

Jawaharlal Nehru Engineering College

Laboratory Manual

FEEDBACK CONTROL SYSTEM

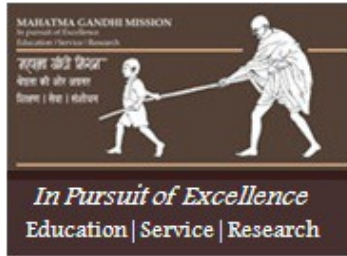
For

Third Year Students

Manual made by

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MGM'S

Jawaharlal Nehru Engineering College

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Department of Electronics & Telecommunication

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- ▶ **Research and lifelong learning attitude,**
- ▶ **Excellent ability to tackle challenges**
- ▶ **Awareness of the needs of society**
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Jawaharlal Nehru Engineering College

Technical Document

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FOREWORD

It is my great pleasure to present this laboratory manual for third year engineering students for the subject of Feedback Control System keeping in view the vast coverage required for visualization of concepts of Control Systems.

As a student, many of you may be wondering with some of the questions in your mind regarding the subject and exactly what has been tried is to answer through this manual.

Faculty members are also advised that covering these aspects in initial stage itself, will greatly relived them in future as much of the load will be taken care by the enthusiasm energies of the students once they are conceptually clear.

H.O.D.

LABORATORY MANUAL CONTENTS

This manual is intended for the Third year students of engineering branches in the subject of Feedback Control System. This manual typically contains practical/Lab Sessions related to Control Systems covering various aspects related to the subject to enhance understanding.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus as practical aspects are the key to understanding and conceptual visualization of theoretical aspects covered in the books.

Good Luck for your Enjoyable Laboratory Sessions.

Prof. Ms. P. B. Murmude

SUBJECT INDEX

1. Do's and Don'ts in the laboratory
2. Lab Experiments:
 1. Plot the Root Locus of a system using MATLAB
 2. Bode Plot using MATLAB
 3. Nyquist Plot using MATLAB
 4. Polar Plot using MATLAB
 5. Study of AC/DC Position Servo System
 6. Study of Synchro Machines
 7. Study of PLC
 8. Study of Response of PID Controller
3. Quiz on the subject
4. Conduction of Viva-Voce Examinations
5. Evaluation and Marking System

DOs and DON' Ts in Laboratory:

1. Do not handle any equipment before reading the instructions/Instruction manuals.
2. Read carefully the power ratings of the equipment before it is switched on whether ratings 230 V/50Hz or 115V/60 Hz. For Indian equipments, the power ratings are normally 230V/50Hz. If you have equipment with 115/60 Hz ratings, do not insert power plug, as our normal supply is 230V/50 Hz, which will damage the equipment.
3. Observe type of sockets of equipment power to avoid mechanical damage.
4. Do not forcefully place connectors to avoid the damage.
5. Strictly observe the instructions given by the teacher/Lab Instructor.

Instruction for Laboratory Teachers::

1. Submission related to whatever lab work has been completed should be done during the next lab session.
2. The promptness of submission should be encouraged by way of marking and evaluation patterns that will benefit the sincere students.

Experiment No.1

Aim: To draw root locus of a system.

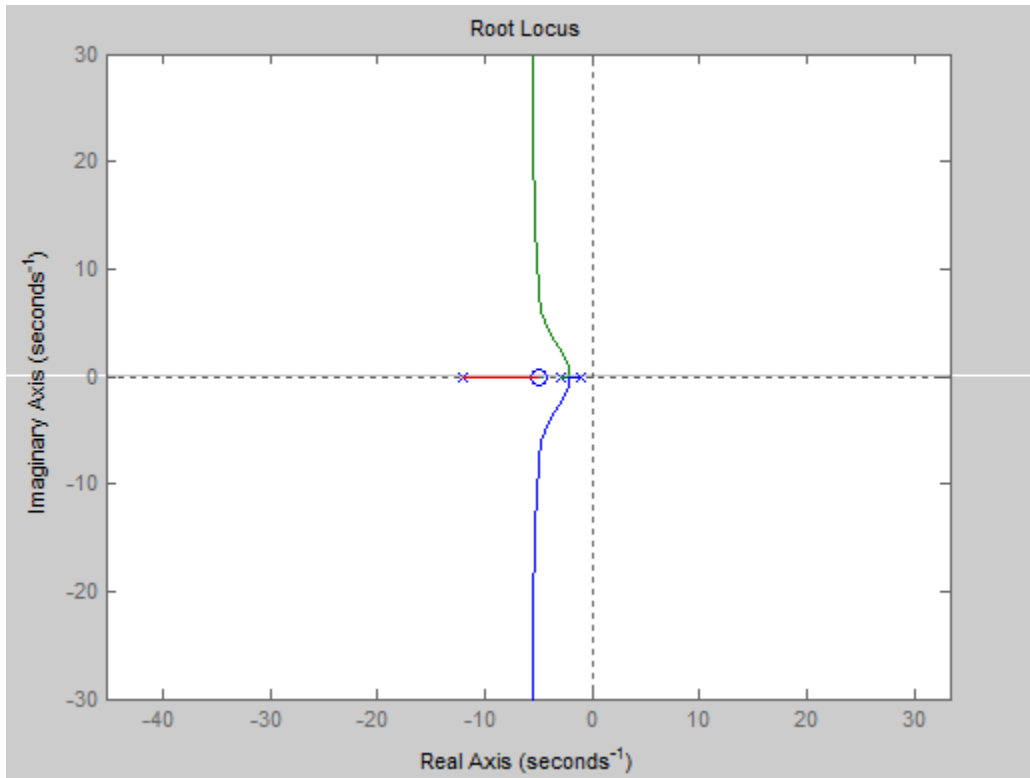
Use MATLAB to draw the root locus for the feedback system whose open loop TF is $G(S)=K(S+5)/(S+1)(S+3)(S+12)$. Find the value of K and determine all the closed loop poles for this value of K.

Theory: Write the theory about root locus of a system.

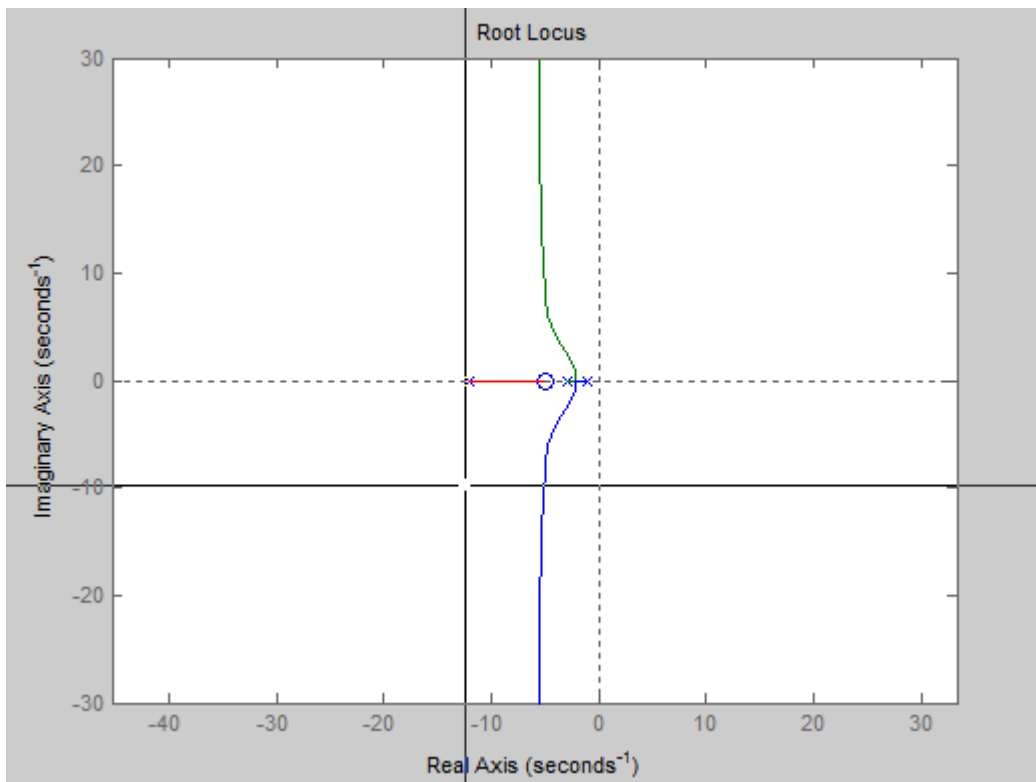
Program:

```
%Root locus for a system with real poles
zol = [-5];
pol = [-1 -3 -12];
G = zpk(zol,pol,1);
rlocus(G);
axis equal;
axis(-20,20,-20,20);
[K, cl_poles] = rlocfind(G)
```

Output:



Select a point in the graphics window



selected_point =

-12.4226 - 9.7826i

K =

162.8806

cl_poles =

-5.2823 +11.3382i

-5.2823 -11.3382i

-5.4353 + 0.0000i

Conclusion: Hence we have plotted the root locus of a system and have observed the results.

Experiment No.2

Aim: To draw bode plot of a system.

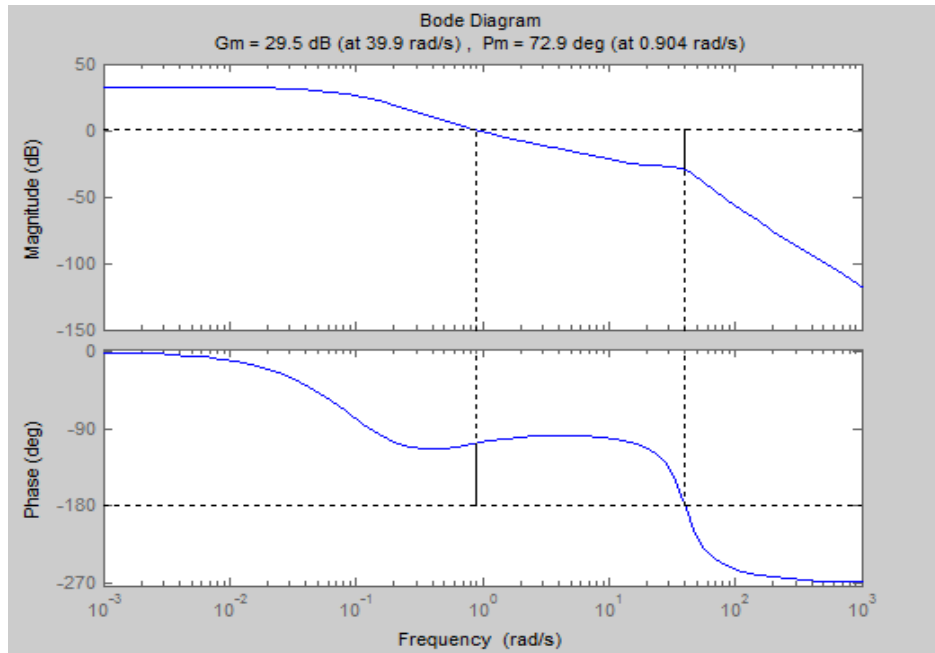
Use MATLAB to draw the Bode plot for the TF $G(S)=(1280*S+640)/(S^4+24.2*S^3+1604.81*S^2+320.24*S+16)$ and $H(S)=1$. Find the gain margin and the phase margin.

Theory: Write the theory about bode plot of a system.

Program:

```
%Bode plot
numG = [1280 640];
denG = [1 24.2 1604.81 320.24 16];
G = tf (numG,denG);
w = logspace(-3,3,100);
H = [1];
T = G*H;
bode (T,w);
margin (T);
```

Output:



Conclusion: Hence we have plotted the bode plot of given system and have observed the results.

Experiment No.3

Aim: To draw nyquist plot of a system.

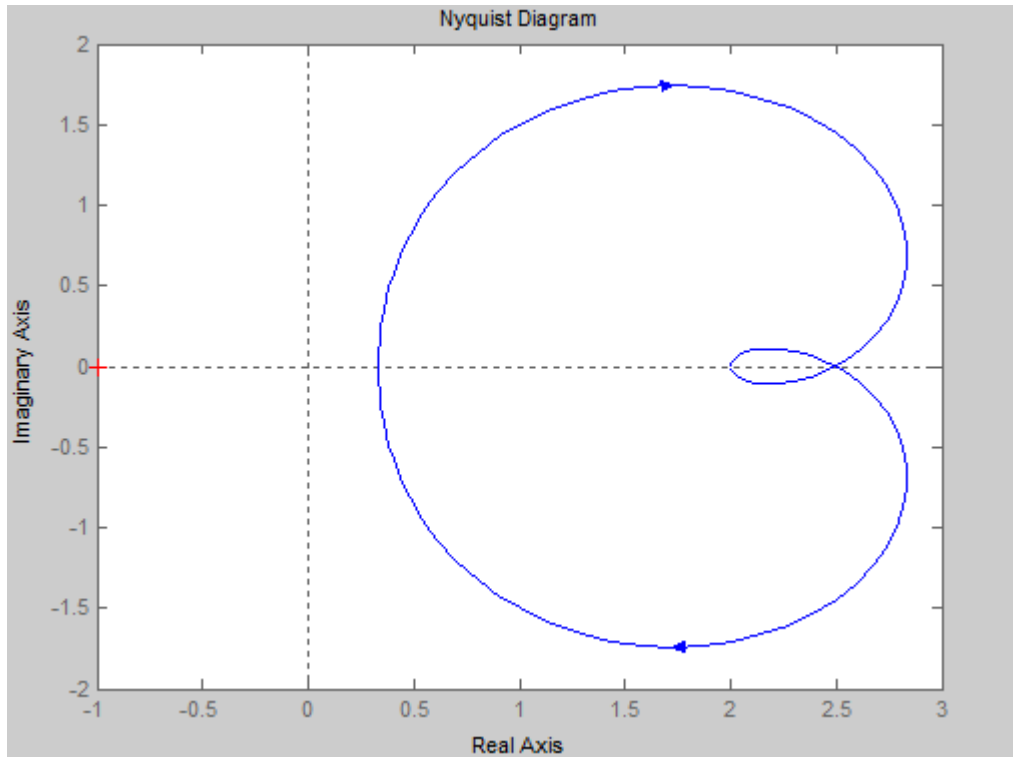
Use MATLAB to draw the Nyquist plot for the TF $G(S)=(2S^2+5S+1)/(S^2+2S+3)$.

Theory: Write the theory about nyquist plot of a system.

Program:

```
%Nyquist Plot
numG = [2 5 1];
denG = [1 2 3];
G = tf (numG,denG);
nyquist (G);
```

Output:



Conclusion: Hence we have plotted the nyquist plot of given system and have observed the result.

Experiment No.4

Aim: To draw the polar plot.

Theory: Write the theory about polar plot of a system.

Program:

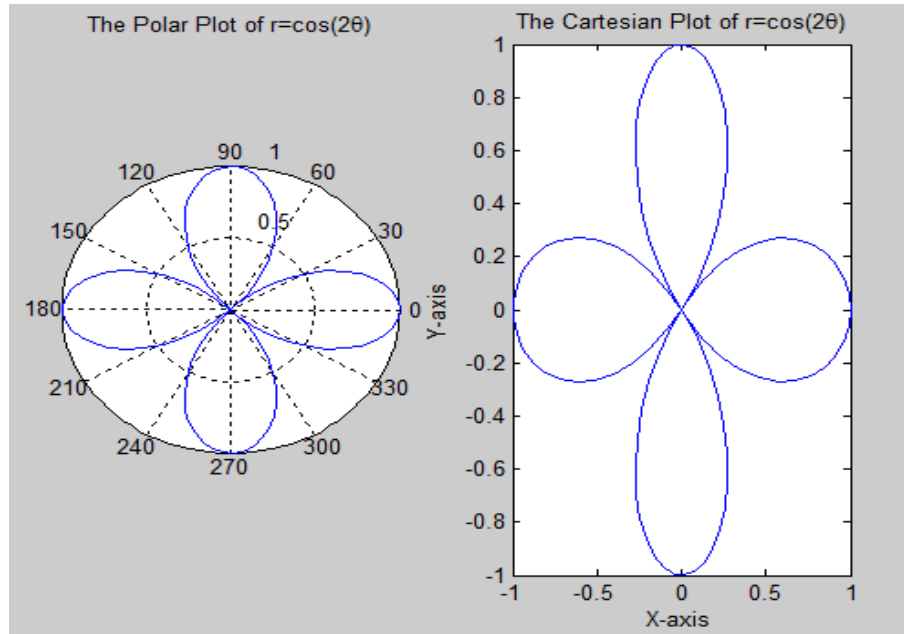
```

theta=linspace(0,2*pi); %generate 100 equally spaced points in the interval [0,2]
r=cos(2*theta); %generate the corresponding r-values
subplot(1,2,1);
polar(theta,r);
title('The Polar Plot of r=cos(2*theta)');
axis equal;
x=r.*cos(theta); %transforming Polar coordinates into Cartesian coordinates
y=r.*sin(theta); %transforming Polar coordinates into Cartesian coordinates
subplot(1,2,2);
plot(x,y);
xlabel('X-axis');

```

```
ylabel('Y-axis');  
title(' The Cartesian Plot of r=cos(2*theta)');
```

Output:



Conclusion: Hence we have plotted the polar plot and have observed the result.

Experiment No.5

Aim: To study A.C./D.C. position servo system.

Apparatus: 1) A.C. position control system set up
2) D.C. position control system set up

Part - I

Operating Instructions:

- 1) Switch on the a.c. mains supply.
- 2) sw1, sw2 & sw3 should be in the position.
- 3) Observe that the input & output pots come in alignment.
- 4) Keep the gain pot almost in max. gain position (almost fully clockwise position).

- 5) Take the input pot to the starting position i.e. very near to the zero position; the output pot will also follow the input pot till the null indicator indicates null position.
- 6) Enter the observations in the tabular column given below.

| Sr.No. | Input angular Position | Output angular Position | Remarks |
|--------|------------------------|-------------------------|---------|
| 01. | 10 Degrees | | |
| 02. | 30 Degrees | | |
| 03. | 50 Degrees | | |
| | | | |
| 10. | 350 Degrees | | |

You may repeat observations with lower amplifier gain to observe that there is greater error with higher gain (i.e. max. gain) you may note that output pot indicates sustained oscillations.

7. You may use the test point black TP1, TP2 & TP3
 - a) TP1 - Black - Excitation voltage for potentiometer system.
 - b) TP2 - Black - Variable point potential for I/P pot.
 - c) TP3 - Black - Variable point potential for O/P pot.

Note that excitation point (TP1-Black) for O/P pot all flouting with repeat to the main ground.
8. Green terminal on the left hand side indicates main ground of the system. You may connect CRO across the TP4 & ground (Green terminal) TP5 & ground to observe the a.c. preampere out/put & servo ampere output respectively.
9. Please note that the switches sw2, sw1 & sw3 are in series with a.c. preampere servo motor reference & control winding.
10. See the front panel of D.C. position control.

11. Vary the Input position pot and observe the output pot till meter shows null deflection.
12. See the figure below

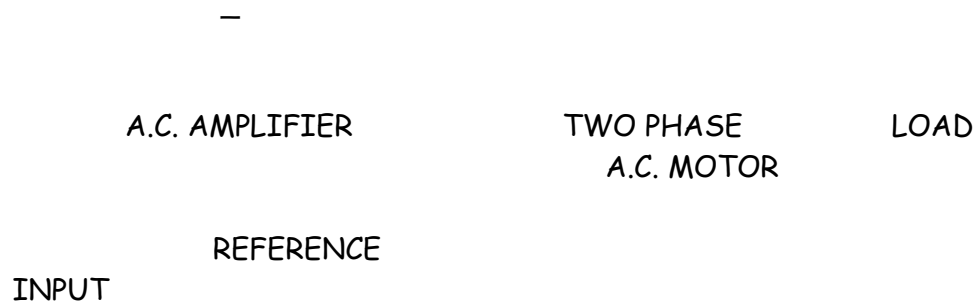


FIG: A.C. POSITION CONTROL SYSTEM
Part - II

Operating Instructions:

- 1) Switch on the a.c. mains supply.
- 2) sw1, sw2 & sw3 should be in the position .
- 3) Observe that the input & output pots come in alignment.
- 4) Keep the gain pot almost in max. gain position (almost fully clockwise position).
- 5) Take the input pot to the starting position i.e. very near to the zero position, the output pot will also follow the input pot till the null indicator indicates null position.
- 6) Enter the observations in the tabular column given below.

| Sr.No. | In/put angular Position | Out/put angular Position | Remarks |
|--------|-------------------------|--------------------------|---------|
| 01. | 10 Degrees | | |
| 02. | 30 Degrees | | |
| 03. | 50 Degrees | | |
| | | | |
| 10. | 350 Degrees | | |

You may repeat observations with lower amplifier gain to observe that there is greater error with higher gain (i.e. max. gain) you may note that output pot indicates sustained oscillations.

7. You may use the test point black TP1, TP2 & TP3

- a. TP1 - Black - Excitation voltage for potentiometer system.
- b. TP2 - Black - Variable point potential for I/P pot.
- c. TP3 - Black - Variable point potential for O/P pot.

Note that excitation point (TP1-Black) for O/P pot all floating with repeat to the main ground.

8. Green terminal on the left hand side indicates main ground of the system. You may connect CRO across the TP4 & ground (Green terminal) TP5 & ground to observe the a.c. preampere out/put & servo ampere output respectively.
9. Please note that the switches sw2 , sw1 & sw3 are in series with a.c. preampere servo motor reference & control winding.
10. See the front panel of D.C. position control.
11. Vary the Input position pot and obscure the output pot till meter shoes null deflection.
12. See the fig below

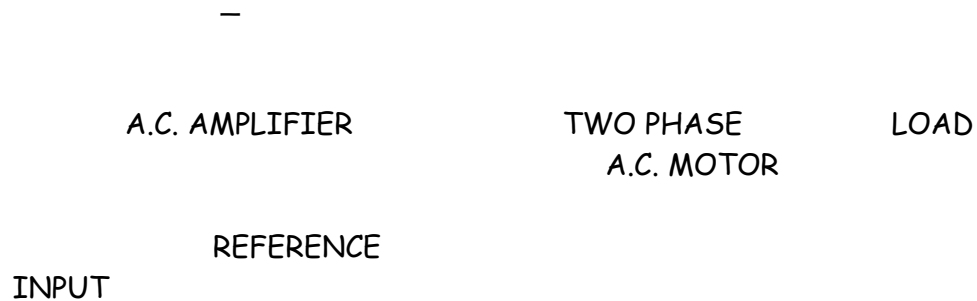


FIG: A.C. POSITION CONTROL SYSTEM

CONCLUSION: -

Experiment No.6

AIM: Study of synchro characteristics.
Study of synchro transmitter / receiver characteristics.

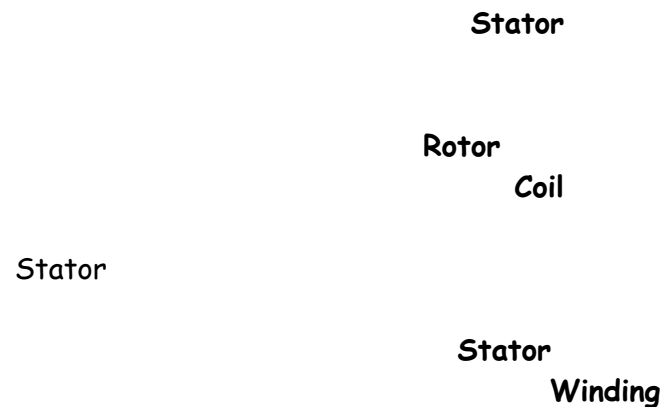
APPARATUS: Synchro transmitter / receiver set-up, multimeter connecting wires etc.

THEORY: Principals: A synchro is an electromagnetic transducer commonly used to convert an angular position of a shaft into an electric signal.

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

Constructional features of synchro transmitter:

fig. -a



Operation : Let an a.c. voltage , $V_r(t) = V_r \sin \omega t$, be applied to the rotor coil which produces a sinusoidally time varying flux directed along its axis and distributed nearly sinusoidally in the air gap along the stator periphery. As the air gap flux is sinusoidally distributed, the flux linking any stator coil is proportional to the cosine of the angle between the rotor and stator coil axes and so is the voltage induced in each stator coil.

Let V_{s1n} , V_{s2n} and V_{s3n} .

Be the voltage induced in the stator coil S_1, S_2 and S_3 with respect to the neutral.

$$V_{s1n} = K V_r \sin \omega t \cos (\theta - 120^\circ)$$

$$V_{s2n} = K V_r \sin \omega t \cos \theta$$

$$V_{s3n} = K V_r \sin \omega t \cos (\theta + 240^\circ)$$

The three terminal voltages of the stator are.

$$V_{s1s2} = V_{s1n} - V_{s2n} = \sqrt{3} K V_r \sin (\theta + 240^\circ) \sin \omega t.$$

$$V_{s2s3} = V_{s2n} - V_{s3n} = \sqrt{3} K V_r \sin (\theta + 120^\circ) \sin \omega t.$$

$$V_{s3s1} = V_{s3n} - V_{s1n} = \sqrt{3} K V_r \sin \theta \sin \omega t.$$

Procedure:

(I)

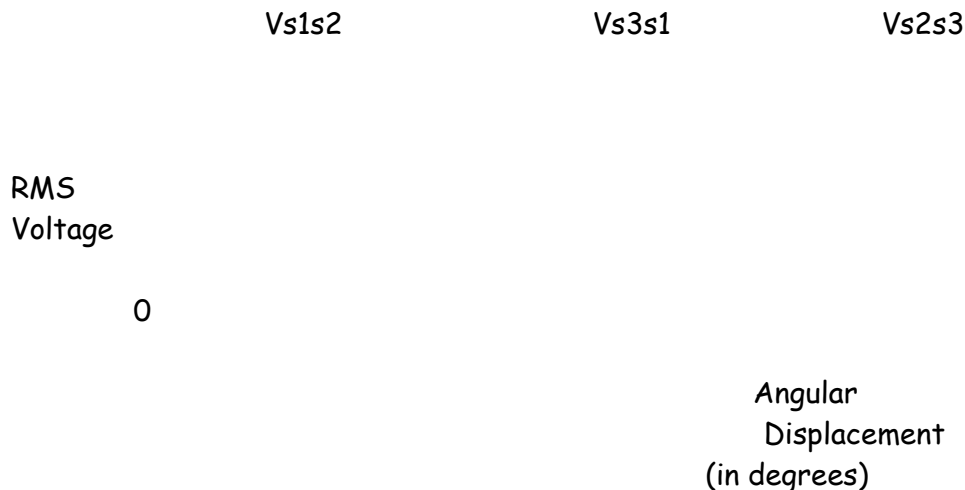
1. Connect the system in main supply.
2. Starting from zero position note down the voltage between stator terminal i.e. V_{s2s1} , V_{s1s3} and V_{s2s3} in a sequential position.
3. Plot the graph of angular position Vs voltage of three winding i.e. terminal voltage.

(II)

1. Connect the system to the main supply.
2. Make connections between corresponding terminals of transmitter and receiver i.e. connect $S1 - S1$, $S2 - S2$ and $S3 - S3$ of transmitter and receiver.
3. Switch on $SW1$ and $SW2$.
4. Move the graph of angular displacement of transmitter to angular displacement in receiver.

Nature of characteristics:

a)



b)

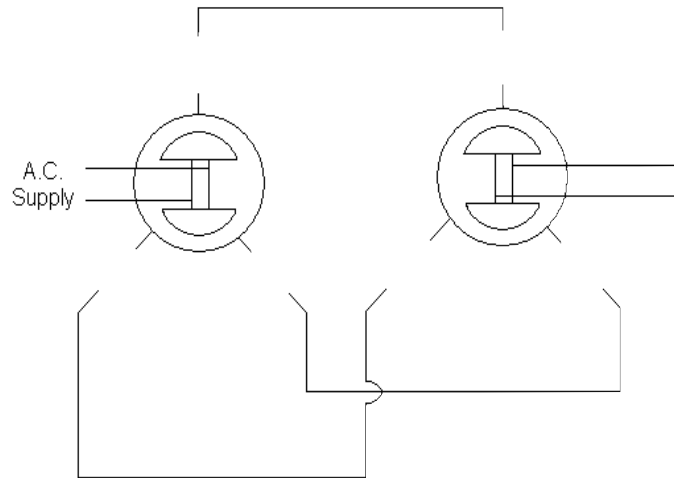
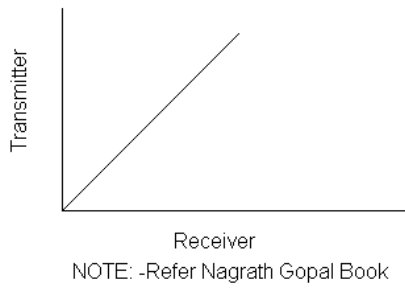


FIG: synchro transmitter and receiver

Observation tables:

| Angular Displacement | VS1S2(V) | VS2S3(V) | VS3S1(V) |
|----------------------|----------|----------|----------|
| | | | |

| Angular Displacement | Receiver Position |
|----------------------|-------------------|
| | |

Conclusion:

Experiment No.7

Aim: To study PLC

Theory:

Overview of PLC:

There are different types of PLCs available in the market manufactured by different companies, so will have an overview of Fatek PLC, model Fatek PLC Fbs-20MA.

- PLC is nothing but an advanced form of microcontroller. It is usually used in industries because of its flexibility and ease of use.
- It can be attached quite easily with computer via serial port as well as usb port.
- PLC is used when we need to automate anything just like microcontroller. We attach our sensors and actuators etc with PLC and then insert some programming code in it and let it do its job.
- You have seen automated lifts, they all are operated with PLC.

- We can use timers, counters, registers in PLC and can get any kind of output from it.
- We can program PLC with different languages and the most commonly used language for PLC is named as Ladder Logic.
- There are three sections of PLC.
- Power Supply - This section provides power to the PLC, in my case it is operated on 220V AC, so when I provide 220V AC to my PLC, it got activated and start performing functions.
- Central Processing Unit (CPU) - It is the actual brain of PLC, it is further divided into several parts i.e. RAM, ROM, EEPROM, microcontroller etc. The programming code is uploaded in this CPU and according to that program, it performs its functions.
- Input / Output Section - This section is the one from where PLC communicates with the external world. We can attach sensors to the inputs of PLC and can operate our motors, actuators etc from the outputs of PLC.
- There are different types of PLCs available in the market manufactured by different companies.
- Few famous PLC companies are Siemens, Mitsubishi, Fatek etc.
- Moreover, they are also available in different sizes and functions. The one I used has 14 inputs and 8 outputs. It doesn't support analog inputs as I don't require them.
- There are PLCs available with analog inputs or you can also buy cards which are interfaced with the PLC and make them capable to work on analog inputs.
- Another function which is not available in my PLC is the Serial communication, but such models are available which supports serial communication.
- So in short, there are several models of PLC available in the market and you have to consider your project demands while buying a PLC.
- Microcontroller is normally used in small products, where you need to control some sensors or some motors etc but when we talk about big automated plants in industries then PLC is always preferred over microcontroller.
- The reason for preferring PLC over microcontroller in big projects is because of its flexibility and ease of use. PLC can be programmed frequently with computer, suppose you have an automated system and you find some bug in it which you want to remove, then what you need to do is simply attach a computer with the PLC of that plant and make changes in the code, which isn't possible with the microcontroller.
- Moreover, PLC has lot of memory, you can add any size of data in it.

- PLC is also long life as compared to microcontroller.
- Last but not the least, PLC has built in cards to control heavy AC voltages, you can get any kind of voltage from PLC i.e. 220V AC etc but if you want to get such voltages from microcontrollers then you have to add some extra circuitry.
- In short, in all industrial automated plants, PLC is used.
- Section 1 is indicating the status of input pins. If inputs are off then this section will remain as shown in above figure, but if any of the inputs get high, then the respective pin indicator will also glow into red, which indicates that this pin is ON. It helps while you are writing programming code for the PLC.
- Section 2 indicates the status of PLC. If PLC is powered up then the POW led will go red, if you have uploaded the code in PLC and start it then the RUN led will go red and if your code has some error then ERR led will go red.
- Section 3 indicates the status of output pins, it will tell you which output is currently ON.

In the below image, Section 4 and 5, these are the input/ output section. If you have a look at it closely then you can see there are two rows of screws, where you plug your wires for inputs and outputs and above them, they are also labeled with white color.



Fig: Front view of PLC

- Section 4 is the inputs pins section, so if you check above there are inputs from X0 to X13, which makes it overall 14 inputs. Moreover, there are two pins labeled as + 24V and - 24V, which PLC is providing us, so if you want to give any input to this PLC you have to make sure that its 24V, otherwise PLC not going to recognize it.
- Section 5 is the output pins section. and you can see there are total 9 outputs starting from Y0 to Y8, now you are getting confused with C0 to C6. C pins are actually the voltage setter, let me explain, in projects there are different outputs are required like your motor is running at 12V DC while your solenoid valve is running at 220VAC. So, there's a need to set these voltages at the output. Here C pins are used. Suppose you need to give 12V output at Y0 and Y1 then give this 12V at C0 and when Y0 or Y1 is ON then they will give 12V at output. In short, when output gets ON it is actually connecting with their respective C pin.
- Lastly, check the Port 0 in the above image, this is the port where you plug your serial wire in PLC and connect it with your computer in order to upload the programming code.
- Microcontrollers programming usually compiled from top to bottom i.e. the compiler first capture the first statement and then moves downward till it reaches the end line

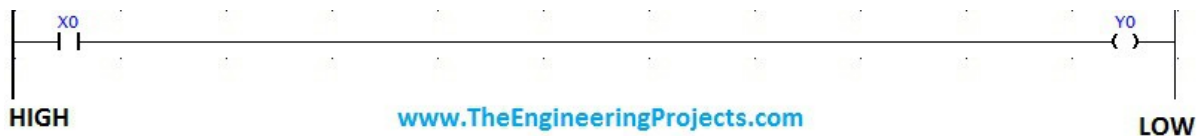
but that's not the case with Ladder Logic Programming for PLC. In ladder logic, the compiler moves from left to right and it gets all the lines at the same time.

Ladder Logic is a programming language used for PLC. Ladder logic is a combination of rungs. Each rung is executed from left to right.

- In the above figure, a single rung of ladder logic is shown. Now as I mentioned earlier, each rung is executed from left to right, so the above rung will also do the same behavior.
- There are two symbols mentioned in the above rung, one is X0 and the other is Y0. X0 is placed on the left side while Y0 is placed on the right side.
- We have seen that X always indicates input and Y indicate output, so in short the above rung has input on the left side while output on the right side.
- So combining all the above discussion, we come to the conclusion that input will be executed first and then output will be executed, as shown below.

Input → Output

- So now the thing is, if we only consider the above rung, the output Y0 will be ON only if input X0 will be ON. If X0 is OFF then Y0 will also be OFF. Consider this rung as a voltage wire as shown in below figure:



- So, now the output will be ON only when it has HIGH and LOW but input is acting as a switch and in normal condition, its OFF so HIGH is not reaching to output so it will remain OFF, as we turn ON the input X0, it will be like the switch is closed and HIGH will pass through the X0 and will reach Y0 and Y0 will turn ON. I tried my best to explain it as simple as I can but still having confusion, ask in comments.

- **Implementation of logic gates:**
- Now let's have a look on different logical gates, we normally create in ladder logic.

1. LOGICAL AND IN LADDER LOGIC FOR PLC

- We all know about the Logical AND gate, in AND gate we get output only if both the inputs are HIGH, otherwise OUTPUT remain OFF.

- The below figure shows the same logical AND gate designed in Ladder Logic diagram:



- Now in the above figure Y0 will be ON when both X0 and X1 are ON, otherwise Y0 will be ON, again consider inputs as switches.
- Its a simple 2 input AND logic, we can add as many inputs as we want in it. For example, below image shows a four input AND gate.



2. LOGICAL OR IN LADDER LOGIC FOR PLC

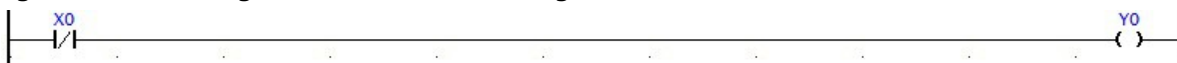
- In Logical OR gate, output goes ON when any of the inputs is ON, lets implement it in our ladder logic form.
- The below figure shows the ladder logic form for OR gate:



- If you check the above figure, if X1 goes ON then our connection will connect and Y0 will be ON, similarly, if X0 is OFF and X1 is ON then again Y0 will be ON because now voltage is coming from X1. Again consider inputs as switch.

3. LOGICAL NOT IN LADDER LOGIC FOR PLC

- In logical NOT gate, output is always opposite to input, if input is HIGH then output will be LOW and vice versa.
- In order to implement NOT gate, we have to consider another type of input, the input which we are using till now is normally open input, means it is open (OFF) in its normal condition and gets closed (ON) when input is supplied, but in ladder logic there's another type of input also present named as normally closed input.
- Normally closed input is closed (ON) in its normal condition and goes open (OFF) when it gets actual input.
- So, using this normally closed input, we can quite easily implement this Logical NOT gate in ladder logic as shown in below figure:



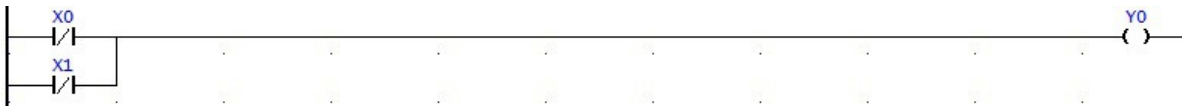
- In the above figure X0 will be ON in normal condition and hence, Y0 will also be ON and when we get actual input then X0 will get OFF and our Y0 will also be OFF.

4. NAND LOGICAL GATE IN LADDER LOGIC FOR PLC

- NAND gate is another type of logical gate, which is normally used. NAND gate is nothing but a simple NOT of AND gate. In simple words, if we add a NOT gate in front of AND gate, we get NAND gate. The truth table of NAND gate is shown in the below figure:

| Input 1 (X0) | Input2 (X1) | Output(Y 0) |
|-----------------|----------------|----------------|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

- It is quite obvious from the truth table of NAND gate that the output will be OFF only when both the inputs will be ON otherwise output will remain ON. So, now lets implement this gate in ladder logic programming.
- The below image shows the implementation of NAND logical gate in Ladder Logic form:



- Now, if you understand the above figure, then its quite obvious. We have used both inputs in normally closed form so when both inputs are OFF the output will be ON. If we get X0 ON then in still we will get the HIGH voltage from X1. If we make X1 ON then we get HIGH voltage from X0, but if we get both X0 and X1 ON then our Y0 will get OFF. Again we are using inputs in normally closed form so when our actual input is OFF then our X0 is closed.

5. NOR LOGICAL GATE IN LADDER LOGIC FOR PLC

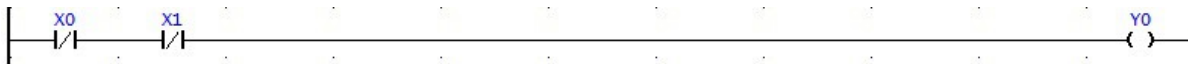
- In NOR gate, we simple place a NOT gate in front of OR gate. Its truth table is shown in below figure:

| Input 1 | Input2 | Output(Y) |
|---------|--------|-----------|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

| | | |
|------|------|----|
| (X0) | (X1) | O) |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

- From the truth table of NOR gate, its quite obvious that its output will be ON when both of its input goes OFF otherwise the output will remain ON. Lets implement this NOR logical gate in Ladder Logic diagram.

- The below figure shows the NOR logical gate in ladder logic diagram:



- If you got the ladder logic form of NAND gate, then its not going to be much problem. Simple two normally closed inputs are placed in series, so now when any of them gets ON, then output will get OFF.

- If you have noticed, whenever NOT gate is involved somewhere, we use normally closed inputs.

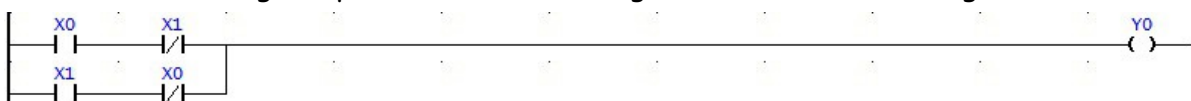
6. XOR LOGICAL GATE IN LADDER LOGIC FOR PLC

- The truth table of XOR gate is shown in below figure:

| Input 1 (X0) | Input2 (X1) | Output(Y O) |
|--------------|-------------|-------------|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

- From the truth table, we can get this thing that, output will ON only when the inputs are in opposite states and output will be OFF when inputs are in same state.

- The ladder logic implementation of XOR gate is shown in below figure:



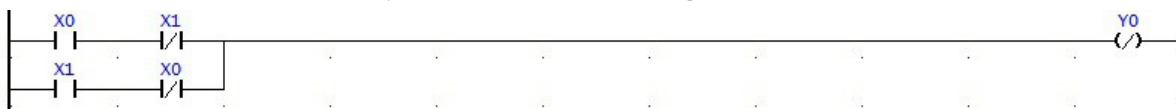
- Now, what we need to do is if both inputs are in same state we need to turn OFF the output. That's what we are doing in above logic diagram. Let's say X0 and X1 both are OFF then the normally open switches will be OFF and they wont let the HIGH voltage pass and hence our Y0 will remain OFF. And if both are ON then the normally closed will be OFF and again Y0 will remain OFF.
- Now if X0 is ON and X1 is OFF, then the first string will connect and our output will ON, and if X0 is OFF while X1 is ON then our second string will connect and will make our output ON. Quite simple and easy.

7. XNOR LOGICAL GATE IN LADDER LOGIC FOR PLC

- Last but not the least XNOR gate, if we add NOT gate in front of XOR gate we get XNOR gate, let's have a look at its truth table below:

| Input 1 (X0) | Input2 (X1) | Output(Y 0) |
|-----------------|----------------|----------------|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

- So, in XNOR gate, we get our output ON when both inputs are in same state otherwise its OFF. Let's implement it in ladder logic form below:



Conclusion:

Experiment No.8

Aim: To study the response of PID controller

Theory:

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) commonly used in industrial control systems. A PID controller continuously calculates an *error value* as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error over time by adjustment of a *control variable*, such as the position of a control valve, a damper, or the power supplied to a heating element, to a new value determined by a weighted sum:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de}{dt}$$

where K_p , K_i , and K_d , all non-negative, denote the coefficients for the proportional, integral, and derivative terms, respectively (sometimes denoted P , I , and D). In this model below

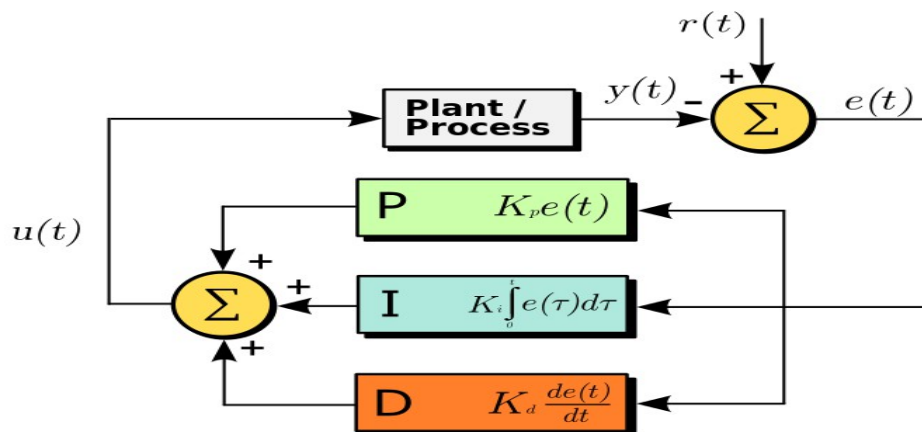


Fig: PID controller model

- *P* accounts for present values of the error (e.g. if the error is large and positive, the control variable will be large and negative),
- *I* accounts for past values of the error (e.g. if the output is not sufficient to reduce the size of the error, the control variable will accumulate over time, causing the controller to apply a stronger action), and
- *D* accounts for possible future values of the error, based on its current rate of change.

As a PID controller relies only on the measured process variable, not on knowledge of the underlying process, it is broadly applicable. By tuning the three parameters of the model, a PID controller can deal with specific process requirements. The response of the controller can be described in terms of its responsiveness to an error, the degree to which the system overshoots a set point, and the degree of any system oscillation. The use of the PID algorithm does not guarantee optimal control of the system or even its stability.

Some applications may require using only one or two terms to provide the appropriate system control. This is achieved by setting the other parameters to zero. A PID controller will be called a PI, PD, P or I controller in the absence of the respective control actions. PI controllers are fairly common, since derivative action is sensitive to measurement noise, whereas the absence of an integral term may prevent the system from reaching its target value.

Now, let's take a look at a PID controller. The closed-loop transfer function of the given system with a PID controller is:

$$\frac{X(s)}{F(s)} = \frac{K_d s^2 + K_p s + K_i}{s^3 + (10 + K_d)s^2 + (20 + K_p)s + K_i}$$

After several trial and error runs, the gains $K_p = 350$, $K_i = 300$, and $K_d = 50$ provided the desired response. To confirm, enter the following commands to an m-file and run it in the command window. You should get the following step response.

```
Kp = 350;
```

```
Ki = 300;
```

```
Kd = 50;
```

```
C = pid(Kp,Ki,Kd)
```

```
T = feedback(C*P,1);
```

```
t = 0:0.01:2;
```

```
step(T,t)
```

$C =$

1

$K_p + K_i \cdot \frac{1}{s} + K_d \cdot s$

s

with $K_p = 350$, $K_i = 300$, $K_d = 50$

Continuous-time PID controller in parallel form.

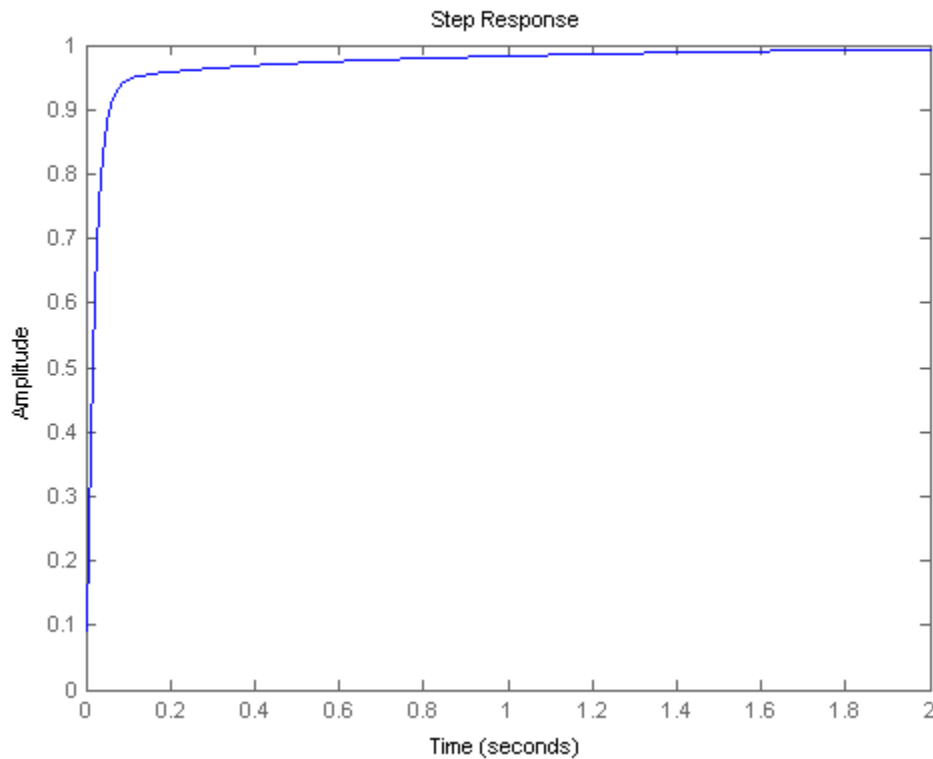


Fig: PID controller response

Now, we have obtained a closed-loop system with no overshoot, fast rise time, and no steady-state error.

General Tips for Designing a PID Controller:

When you are designing a PID controller for a given system, follow the steps shown below to obtain a desired response.

1. Obtain an open-loop response and determine what needs to be improved
2. Add a proportional control to improve the rise time
3. Add a derivative control to improve the overshoot
4. Add an integral control to eliminate the steady-state error
5. Adjust each of K_p , K_i , and K_d until you obtain a desired overall response.

Conclusion:

3. Quiz on the Subject:

1. In an open loop control system

- (a) Output is independent of control input
- (b) Output is dependent on control input
- (c) Only system parameters have effect on the control output
- (d) None of the above

Ans: a

2. For open control system which of the following statements is incorrect ?

- (a) Less expensive
- (b) Recalibration is not required for maintaining the required quality of the output
- (c) Construction is simple and maintenance easy
- (d) Errors are caused by disturbances

Ans: b

3. A control system in which the control action is somehow dependent on the output is known as

(a) Closed loop system (b) Semiclosed loop system (c) Open system (d) None of the above

Ans: a

4. In closed loop control system, with positive value of feedback gain the overall gain of the system will

(a) decrease (b) increase (c) be unaffected (d) any of the above

Ans: a

5. Which of the following is an open loop control system ?

(a) Field controlled D.C. motor (b) Ward leonard control
(c) Metadyne (d) Stroboscope

Ans: a

6. Which of the following statements is not necessarily correct for open control system ?

(a) Input command is the sole factor responsible for providing the control action
(b) Presence of non-linearities causes malfunctioning
(c) Less expensive
(d) Generally free from problems of non-linearities

Ans: b

7. In open loop system

(a) the control action depends on the size of the system
(b) the control action depends on system variables
(c) the control action depends on the input signal
(d) the control action is independent of the output

Ans: d

8 has tendency to oscillate.

(a) Open loop system (b) Closed loop system (c) Both a and b (d) Neither a nor b

Ans: b

9. A good control system has all the following features except

(a) good stability (b) slow response (c) good accuracy (d) sufficient power handling capacity

Ans: b

10. A car is running at a constant speed of 50 km/h, which of the following is the feedback element for the driver ?

(a) Clutch (b) Eyes (c) Needle of the speedometer (d) Steering wheel

Ans: c

11. The initial response when the output is not equal to input is called

- (a) Transient response
- (b) Error response
- (c) Dynamic response
- (d) Either of the above

Ans: a

12. A control system working under unknown random actions is called

- (a) computer control system
- (b) digital data system
- (c) stochastic control system
- (d) adaptive control system

Ans: c

13. An automatic toaster is a _____ loop control system.

- (a) open
- (b) closed
- (c) partially closed
- (d) any of the above

Ans: a

14. Any externally introduced signal affecting the controlled output is called a

- (a) feedback
- (b) stimulus
- (c) signal
- (d) gain control

Ans: b

15. A closed loop system is distinguished from open loop system by which of the following?

- (a) Servomechanism
- (b) Feedback
- (c) Output pattern
- (d) Input pattern

Ans: b

16 is a part of the human temperature control system.

- (a) Digestive system
- (b) Perspiration system
- (c) Ear
- (d) Leg movement

Ans: b

17. Which of the following is exhibited by Root locus diagrams ?

- (a) The poles of the transfer function for a set of parameter values
- (b) The bandwidth of the system
- (c) The response of a system to a step input
- (d) The frequency response of a system
- (e) None of the above

Ans: a

18. is a closed loop system.

- (a) Auto-pilot for an aircraft
- (b) Direct current generator

(c) Car starter

(d) Electric switch

Ans: a

19. If the gain of the critical damped system is increased it will behave as

(a) oscillatory (b) critically damped

(c) overdamped (d) underdamped

Ans: d

20. A.C. servomotor is basically a

(a) universal motor

(b) single phase induction motor

(c) two phase induction motor (d) three phase induction motor

Ans: c

4. Conduction of VIVA-VOCE Examinations:

Teacher should conduct oral exams of the students with full preparation. Normally the objective questions with guess are to be avoided. To make it meaningful, the questions should be such that depth of the student in the subject is tested. Oral Exams are to be conducted in co-cordial situation. Teachers taking oral exams should not have ill thoughts about each other & courtesies should be offered to each other in case of opinion, which should be critically suppressed in front of the students.

5. Evaluation and Marking System:

Basic honesty in the evaluation and marking system is essential and in the process impartial nature of the evaluator is required in the exam system. It is a primary responsibility of the teacher to see that right students who really put their effort & intelligence are correctly awarded.

The marking pattern should be justifiable to the students without any ambiguity and teacher should see that students are faced with just circumstance.