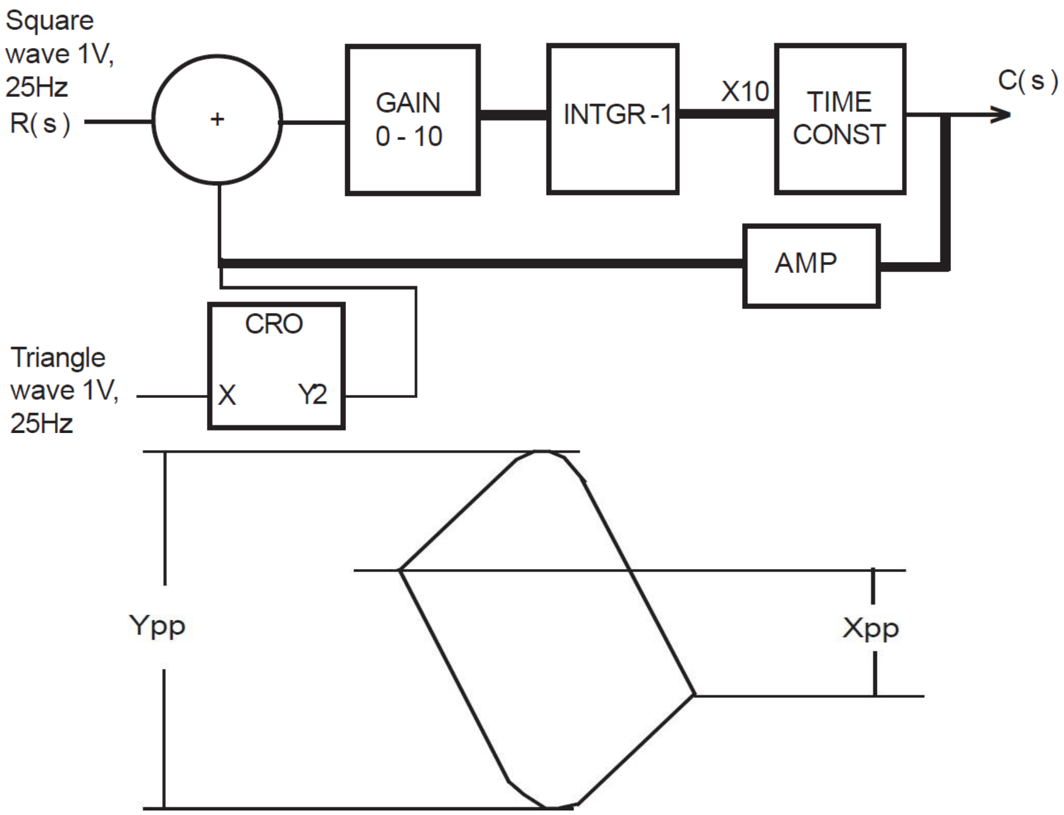


Fig 6. Above second order close loop system. XY connection.

Below the output waveform to evaluate ess = Ypp - Xpp. (see procedure)
Note: - there is some difference arise in both open loop and close loop calculations, since there are few source of errors
#The measurements are done on lab CRO and there is most possibility of mismatch in results between two the work lab and lab in practice.
#The set up implies on integrated circuits, in which bias current and other parameters affect the results between piece to piece or say between set up to set up, thus results are carried out on one set up in one production for time saving (assuming that the results are in close factor).
#As the set up performance is time dependent and time is basically found from time base of CRO under observation, then there may be possibilities arises to mismatch the results.
It is suggested that open loop performance must be carried out on same lab instrument.

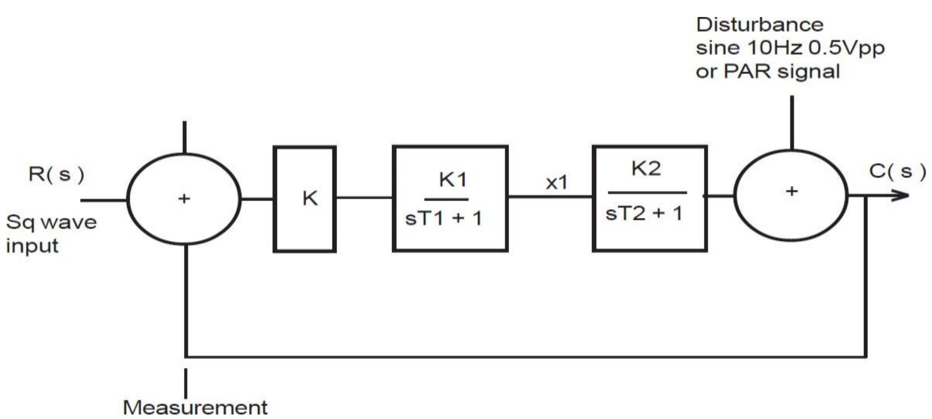


Fig. 7a. Way to connect disturbance adder in the second order circuit at output.

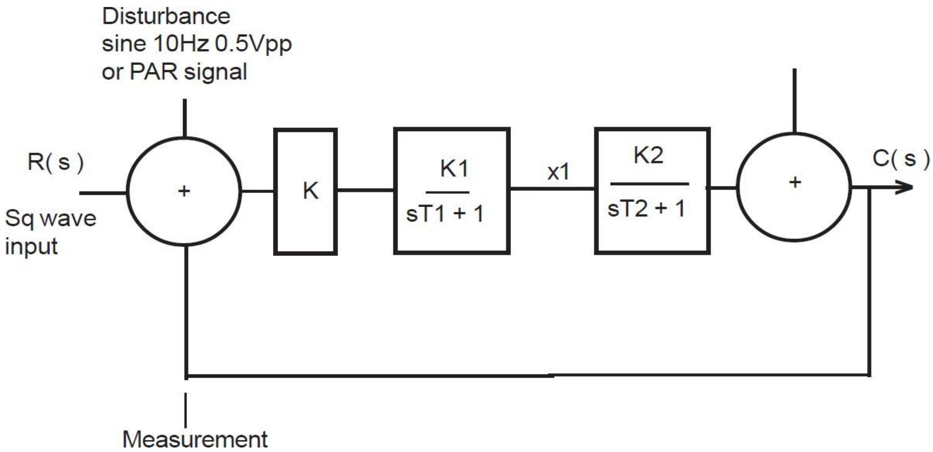


Fig. 7b. Way to connect disturbance adder in the second order circuit at input.

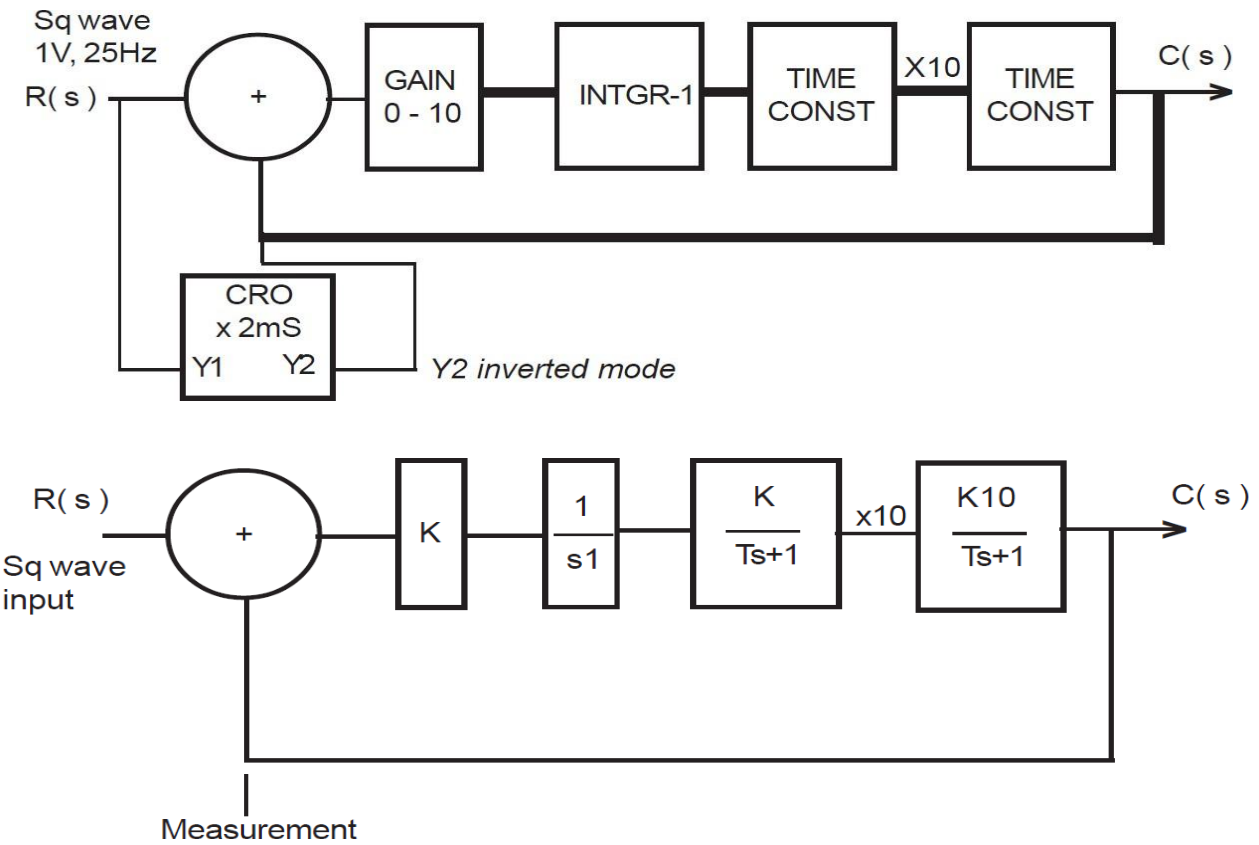
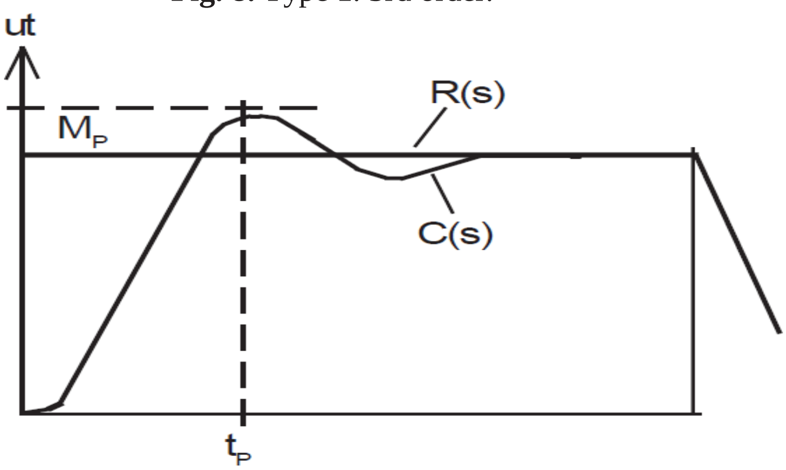


Fig. 8. Type 1. 3rd order.



EXPERIMENT NO: 2

TIME RESPONSE OF SECOND ORDER SYSTEM

AIM:- To study the stroboscope & measure the shaft speed.

APPARATUS REQUIRED:

Digital handheld stroboscope with:

- Range: 50–20,000 FPM
- Accuracy: ±(0.05% + 1 digit)
- LCD display

THEORY:

A. Definition of a Stroboscope

A stroboscope is a precision optical instrument used to measure rotational speed, oscillatory motion, and periodic mechanical behavior through the emission of controlled, high-frequency flashes of light. It enables the visualization of rapidly moving objects by creating the illusion of stationary or slow motion when the flashing frequency matches the motion of the object. Unlike contact-based instruments, the stroboscope provides a non-contact measurement technique, making it particularly suitable for high-speed rotating machinery, fragile systems, and hazardous environments.

B. **Principle of Operation**

The stroboscope operates based on the stroboscopic effect, a phenomenon in which a periodically moving object appears stationary when illuminated by flashes of light at the same frequency as its motion. When the flashing frequency is synchronized with the rotational speed, each flash illuminates the object at the same angular position. As a result, the human eye perceives the object as stationary.

C. Mathematical Framework

Let: fs = stroboscope flashing frequency (Hz)

fr = actual rotational frequency (Hz)

n = harmonic number

A stationary image occurs when:

$$fs = fr / n$$

Thus:

$$fr = n \cdot fs$$

And in RPM:

$$RPM = 60 \cdot fr$$

Because multiple values of n can satisfy the condition, multiple stationary images may appear, requiring proper interpretation to determine the true rotational speed.

D. Aliasing and Visual Interpretation

The stroboscope demonstrates aliasing, a phenomenon in which a signal appears distorted when sampled at discrete intervals.

In rotating systems, this results in:

- Apparent stationary motion
- Apparent slow forward motion
- Apparent reverse motion

These are optical illusions caused by improper synchronization and not actual changes in motion.

E. Engineering Applications

- Measurement of rotational speed (motors, spindles, fans)
- Vibration analysis and modal identification
- Fault detection (imbalance, misalignment)
- Inspection of rotating components
- Preventive and predictive maintenance

F. Advantages and Limitations

Advantages:

- Non-contact measurement
- Safe for high-speed applications

- Real-time visualization

Limitations:

- Harmonic ambiguity
- Requires operator judgment
- Sensitive to lighting and visibility conditions

PROCEDURE:

Ensure the rotating object is clearly visible and safe to observe.

2. Place a distinct reference mark on the rotating component.

3. Turn ON the stroboscope and confirm display is functioning.

4. Set the flashing frequency to a low initial value.

5. Direct the stroboscope toward the rotating object.

6. Gradually increase the flashing frequency.

7. Observe the motion of the object carefully.

8. Adjust until the object appears stationary.

9. Fine-tune to minimize apparent drift.

10. Record the frequency (FPM).

11. Repeat for at least three trials.

12. Identify other stationary conditions (harmonics).

13. Convert FPM to RPM.

14. Turn OFF the device after use.

EXPERIMENT NO: 6

STEPPER MOTOR CONTROL

AIM:

Experiment to study the stepper motor characteristics and its control through microprocessor kit.

INTRODUCTION

This experimental set up is designed to study of a small stepper motor fitted with calibrated dial and servo potentiometer in see through cabinate. The main unit has a motor controller, pulse sequence generator, variable frequency square wave oscillator, single step monopulser and wobbling signal to observe dynamic response. The unit can be interface with μP kit feeding appropriate programme given at end pages.

Stepper Motor : A stepping motor is an electromagnetic incremental actuator which converts electric pulses to machanical movements. In rotary step motor the output (shaft) rotates in equal increments in response to a pulse train of input pulses. In general dc motors the speed is governed by applied motor voltages which runs contineously and its direction get reversed when the polarity of input voltages is reversed. Whether properly controlled output steps of a stepping motor are equal in number to the input pulses number. Reversing the order of pulse sequence reverse the motor direction and the speed of the motor can increament/decreament by repeatation rate. These are the prime features of a stepping motor. The features of given stepping motor used in this set up following

Type of the motor : PM Hybrid DC stepping motor, two phase biflar wounded.

Stepping angle : $1.8^0 \pm$ Non - cumulative.

Step/resolution : 200/rev

Torque : 3.0 Kg/cm.

Supply : DC 12V/0.6Amp/phase.

In basic some important points are,

- There is no control winding min stepping motor. All windings are indentical.
- The stepping rate is a matter of frequency rather than voltage.
- When motor receive no pulse it remain locked in position and no current flows through it.
- A pulse input having two phases (instead of contineous pulses) will move the shaft of the motor precisely in steps.
- Stepping motors are programmed for three main parameters namely, Direction, speed and number of steps.

Relation between phase and pulse sequence

The stepper motor used here is shown below in diagram. It has four coils wounded in such manner that there are two phases (anti wound coils) A and B. The motor is excited with pulse sequence as shown below in the table. Note that there are two logic 1, are in each sequence. The table shows that the motor runs in phase A, AB, B and AB alternatly. This provision avoid overstepping and improve the response. The reversel of direction is easier as to invert the serial of pulse sequences. The speed of the motor is a matter of repeatation frequency. This confind our required parameters as stated earlier.

Table of the motor pulse sequences

Sr	Phase 1	2	3	4
01	0	0	1	1
02	1	0	0	1
03	1	1	0	0
04	0	1	1	0

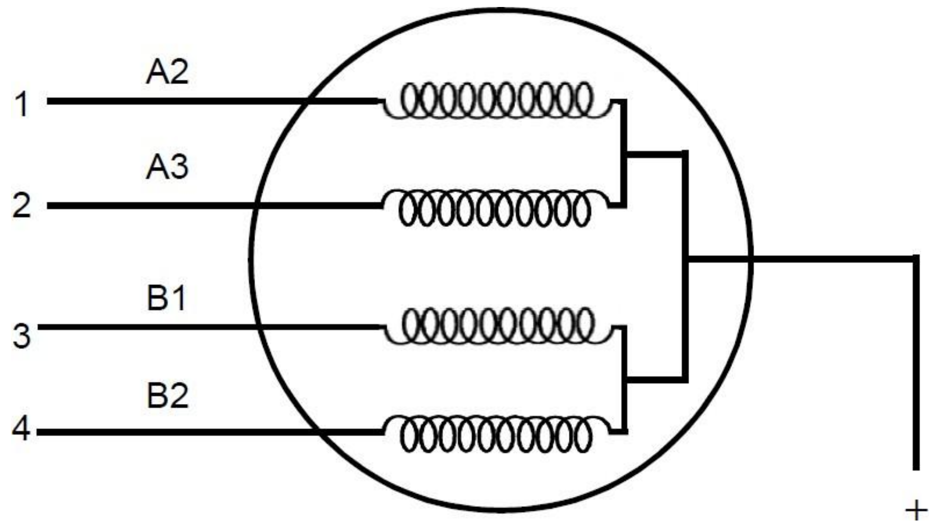


Fig. 1 **Stepper motor with its phases.**

In biflar (parallel) wound coils the start of one coil is called phase one and the end of the other coil is called phase two.

About the set up

The motor unit consists a stepper motor, a dial to detect the angular displacement and servo pot to observe motor dynamic response. The main unit consists a pulse generator having frequency from 10Hz to 100Hz app. A pulse sequence generator to obtain required pulse sequences, a controller card to drive the motor. LEDs are fitted at output of controller card to visualize the sequences. A monopulser arrangement provided for single stepping studies. The motor dynamics are studied by wobbulating arrangement. Sockets are provided to change the motor phases with the drive circuit. A 9 pin D connector is fitted upon the panel for uP interface with interface circuitry.

Step response of the stepping motor (without load)

When a single step oa a motor is made a typical response is shown by a frequency the response curve change to fig 2. In fig. 1 it is clear that motor setting time depends upon loading and input sequence factor. When motor is run at higher timing sequence (freq.) it can overstepped.

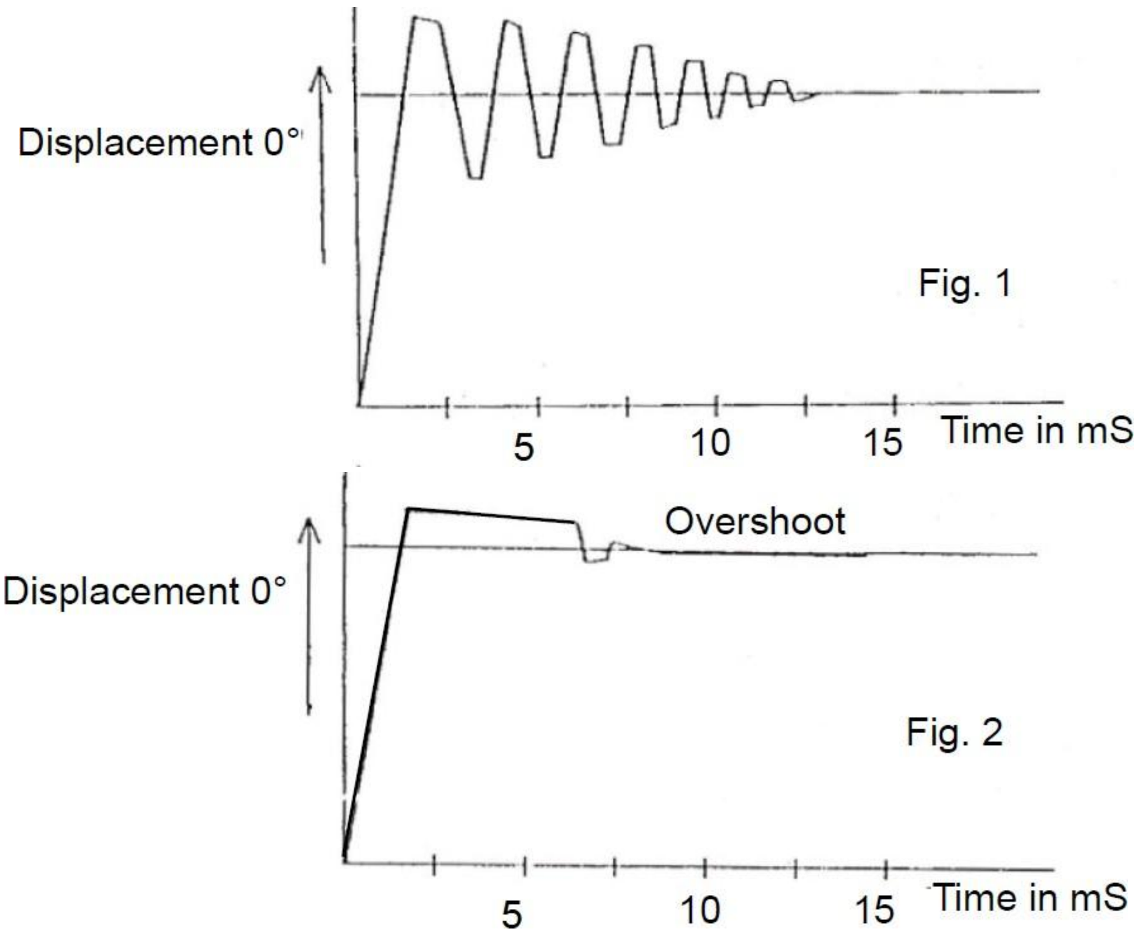
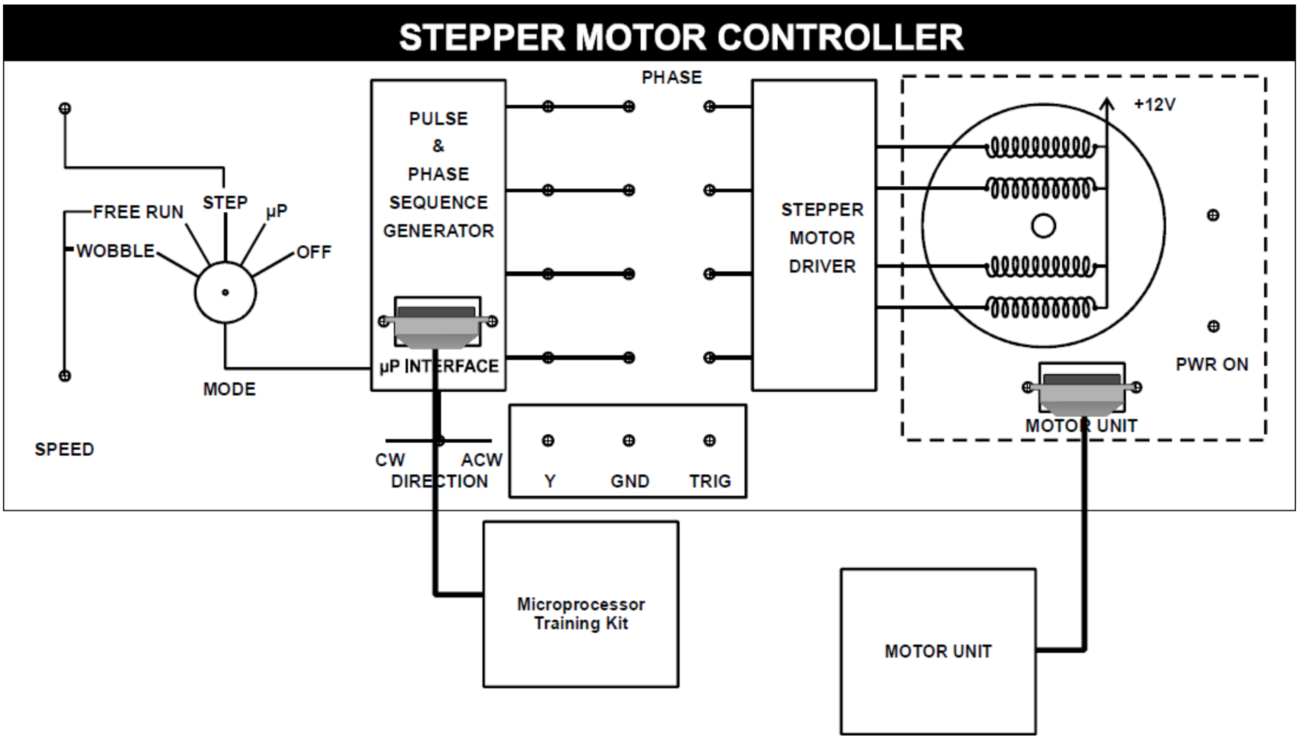


Fig. 2 Step response.



Exp. 3. Front panel view.

BASIC STEP ANGLE MOVEMENT.

PROCEDURE

1. Connect motor unit with the main unit, with D type connector marked as MOTOR UNIT. Connect all the phases of the motor to their respective outputs
   i.e. 1 with 1, 2 with 2 and so 3 and 4.
2. Select SINGLE STEP for the mode selector. Switch on the power.
3. Note the dial position in degree from the top of the motor unit. Select CW direction from the direction selector mini toggle switch. Note the LED status respect to phase.
4. Press the step key for 10 or 20 times making a delay of 1 second between two steps. Note the position of the dial.
5. Press 10 or 20 times more and note the readings as before.
6. Calculate the step angle as displacement in degree/number of key strokes (steps).
7. Plot step signal stroke v/s degree curve and find out the error/degree.
8. Repeat the above steps making direction anticlockwise.

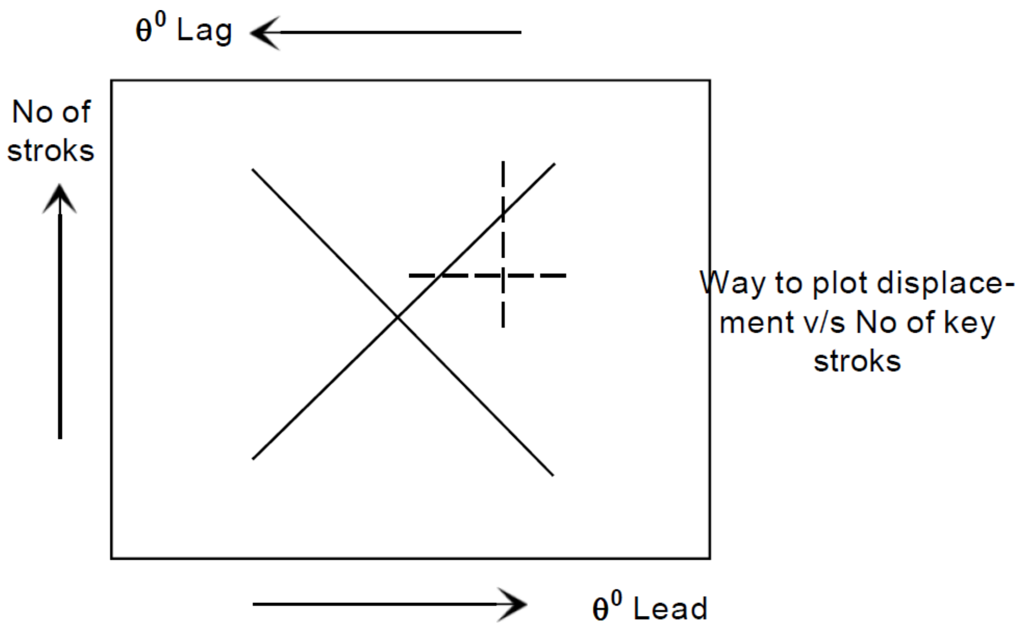
   Conclude the result.

STUDY OF PHASE PULSE SEQUENCE.

PROCEDURE

1. Remain the set up as before. Note the position of the motor in degree Select CW direction.
2. Note the status of the LEDs in respect to the phase.
3. Apply one step by pressing key briefly and note the LED status.
4. Apply 2 or 3 pulses and note the LED status for each step. Tabulate the observations.
5. Note the dial reading and find out the rotation direction.
6. Select CCW mode and repeat the process. Find out the direction of rotation and LED status.

Tabulate the sequences of LEDs and the direction of movement (clock-wise or counter clockwise) and conclude the results.



Exp. 4. Study of speed and direction.

Other apparatus required : CRO and stop watch.

PROCEDURE

1. Remain the set up as experiment a. Select FREE RUN from the modes selector switch.
2. Connect CRO Across the ground and Trig socket. Select CW direction.

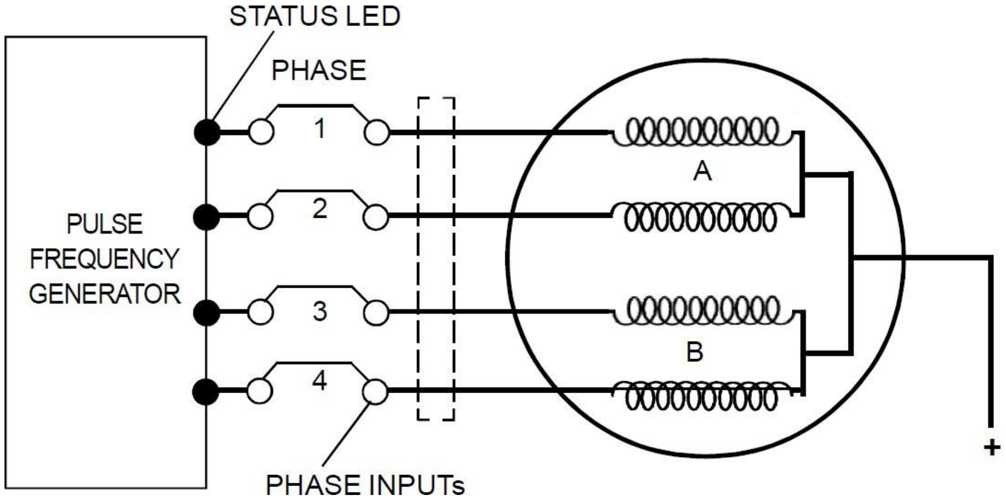
   Adjust free run frequency to 10Hz = 100mS from CRO
3. Measure shaft rotation with the stop watch for predetermined period say for 60 seconds and record it. Find out the motor speed from frequency repeatation rate and compare it with the recorded speed.
4. Select CCW mode and repeat the steps.
5. Adjust free run frequency to 20Hz = 50mS from CRO. Watch the increament of speed. Calculate the motor speed from the applied frequency and number of steps.
6. Adjust free run frequency to 50Hz = 20mS, and note the motor speed further increamented. Connect DRO at each of the phase and trace the pulse wavefom for each phase. If timing problem occurs connect ext trig of CRO with Trig socket. Switch off the power.

   *As it is found in last practical that the step of the motor is related with pulse sequences. In exp a, it is ound that motor advances one step/ pulse. Thus for 100mS pulse the motor will run at 10 steps/sec or 3 rpm (since 200 step/rev.)

DYNAMIC RESPONSE

PROCEDURE

1. Connect CRO at Y and ground free run mode from the mode switch.
2. Connect phase 1 with input 2 and phase 2 with input 1. The operation is now in phase A mode.
3. Switch on the power and adjust free run frequency to observe a stationary pattern upon CRO (start from low frequency to avoid overstepping). Trace the pattern.
4. Connect phase 3 with 4 and 4 with 3 input. The motor operation is now in phase B mode. Trace the pattern from CRO as avove.
5. Connect all phases to respective outputs. Select Wobbling and observe the pattern. When input frequency is larg compared with settling time is, the motor overstepped which can be seen from the dial position Conclude the results.



Exp. 5. Typical layout of connections.

EXPERIMENT NO: 6

TEMPERATURE CONTROLLER USING PID

AIM:

To study the performance of P, PI, PID controller's used to control the temperature of an oven.

APPRATUS:

Temperature control kit.

Oven

Patch cards

Stop watch

THEORY:

The system consists of a versatile controller and electrically heated model process and a conditioning unit.

The model is an aluminium process block surrounded by a symmetrically located lamp bank which serves to heat the process block. Platinum resistance thermometer is used in order to sense the temperature of the process block. The model is a speeded version of an industrial process with the time constants shortened to make the experiments of appropriate duration for engineering college laboratories and university labs.

The control problem investigated that of maintaining the process temperature under variation of heat losses by changing the flow of cooling air passed through the model.

The conditioning unit uses a stabilized power supply feeding a bridge circuit for which PT-100 element forms one of the four arms. The required process temperature is adjusted with the help of a precision ten turn helical potentiometer with dial.

The error signal is suitably modified to drive a temp. Deviation meter.

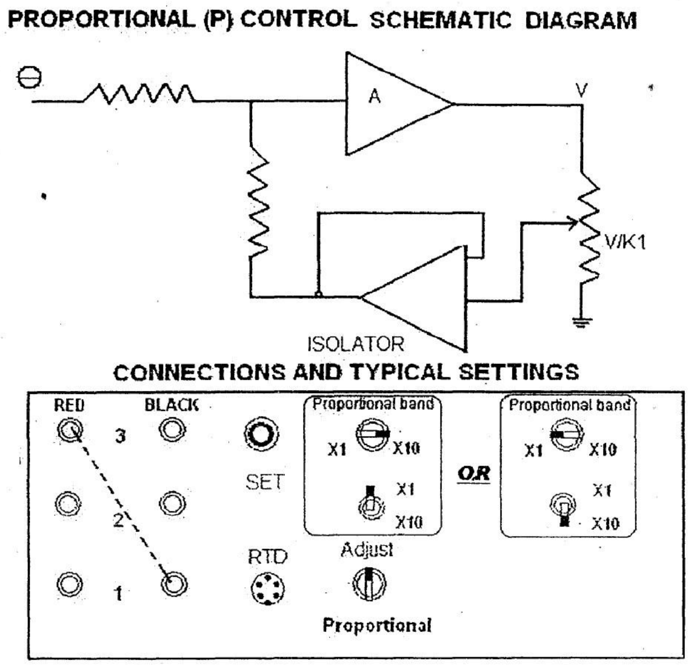
Following are the various modes of control which can be patched on the system.

1. Proportional controller (P)
2. Proportional + Integral (P+I)
3. Proportional + Derivative (P+D)
4. Proportional + Integral + Derivative (P+I+D)

All the normal parameters such as proportional band, integral and derivative time etc. are adjusted over a wide range. The percentage of power indicates output as the percentage of full power supplied to the heater.

The control of power to the process heater (lamp bank) is obtained by using a solid state relay. The control section is electrically isolated from the conditioning unit with help of an optocoupler isolator (L.E.D. and photo transistor link) The flow of cooling air is generated with the help of a fan which is controlled from a solid state regulator using a triac circuit.

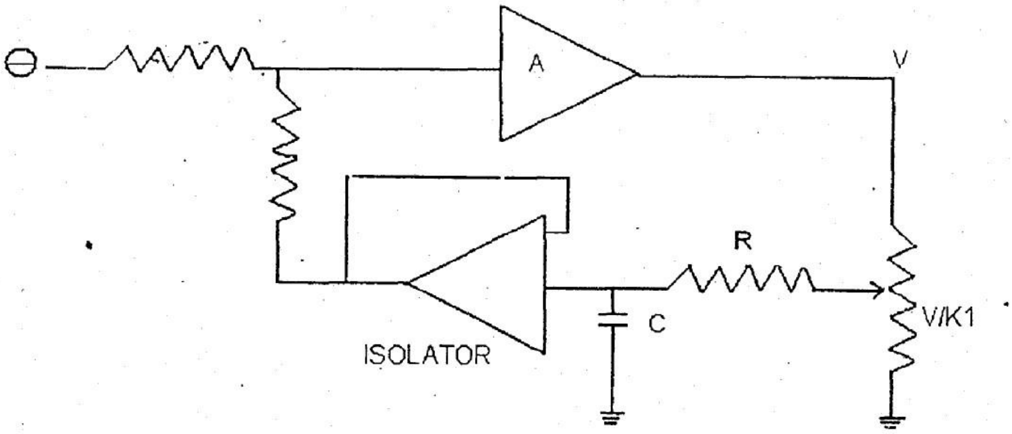
CIRCUIT DIAGRAMS



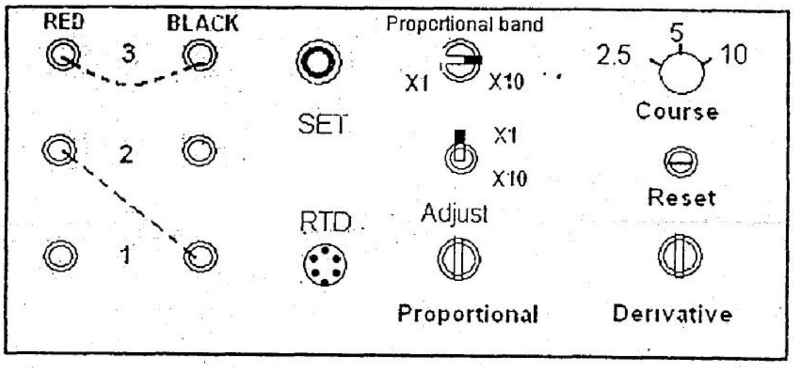
NOTE: FOR PROPORTIONAL BAND OR GAIN ADJUSTMENTS . BOTH THE ALTERNATIVES ARE SHOWN AND ARE VALID.

IF SET POT IS ADJUSTED AT 20 OHMS WITH NULL ON DEVIATION METER, THEN ADJUST POT IS USED TO GET +/- 5 DEGREES DEVIATION WITH SET POT DISTURBED BY 2 OHMS ON EITHER SIDE.

FIGURE NO.6



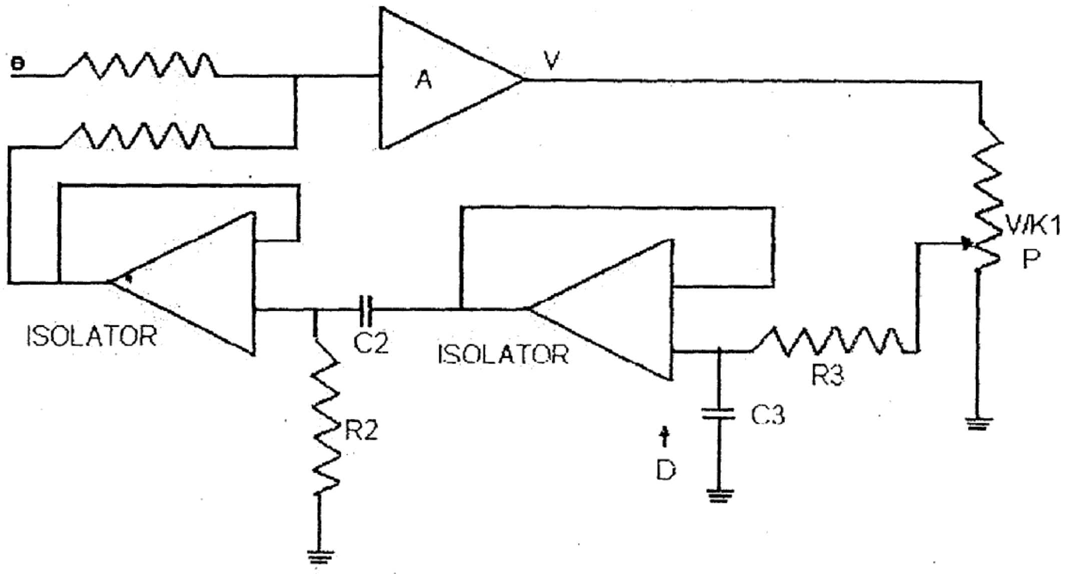
PROPORTIONAL + DERIVATIVE CONTROL (SCHEMATIC DIA.)



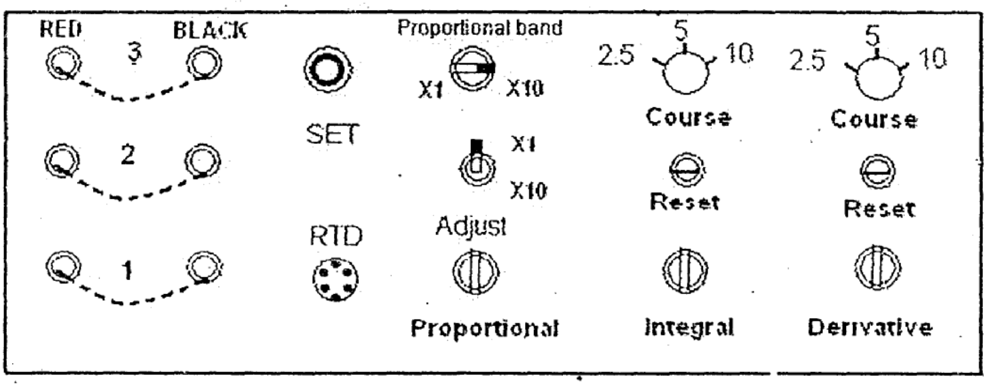
CONNECTIONS AND TYPICAL SETTINGS

RESET BUTTON MUST BE PUSHED BEFORE STARTING EXPT

FIGURE NO. 8



CONNECTIONS AND TYPICAL SETTINGS
FOR P + I + D ACTION



PUSH RESET BUTTONS BEFORE STARTING EXPT

FIGURE 9

PROCEDURE:-

1) Before connection keep all the pots are in fully anticlockwise and all switches in downward position means X10 sec. position. Do not connect heater and 5 pin socket. Keep the fan regulator OFF.
2) For the calibration plug the main socket & switch ON the unit. Connect the 5pin socket (RTD) .Short the Red 3 & block 1 by using link as per fig. no.6.By adjusting the 10 turn pot set the deviation meter on 0° C. Note the 10 turn pot reading in ohms & multiply by 2.5° C. the answer is room temperature because ; 1= 2.5°C .
3) Adjusting the pot 2 OHMS towards the – ve & +ve respectively for calibration.
4) Set the temperature by using 10 turn pot by adding 20° C in the room temperature. Switch ON the fan at slow position & start to take reading as per table. Take the reading till +2°C & suddenly increase fan speed for 2nd table.
5) In P controller you can observe the offset error .For removing this error add INTEGRAL means P+I. Keep the fan speed as constant.
6) Do the connection as per fig.7. & press the reset button of the integral till 5Secs. & remove. This is for discharging the condenser or reset the system.
7) And take the readings as per table fan in slow (slow disturbance) & fast position(High disturbance) & plot the graph. In this case you can see the error for some time then there is no error. But the load is increase then the system will again disturb & it will take again some time for removing the error.
8) For removing this draw back We must add P+D means proportional + Derivative. Do the connection as per fig.No.8 again press the derivative RESET button till 5 Seconds for discharging the condenser. And start to take reading as table in slow & Fast speed. Plot the graph.
9) Then finally for observing PID do the connection as per fig. 9.
10) PID means the process which find , remove the error from control system.

EXPERIMENT NO: 7

COMPENSATION DESIGN

AIM: Experiment to study Compensation design.

Introduction:

Compensation network are oftenly used to made appreciable improvement in transient response and small change in steady state accuracy. This set up has facilitate to study and design implementation of such networks. Three of such networks are given in the set up and performance of other designed networks can be implemented using few passive components.

Set up description: The setup is divided in to three parts (a) Signal sources, (b) Uncompensated system, and (c) Compensators.

a. There are three signal sources provided in the set up.

1. **Sine Wave** : It is available through socket in marked frequencies spanning across two decades as, 10Hz to 1000Hz. The signal has (8Vpp approx.) un-calibrated output with reference to ground. The frequency selection is made with coarse selector between X10 or X100 and multiplied with dial digit.

2. **Square Wave** : It is available in fixed frequency, 40Hz. The output is fixed about 1Vpp in amplitude.

3. **Phase Angle Meter** : It is an analog meter provided to take readings of respective phase angle between given signal input - output, where its one input is connected internally with sine wave source. Tolerance ±05°, ±1 count.

b. These are simulated system of unknown dynamics

1. **Process or plant** : It consists of an active network simulation of second order system. The transfer function is, $K/(sT+1)^2$.

2. **Gain 2 Block** : It is an amplifier provided to compensate the K_c. The gain setting is variable between, $-K_c = 0 - 10$, by mean of a calibrated dial. The input/output is phase shifted by 180°.

3. **Error Detector Cum Gain** : This block has two inputs (e1, e2) and an amplifier has an output equal to $e_0 = K_A$ (e1 + e2), where K_A is variable between 1-10 by a calibrated dial and e_1 is 1Vpp Square Wave. The input/output is in phase.

4. **Compensation Circuit** : There are three compensation circuits as Lag, Lead and Lag - Lead with transfer functions in form of $Gc(s) = (K_c)\alpha(sT1+1/sT2+1)$ and $(K_c)\beta(sT1+1/sT2+1)$ where (K_c) is implemented by gain compensation amplifier by Gain 2 Block.

c. **Power Supply** : The set up has two symmetrical DC regulated power supplies for signal sources and systems.

d. **Amp.** : It is an inverting amplifier having $K=-1$, required to invert phase of feedback signal.

About the experiment:

The experimental work is divided in two parts :

1. (a - e) the open loop response and

2. (A - B) the close loop response.

In open loop response in first step the magnitude / frequency and phase / frequency plots are performed. A dual trace CRO is essential for experimental steps (optional phase angle meter).

Exp. 1 – Open loop response.

EQUIPMENT REQUIRED

1. Lead - Lad Compensator System
2. Dual Trace CRO
3. Phase Angle Meter (Optional)

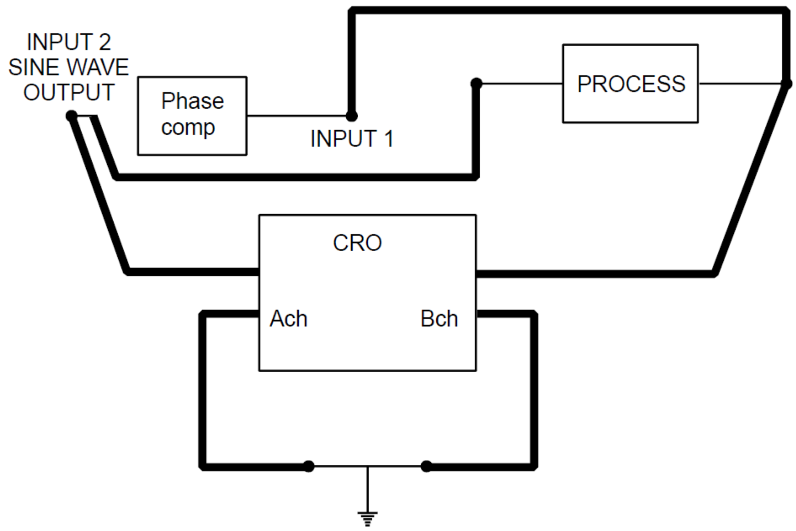


Fig. 1 Open loop response of process.

PROCEDURE

1.1 Connect the sine source with process / plant input. Connect CRO across input and output (dual trace mode). Measure input voltage A = ...Vpp.

1.2 Start from the low frequency end (10Hz), increase frequency in step of 10, 20, 30, 40, 50Hz for linear mode 10, 20, 40, 80, 100, 200 for octace mode and note the output voltage Vpp as B. Note the phase difference for each test frequency.

1.3 Prepare a table between input - output volts, the gain magnitude in dB ($20\log_{10}B/A$) and phase angle in degree.

1.4 Sketch the phase / frequency (Bode plot) response for smooth curves upon semilog paper. From the low frequency and obtain the error coefficient and required gain K_A.

Typical table (example) for plotting of response curve (Process or plant)

f Hz	A Vpp	B Vpp	Gain dB	/ ϕ
10	...V	...V	dB	n°
20	"	"	...	...
40	"	"	...	...
80	"	"	...	...
100	"	"	...	...
200	"	"	...	...
400	"	"	...	...
800	"	"	...	...
1000	"	"	...	...

Typical table (example) for plotting of response curve (Process or plant)

Freq	A Vpp	B Vpp	Gain dB	ϕ
10	...V	...	...	...
20	"	"	...	...
40	"	"	...	...
80	"	"	...	...
100	"	"	...	...
200	"	"	...	...
400	"	"	...	...
800	"	"	...	...
1000	"	"	...	...

Exp. 2 – Open loop response of Lag compensator.

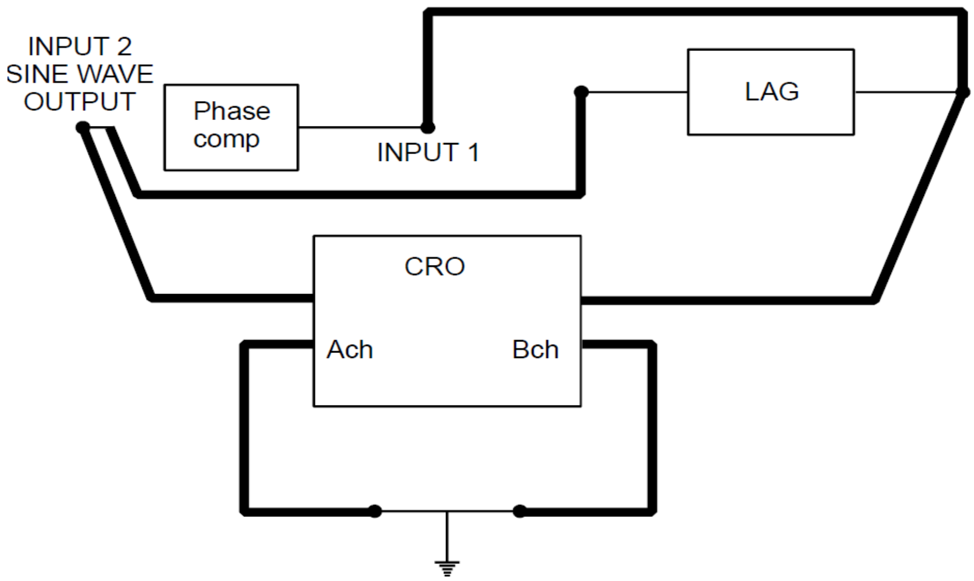


Fig. 2 Open loop response of Lag compensator.

PROCEDURE

2.1 Connect the sine source with Lag input. Connect CRO across input and output (dual trace). Measure input voltage A...........Vpp.

2.2 From the low frequency end (10Hz) note the output voltage Vpp as B. Note the phase difference for each test frequency as previous experiment.

2.3 Prepare a table between input - output volts, the gain magnitude in dB ($20\log_{10}B/A$) and phase angle in degree.

2.4 Sketch the Bode plot for smooth curves upon semilog paper. From the low frequency end obtain the error coefficient and gain K.

Typical table (example) for plotting of response curve (Lag Compensator)

Freq	A Vpp	B Vpp	Gain dB	ϕ
10	...V	...	...	...
20	"	...	...	...
40	"	...	...	...
80	"	...	...	...
100	"	...	...	...
200	"	...	...	...
400	"	...	...	...
800	"	...	...	...
1000	"	...	...	...

Exp. 3 – Open loop response of Lead compensator.

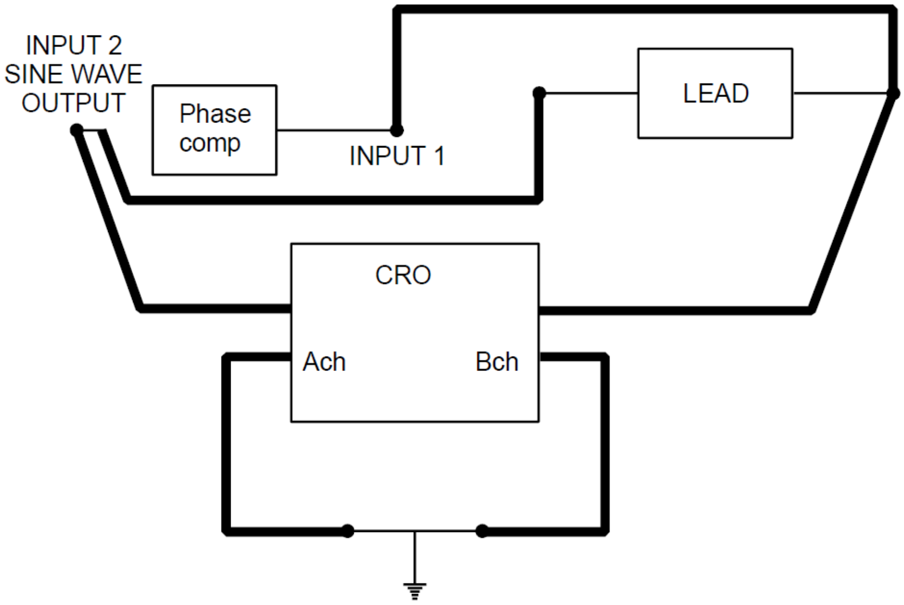


Fig. 3 Open loop response of Lead compensator.

PROCEDURE

3.1 Connect the sine source with Lag input. Connect CRO across input and output (dual trace). Measure input voltage A..........Vpp.

3.2 From the low frequency end (10Hz) note the output voltage Vpp as B. Note the phase difference for each test frequency as previous experiment.

3.3 Prepare a table between input - output volts, the gain magnitude in dB ($20\log_{10}B/A$) and phase angle in degree.

3.4 Sketch the Bode plot for smooth curves upon semilog paper. From the low frequency end obtain the error coefficient and gain K.

Typical table (example) for plotting of response curve (Lead Compensator)

Freq	A Vpp	B Vpp	Gain dB	ϕ
10	...V	...	...	...
20	"	...	...	...
40	"	...	...	...
80	"	...	...	...
100	"	...	...	...
200	"	...	...	...
400	"	...	...	...
800	"	...	...	...
1000	"	...	...	...

Exp. 4 – Open loop response of Lag-Lead compensator.

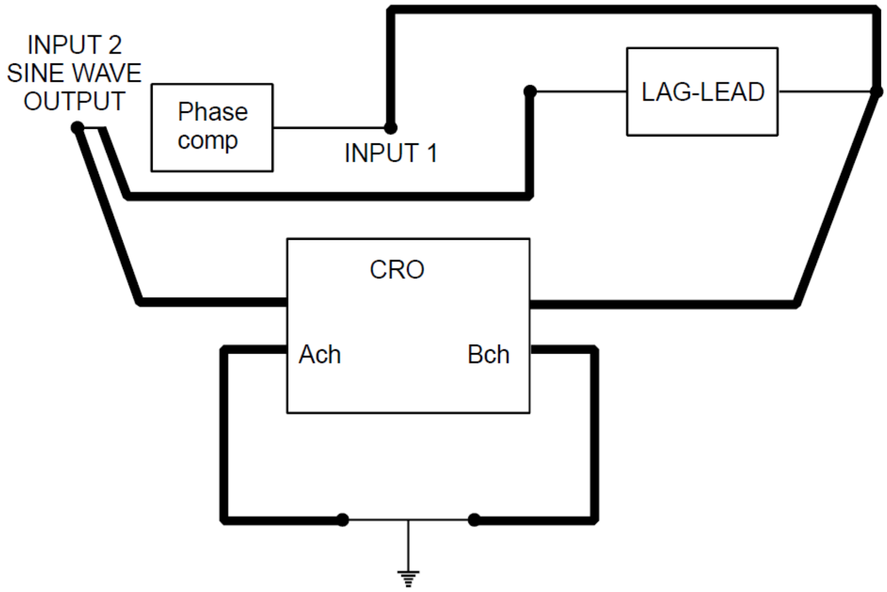


Fig. 4 Open loop response of Lag-Lead compensator.

PROCEDURE

4.1 Connect the sine source with Lag input. Connect CRO across input and output (dual trace). Measure input voltage A...........Vpp.

4.2 From the low frequency end (10Hz) note the output voltage Vpp as B. Note the phase difference for each test frequency as previous experiment.

4.3 Prepare a table between input - output volts, the gain magnitude in dB ($20\log_{10}B/A$) and phase angle in degree.

4.4 Sketch the Bode plot for smooth curves upon semilog paper. From the low frequency end obtain the error coefficient and gain K.

Typical table (example) for plotting of response curve (Lag - Lead Compensator)

Freq	A Vpp	B Vpp	Gain dB	ϕ
10	...V	...	...	...
20	"	...	...	...
40	"	...	...	...
80	"	...	...	...
100	"	...	...	...
200	"	...	...	...
400	"	...	...	...
800	"	...	...	...
1000	"	...	...	...

Exp. 5 – Open loop response of Plant with compensator.

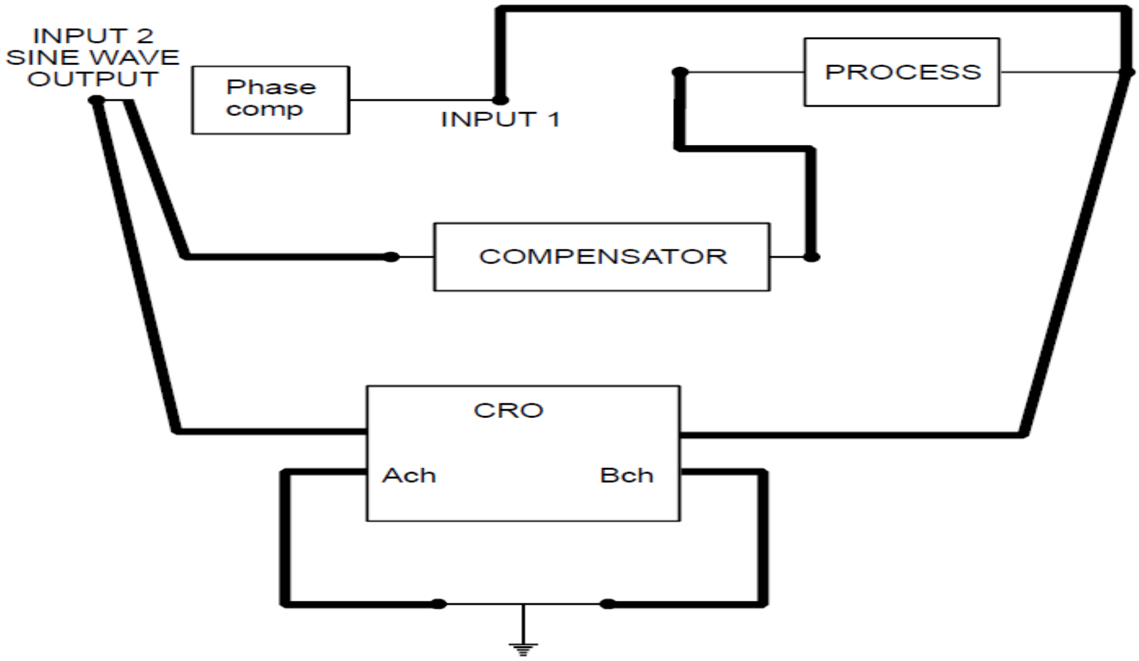


Fig. 5 Open loop response of Plant + compensator.

PROCEDURE

5.1 Connect the system as shown in fig. 3. Measure sine wave signal of .....Vpp at the input of the compensator with connecting CRO channels at input / output.

5.2 The readings between input / output as A and B, phase relation between them may be taken either by linear increment as, 10, 20, 30, 40, ... or by octave steps, as 10, 20, 40, 80, 100, 200, 400, 800 & 1000Hz.

5.3 Tabulate the results as given in exemplary tables.

Typical table (example) for plotting of response curve Plant + (Lag)

Freq	**A Vpp**	**B Vpp**	**Gain dB**	ϕ °
10	...V	...	...	...
20	"	...	...	...
40	"	...	...	...
80	"	...	...	...
100	"	...	...	...
200	"	...	...	...
400	"	...	...	...
800	"	...	...	...
1000	"	...	...	...

Typical table (example) for plotting of response curve Plant + (Lead)

Freq	A Vpp	B Vpp	Gain dB	$\phi°$
10	...V	...	...	...
20	"	...	...	...
40	"	...	...	...
80	"	...	...	...
100	"	...	...	...
200	"	...	...	...
400	"	...	...	...
800	"	...	...	...
1000	"	...	...	...

Typical table (example) for plotting of response curve Plant + (Lag - Lead)

Freq	A Vpp	B Vpp	Gain dB	$\phi°$
10	...V	...	...	...
20	"	...	...	...
40	"	...	...	...
80	"	...	...	...
100	"	...	...	...
200	"	...	...	...
400	"	...	...	...
800	"	...	...	...
1000	"	...	...	...

Exp. 6 – Closed loop response of Plant with compensator.

PROCEDURE

6.1 Connect process with Lag compensator and gain 2, in the circuit Remain the gain 1 to previous adjustment (for example 3.2). Adjust gain 2, to compensate the compensator loss (10dB/decade = gain 3.2). Note the gain 2 setting from the dial. Trace the waveform upon paper, with record of Mp, tp and e_{ss}.

Compute ζ and ωn for process with Lag compensator.

6.2 Connect process with Lead compensator and gain 2, in the circuit. Trace the waveform upon paper, with record of Mp, tp and e_{ss}.

Compute ζ and ωn for process with Lead compensator.

6.3 Connect process with Lag - Lead compensator and gain 2, in the circuit. Trace the waveform upon paper, with record of Mp, tp and e_{ss}.

Compute ζ and ωn for process with Lag-Lead compensator.

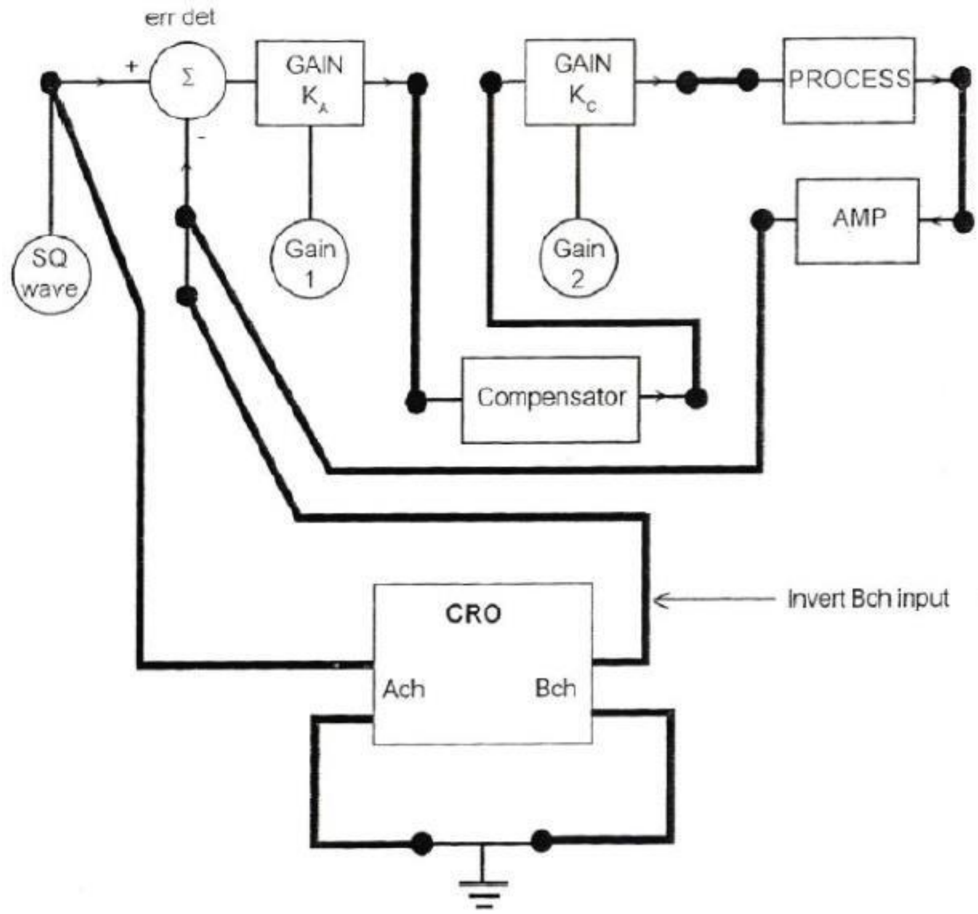


Fig. 6 Closed loop response of Plant + compensator.

Now from the transient response for each experiment tabulate the result.

Typical table (example) for comparison of close loop transient response. Test frequency 40Hz sq 1Vpp.

Configuration	**Mp**	**tp**	e_{ss}	ζ	ωn	**Comment**
Process only	...	...mS	...V	...	...rd	...
Process + Lag	...	...mS	...V	...	...rd	...
Process + Lead	...	...mS	...V	...	...rd	...
Process + Lag -Lead	...	...mS	...V	...	...rd	...

EXPERIMENT NO: 10

CHARACTERISTICS OF AC SERVO MOTOR

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

APPARATUS REQUIRED:

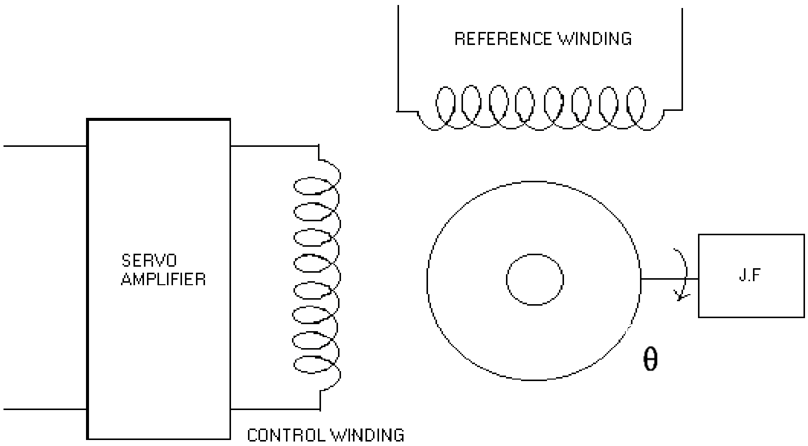
1. AC Servo Motor study unit containing of
   a) Ammeter
   b) Control Voltage Transformer
   c) Load Potentiometer
   d) Speed Indicator
2. Digital Multi Meter

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

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

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

CIRCUIT DIAGRAM:



CIRCUIT DIAGRAM:-AC SERVO MOTOR

PROCEDURE

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

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

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

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

7. Calculate the power and torque developed.

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

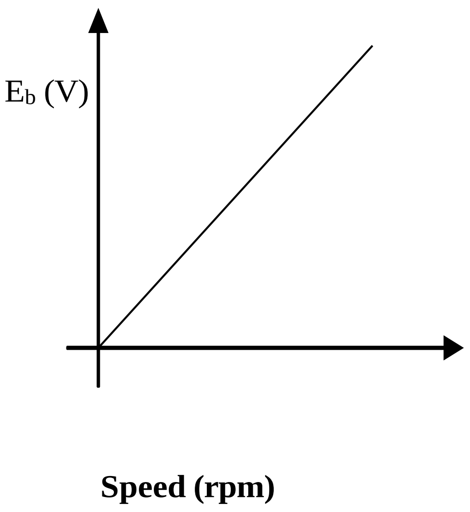
Sl.No	Speed –RPM	Back EMF (E_b)Volts

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

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

<u>MODEL GRAPHS</u>

<u>SPEED (N) Vs Back e.m.f (Eb)</u>



<u>SPEED (N) Vs Torque</u>