

CONTROL SYSTEMS AND SIMULATION LAB

LAB MANUAL

Subject Code : **AEE115**
Regulations : **R16 - IARE**
Class : **II Year II Semester (EEE)**



DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal – 500 043, Hyderabad



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Dundigal, Hyderabad - 500 043

Department of Electrical and Electronics Engineering

Program Outcomes	
PO1	Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
PO2	Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3	Design / Development of Solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
PO4	Conduct Investigations of Complex Problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO5	Modern Tool Usage: Create, select, and apply appropriate techniques, APPRATUS, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
PO6	The Engineer and Society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7	Environment and Sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO9	Individual and Team Work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO10	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO11	Project Management and Finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
PO12	Life - Long Learning: Recognize the need for, and have the preparation and ability to engage in independent and life - long learning in the broadest context of technological change.
Program Specific Outcomes	
PSO1	Professional Skills: Able to utilize the knowledge of high voltage engineering in collaboration with power systems in innovative, dynamic and challenging environment, for the research based team work.
PSO2	Problem - Solving Skills: Can explore the scientific theories, ideas, methodologies and the new cutting edge technologies in renewable energy engineering, and use this erudition in their professional development and gain sufficient competence to solve the current and future energy problems universally.
PSO3	Successful Career and Entrepreneurship: The understanding of technologies like PLC, PMC, process controllers, transducers and HMI one can analyze, design electrical and electronics

Program Outcomes

principles to install, test , maintain power system and applications.

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ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp. No.	Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	Time response of Second Order system	PO2, PO4	PSO1, PSO2
2	Transfer function of DC motor	PO2, PO4	PSO2
3	Characteristics of Ac Servo Motor	PO1, PO2, PO3	PSO2
4	Effect of various Controllers on second order systems.	PO1, PO3, PO4	PSO1, PSO2
5	Compensator	PO1, PO2, PO3, PO4	PSO1, PSO2
6	Temperature Controller	PO1, PO3, PO4	PSO1, PSO3
7	Design and verification of Op-Amp Based PID Controller	PO1, PO3	PSO1, PSO3
8	Stability Analysis Using Digital Simulation	PO1, PO3, PO4	PSO1, PSO3
9	State Space Model Using Digital Simulation	PO1, PO3, PO4	PSO1, PSO3
10	Ladder Diagrams Using PLC	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2
11	Truth Tables Using PLC	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2
12	Implementation Of Counter Using PLC	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2
13	Blinking Lights Using PLC	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2
14	Water Level Control Using PLC	PO1, PO2, PO3, PO4, PO5	PSO1, PSO2

CONTROL SYSTEMS AND SIMULATION LABORATORY

OBJECTIVE

The objective of the lab is to design a system and calculate the transfer function, analyzing the stability of the system (both open and closed loop, with positive and negative feedback) with time domain approach and frequency response analysis, using MATLAB and also developing the system which is dynamic in nature with state space analysis approach.

OUTCOMES:

Upon the completion of Control Systems practical course, the student will be able to attain the following:

1. Recognize the symbols for the different parts of a block diagram: functional blocks, summing blocks and branch points. Simplify a block diagram using block diagram algebra to obtain a transfer function between any two points in the diagram.
2. Model a mechanical (masses, dampers and springs) and electrical system (inductors, resistors, capacitors) in the form of a transfer function.
3. Determine the impulse, step, and ramp response of a system, given a transfer function model.
4. Perform Routh's stability criterion and root locus of a system to determine stability. For systems with unknown values, determine the range of values for which the system will be stable and explain how adding a pole or a zero affects the stability.
5. Analyze feedback control systems in the time and frequency domain to use state space concepts to describe systems.
6. Recognize the "type" of a system (based on the number of free integrators) and discuss the expected error characteristics as related to step, ramp, and acceleration inputs.
7. Interpret design criteria as related to the closed loop pole location on the complex plane.
8. Draw the Frequency response plots like Bode, Nyquist and Polar plots (magnitude and phase) for a given transfer function.
9. Design feedback compensators to achieve a set of desired closed loop system characteristics and design a compensator in the frequency domain to meet specific design requirements using a lead compensator, lag compensator, or lead-lag compensator.
10. Develop a PLC program for an automatic control system of a medium degree of complexity and select the right hardware for a given application.
11. Consider such aspects of the automation system as network communication, human machine interface, safety and protection against interference.

EXPERIMENT - 1

TIME RESPONSE OF SECOND ORDER SYSTEM

1.1 AIM:

To study the time response of a second order series RLC System.

1.2 APPARATUS:

S. No.	Equipments	Quantity
1	Second order system study unit.	1
2	Cathode Ray Oscilloscope	1
3	Multi meter	1
4	Connecting Leads	1

1.3 THEORY

The time response has utmost importance for the design and analysis of control systems because these are inherently time domain systems where time is independent variable. During the analysis of response, the variation of output with respect to time can be studied and it is known as time response. To obtain satisfactory performance of the system with respect to time must be within the specified limits. From time response analysis and corresponding results, the stability of system, accuracy of system and complete evaluation can be studied easily.

Due to the application of an excitation to a system, the response of the system is known as time response and it is a function of time.

The two parts of response of any system:

- (i) Transient response
- (ii) Steady-state response.

Transient response: The part of the time response which goes to zero after large interval of time is known as transient response.

Steady state response: The part of response that means even after the transients have died out is said to be steady state response.

The total response of a system is sum of transient response and steady state response:

$$C(t) = C_{tr}(t) + C_{ss}(t)$$

TIME RESPONSE OF SECOND ORDER CONTROL SYSTEM: A second order control system is one wherein the highest power of 's' in the denominator of its transfer function equals 2.

Transfer function is given by:

$$TF = \frac{\omega_n^2}{s^2 + 2\delta\omega_n + \omega_n^2}$$

ω_n —is called natural frequency of oscillations.

$\omega_d = \omega_n \sqrt{1 - \delta^2}$ is called damping frequency oscillations.

δ -affects damping and called damping ratio.

$\delta\omega_n$ is called damping factor or actual damping or damping coefficient.

1.4 BLOCK DIAGRAM:

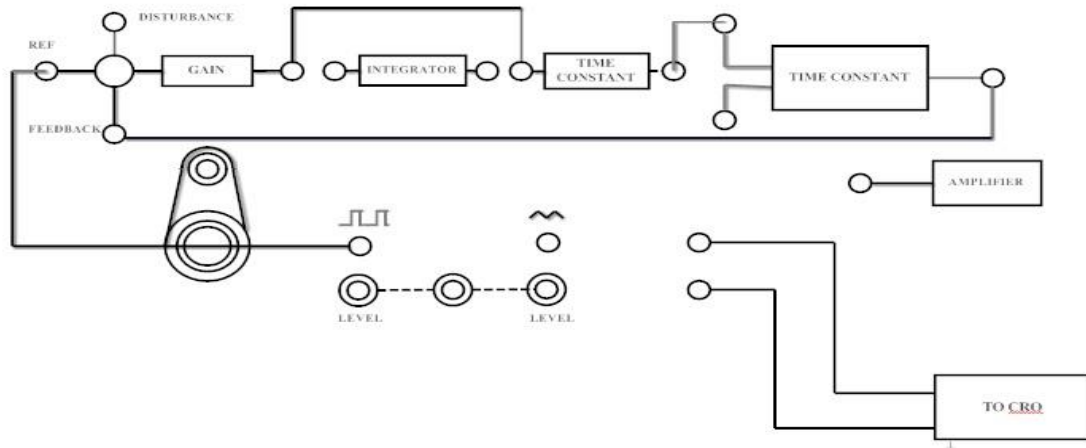


Fig – 1.1 Time Response of Second order System

1.5 CIRCUIT DIAGRAM:

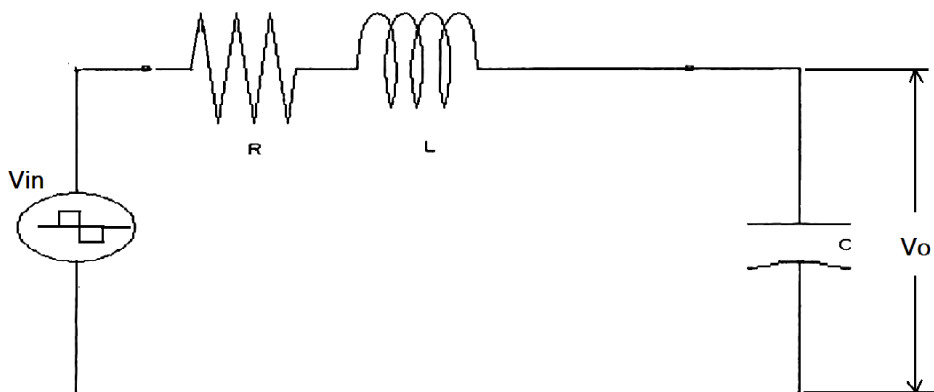


Fig – 1.2 Series RLC second order Equivalent

1.6 PROCEDURE:

1. Connections are given as per the block diagram.
2. Adjust the input square wave such that the magnitude of the wave is 1V (p-p).
(Check the square wave in CRO by placing CRO in Channel 1 mode).
By varying gain note down the corresponding readings of Peak Time (T_P), Delay Time (T_d), Rise Time (T_r), Settling Time (T), Maximum peak over shoot.
3. Take the corresponding values of Peak Time (T_P), Peak Over Shoot (μ_P) (i.e. Max Peak Value -1) using trace papers.
4. Calculate Damping Ratio (δ), Undamped Natural Frequency (ω_n) from the following formulae

$$\delta = \ln(\mu_P) / \sqrt{[\pi]^2 + \ln(\mu_P)^2}$$

$$\omega_n = \pi / T_P \sqrt{1 - \delta^2}$$

5. Calculate the parameters L & C of RLC system using the following formulae

$$\delta = (R/2) \sqrt{C/L}$$

$$\omega_n = 1 / \sqrt{LC}$$

6. Now calculate Settling Time (T_s), and Damped Frequency (ω_d) using the following formulae

$$T_s = 4 / (\delta \omega_n) \text{ ----- (2\% Settling Time)}$$

$$\omega_d = \omega_n \sqrt{1 - \delta^2}$$

1.7 TABULAR COLUMN:

S. No.	Gain	Peak Time (T_P)	Rise Time (T_R)	Delay Time (T_d)	Maximum Peak (μ_P)	Undamped natural frequency (ω_n)	Settling Time (T_s)

S. No.	R	L	C	Maximum Peak (μ_P)	Peak Time (T_P)	Damping Ratio (δ)	Undamped natural frequency (ω_n)	Damped Frequency (ω_d)	Settling Time (T_s)
1									
2									
3									
4									
5									

1.8 MODEL GRAPH:

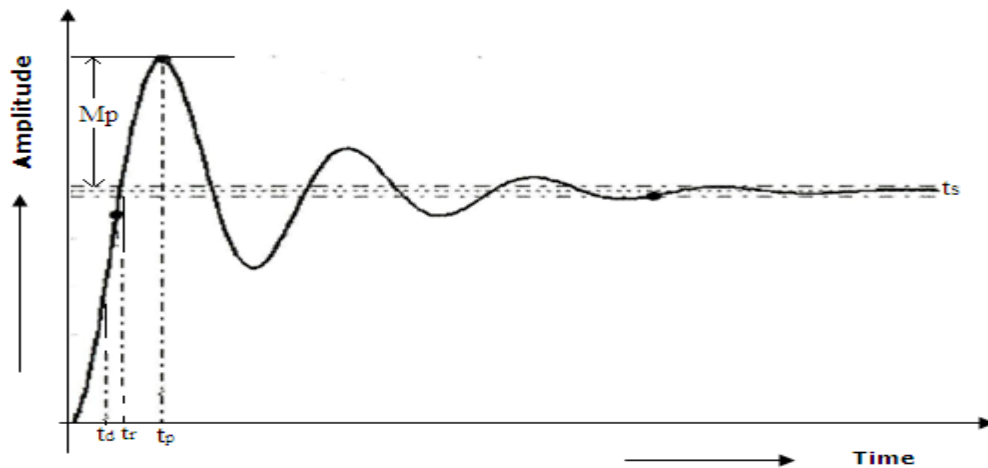


Fig - 1.3 Time Specifications of Second order System

1.9 RESULT:

1.10 PRE LAB VIVA QUESTIONS:

1. What are the Open loop and closed loop control systems?
2. Give the advantages of closed loop control systems.
3. What do you mean by feedback and what are the types of feedback?
4. What is a system?
5. Define rise time, peak time, settling time, peak overshoot, damping ratio, steady state error.

1.11 LAB ASSIGNMENTS:

1. To study the time response of a second order series RLC System to determine the parameters of L & C from ramp input
2. To study the time response of a second order series RLC System to determine the parameters of L & C from sinusoidal input

1.12 POST LAB VIVA QUESTIONS:

1. In this experiment what type of feedback is used? Why?
2. Give a practical example for a first order system.
3. Give a practical example for a second order system.

EXPERIMENT - 2

TRANSFER FUNCTION OF DC MOTOR

2.1 AIM:

To determine the transfer function of armature controlled dc motor by performing load test on dc motor and speed control by armature voltage control to plot characteristics between back e.m.f. and angular velocity and armature current Vs torque.

2.2 APPARATUS:

S. No	Name of the Equipment	Quantity
1	Armature controlled DC motor	1
2	Patch cards	1
3	Tachometer	1

2.3 FRONT PANEL DETAILS:

AC, IN : Terminals to connect 230V AC mains supply.

Armature VA : Potentiometer to vary the armature voltage from 0 – 200V.

ON / OFF : ON / OFF switch for arm voltage with self start.

0 – 200V DC : 0 – 200V variable DC supply for armature

0 – 230V AC “ 0 – 230V variable AC supply to final inductance of field coil with NC lamp
(AC Voltage Controller)

2.4 CIRCUIT DIAGRAM:

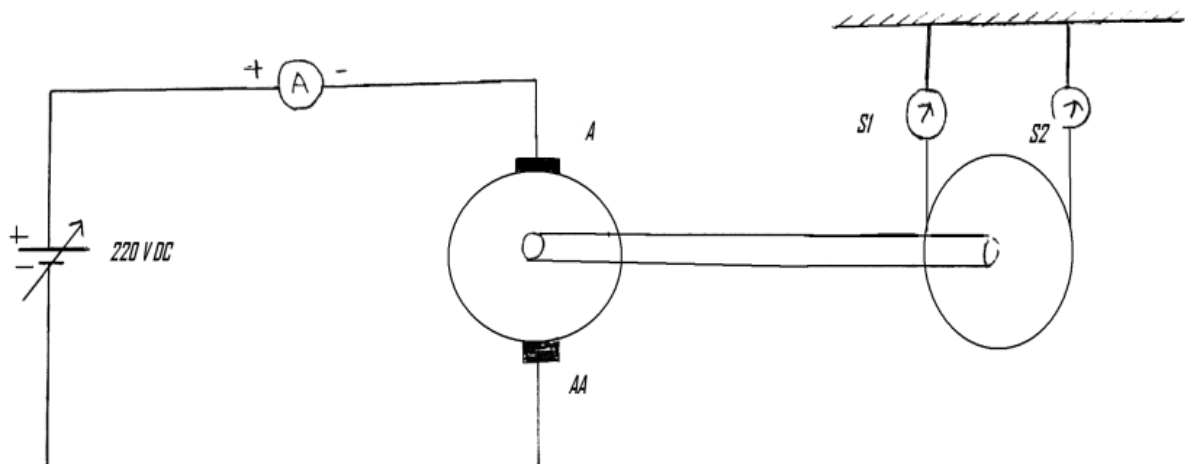


Fig – 2.1 Load Test on DC Motor

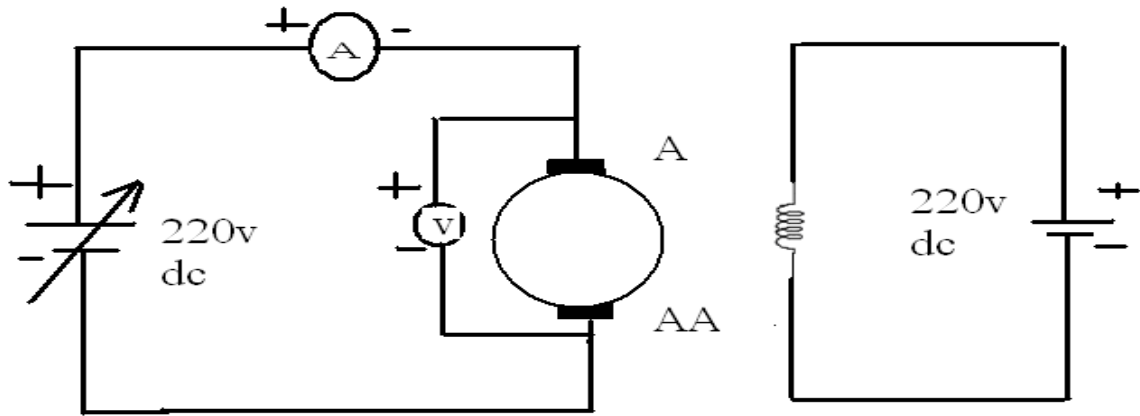


Fig – 2.2 Armature voltage control

2.5 THEORY:

The speed of DC motor is directly proportional to armature voltage and inversely proportional to flux in field winding. In armature controlled DC motor the desired speed is obtained by varying the armature voltage.

Let R_a = Armature resistance, Ohms

L_a = Armature Inductance , Henris

I_a = Armature current, Amps

V_a = Armature voltage, Volts

E_b = Back emf,

K_t = Torque constant, N-m/A

T = Toque developed by motor, N=m

q = Angular displacmenet of shaft, rad

J = Moment of inertia of motor and load, Kg-m²/rad.

B = Frictional coefficient of motor and load, N-m/rad-sec.

K_b = Back emf constnat, V/(rad-sec)

By applying KVL to the equvallent circuit of armature, we can write,

$$I_a R_a + L_a \left(\frac{dI_a}{dt} \right) + E_b = V_a$$

Torque of DC motor proportional to the product of flux & current. Since flux is constant.

$$T \propto I_a$$

$$T = K_t I_a$$

The differential equation governing the mechanical system of motor is given by

$$J \frac{d^2 \theta}{dt^2} + B \frac{d\theta}{dt} = T$$

The back emf of DC machine is proportional to speed of shaft.

$$E_b \propto d\theta/dt; \text{ Back emf, } E_b = K_b(d\theta/dt)$$

The Laplace transform of various time domain signals involved in this system are

$$L[V_a] = V_a(s); L[E_b]=E_b(s); L(T) = T(s); L[I_a] = I_a(s); L[\theta]=[s]$$

On taking Laplace transform of the system differential

$$I_a(S) + L_a S \cdot I_a(S) + E_b(S) = V_a(S) \quad (1)$$

$$T(s) = K_t I_a(s) \quad (2)$$

$$J S^2 \theta(s) + B s \theta(s) = T(s) \quad (3)$$

$$E_b(s) = K_b s \theta(s) \quad (4)$$

On equating equations (2) & (3)

$$K_t I_a(s) = (J s^2 + B s) \theta(s)$$

$$I_a(s) = \frac{(J s^2 + B s)}{K_t} \theta(s)$$

equation (1) can be written as

$$(R_a + s L_a) I_a(s) + E_b(s) = V_a(s)$$

substitute $E_b(s)$ & $I_a(s)$ in above equation, we get

$$(R_a + s L_a) \frac{(J s^2 + B s)}{K_t} \theta(s) + K_t I_a(s) = V_a(S)$$

$$\frac{(R_a + s L_a)(J s^2 + B s) + K_b K_t s}{K_t} = V_a(S)$$

the required transfer functions is $q(s) / V_a(s)$

$$\frac{\theta(s)}{V_a(s)} = \frac{K_t}{(R_a + s L_a)(J s^2 + B s) + K_b K_t s} = \frac{K_t}{R_a \left(\frac{s L_a}{R_a} + 1 \right) B s \left[1 + \frac{J s^2}{B s} \right] + K_b K_t s}$$

$$\frac{\theta(s)}{V_a(s)} = \frac{\frac{K_t}{R_a B}}{s \left[(1 + s T_a)(1 + s T_m) + \frac{K_b K_t}{R_a B} \right]}$$

where , $L_a/R_a = T_a =$ Electrical Time constant

and $J/B = T_m =$ mechanical time constant

The parameters which determine the transfer function are K_t, K_b, R_i, L_a, B, J and these parameters are found by conducting the following tests

Brake Test

This test is conducted to find torque constant K_t and Back emf constant K_b . It is a direct method and consists of applying a brake to water cooled pulley mounted on the motor shaft. A belt is wound round the pulley and its two ends are attached to two spring balances S_1 and S_2 . The tension of the belt can be adjusted with the help of the wheels. Obviously, the force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances.

S_1 and S_2 spring balances in Kg.

R is the radius of the brake drum in meters.

N is the speed of the motor in rpm.

Torque $T = (S_1 - S_2) R \times 9.81$ N-m.

The slope of plot between E_b Vs w gives K_b .

The slope of plot between Torque Vs Ia gives Kt.

SPEED CONTROL BY ARMATURE VOLTAGE CONTROL:

This test is conducted for determines B. The motor is run on no load with a suitable excitation by connectivity it to a d.c. source. The only torque under no load condition at any constant speed is the friction. Torque B_y only. The plot between torque and speed gives the B.

2.6 PROCEDURE:

I) LOAD TEST ON DC MOTOR

1. Circuit connections are made as per the circuit diagram.
2. Connect 220V fixed DC supply to the field of DC motor and brake drum belt should be lessened.
3. Start the motor by applying 0 - 220V variable DC supply from the controller till the motor rotates at rated speed.
4. Note down meter readings which indicates no load reading.
5. Apply load in steps up to rated current of the motor and note down corresponding I, N, F1 & F2 readings.
6. Switch off the armature DC supply using armature supply ON / OFF switch and then switch OFF the MCB.

II) SPEED CONTROL BY ARMATURE VOLTAGE CONTROL:

1. Circuit connections are made as per the circuit diagram. ,,
2. Connect 220V fixed DC supply to the motor field. Keep the armature control pot at its Maximum position and switch at off position.
3. Switch ON the MCB, Switch on the armature control switch. Vary the armature voltage and Note down the speed and the corresponding meter readings.
4. Repeat the same for different armature voltages.

2.7 PRECAUTIONS:

1. Connect the polarities correctly and vary the knobs slowly. Avoid loose connections.
2. Take the readings without parallax errors.

2.8 OBSERVATION TABLE:

1. LOAD TEST:

S.No	Speed (r.p.m)	IA(A)	F1 (Kg)	F2 (Kg)	T = (F1 – F2)x6.5x9.81 N.M.
1					
2					
3					
4					
5					

2. ARMATURE VOLTAGE CONTROL:

S.No	Speed (r.p.m)	Ia(A)	V (volts)	Eb = V-IaRa	W = 2 Π N/60
1					
2					
3					
4					
5					
6					

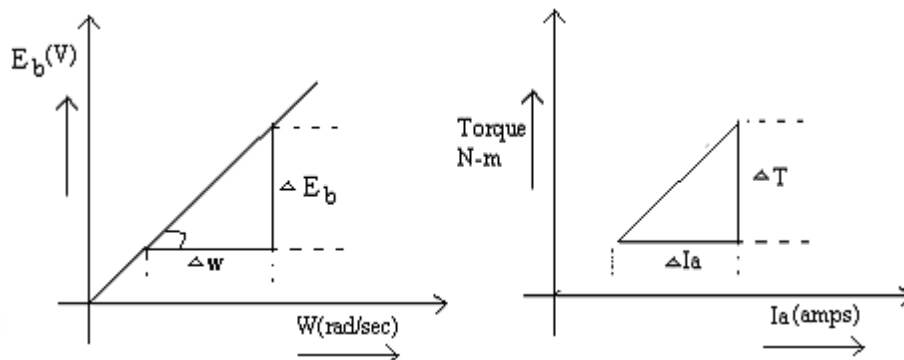


Fig – 2.3 Model Graphs

2.9 MODEL CALCULATIONS:

a). Motor Paramaters

DC motor – 0.5 HP / 220V / 1500 rpm

Arm resistance $R_a = 1.8\Omega$

Arm Inductance $L_a = 135\text{mH}$

Field Resistance $R_F = 650\Omega$

Field inductance $L_f = 21 \text{ H}$

Moment of inertia $J = 0.024 \text{ Kg/m}^2$

Friction co-efficient $B = 0.8$

TRANSFER FUNCTIONS:

$$\frac{\omega(s)}{V_a(s)} = \frac{K_{m1}}{s\tau + 1}$$

$$K_{m1} = \frac{K_b}{R_a B + K_b K_t}, \tau = \frac{J R_a}{K_b K_t}$$

$$\frac{\omega(s)}{V_a(s)} = \frac{K_{m2}}{s\tau + 1}, K_{m2} = \frac{R_a}{R_a B + K_b K_t}$$

$$\frac{I_a(s)}{V_a(s)} = \frac{K_{m3}(S\tau_m + 1)}{s\tau + 1}$$

$$K_{m3} = \frac{B}{RaB + K_bK_t} = \frac{J}{B}$$

2.10 RESULT:

2.11 PRE LAB VIVA QUESTIONS:

1. Why does the speed fall slightly when the D.C. shunt motor is loaded?
2. What will happen if the field current of the D.C. shunt motor gets interrupted?
3. What are the possible errors in the experiment?
4. How will you avoid the breaking arrangements getting heated?
5. Up to what capacity of motor can this type of test be done?
6. Why the motors are not operated to develop maximum power.
7. By applying which law, the direction of rotation of d.c. motor can be determined.

2.12 POST LAB VIVA QUESTIONS:

1. The transfer function dc motor with armature control is ____ system.
2. The transfer function dc motor with field control is ____ system.
3. What is order the of the transfer function of DC motor?
4. The motor time constant is given by; _____
5. In armature control _____ is maintained constant.
6. Armature control is suitable for speeds _____

EXPERIMENT - 3

CHARACTERISTICS OF AC SERVO MOTOR

3.1 AIM:

To study AC servo motor and note its speed torque Characteristics

3.2 APPARATUS:

S. No.	Equipments	Quantity
1	AC Servo Motor Setup	1
2	Digital Multi meter	1
3	Connecting Leads	As per requirement

3.3 THEORY

A servo motor is a linear or rotary actuator that provides fast precision position control for closed-loop position control applications. Unlike large industrial motors, a servo motor is not used for continuous energy conversion. Servo motors work on servo mechanism that uses position feedback to control the speed and final position of the motor. Internally, a servo motor combines a motor, feedback circuit, controller and other electronic circuit.

It uses encoder or speed sensor to provide speed feedback and position. This feedback signal is compared with input command position (desired position of the motor corresponding to a load), and produces the error signal (if there exist a difference between them).

The error signal available at the output of error detector is not enough to drive the motor. So the error detector followed by a servo amplifier raises the voltage and power level of the error signal and then turns the shaft of the motor to desired position.

Types of Servo Motors

Basically, servo motors are classified into AC and DC servo motors depending upon the nature of supply used for its operation. Brushed permanent magnet DC servo motors are used for simple applications owing to their cost, efficiency and simplicity.

These are best suited for smaller applications. With the advancement of microprocessor and power transistor, AC servo motors are used more often due to their high accuracy control.

3.4 CIRCUIT DIAGRAM:

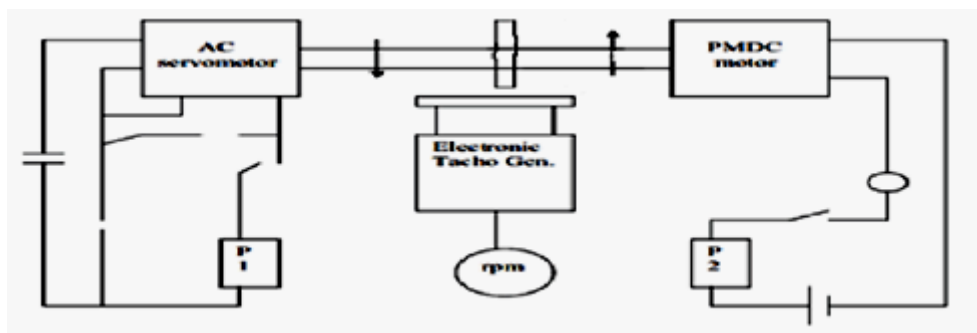


Fig – 3.1 Block Diagram of characteristics of AC servo motor

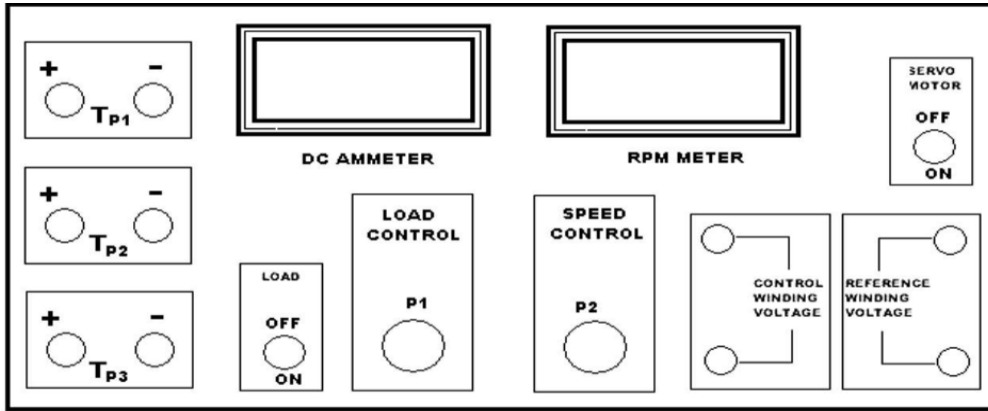


Figure 3.2 Front Panel of AC Servo-motor Controller

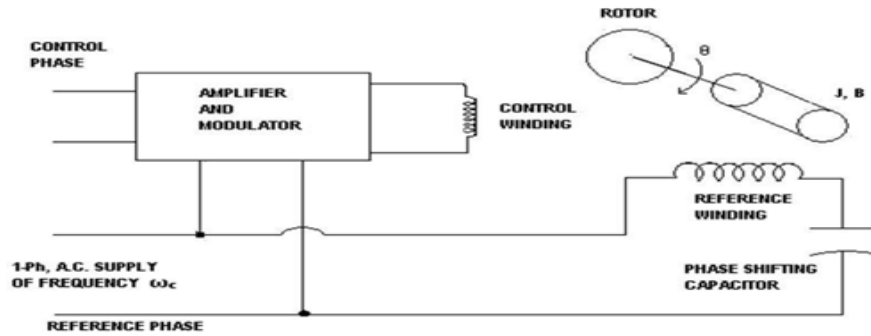


Figure 3.3 Symbolic Representation of Ac Servomotor

3.5 PROCEDURE:

- 1 Switch ON the power supply switches ON S1. Slowly increase control P1 so that AC servomotor starts rotating. Connect DVM across DC motor sockets (red & black). Vary the speed of servomotor gradually and note the speed N rpm and corresponding back emf EB across DC motor.
- 2 Connect DVM across servo motor control winding **socked** (yellow) and adjust AC Servomotor voltage to 70V and note speed N rpm in table.
- 3 Switch on S2 to impose load on the motor due to which the speed of AC motor Decreases. Increase the load current by means of P2 slowly and note corresponding speed N rpm and Ia. Calculate $P = I_a * E_b$ and $Torque = \frac{P \times 1.019 \times 104 \times 60}{2\pi N}$ N/m

3.6 TABULAR COLUMN:

TABLE - 1:

S. NO	SPEED (N) rpm	E _b volts

TABLE – 2

S.NO	Ia amp	E_b	Speed (N)rpm	P watt	Torque
1					
2					
3					
4					

3.7 PRECAUTIONS:

- 1 Apply voltage to servomotor slowly to avoid errors.
- 2 Impose load by DC motor slowly.
- 3 Take the reading accurately as the meter fluctuates.
- 4 Switch OFF the setup when not in use.

3.8 MODEL GRAPH:

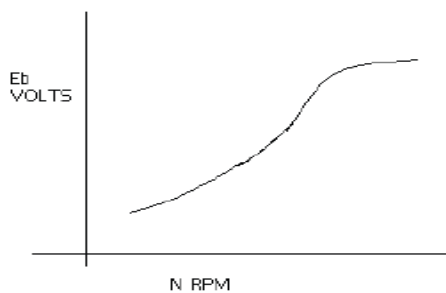


Fig -3.4 Speed Vs E_b

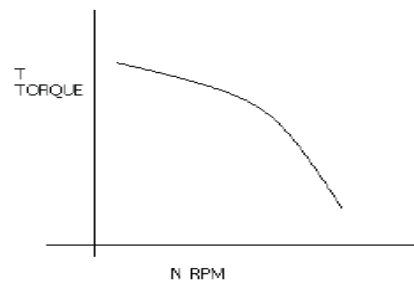


Fig – 3.5 Torque Vs Speed

3.9 RESULT:

3.10 PRE LAB VIVA QUESTIONS:

1. What is AC servo motor?
2. What is the use of AC servo motor?
3. What are the advantages of AC servo motor?
4. What is the important parameter of AC servo motor?
5. On what factor does the direction of rotation of AC servo motor depend.

3.11 POST LAB VIVA QUESTIONS:

1. What is the drawback of AC servo motor?
2. How the drawback of positive in AC servo motor is overcome?
3. What is the input of AC servo motor in feedback control application?
4. What is the phase relationship between reference voltage and control voltage?
5. What are the types of AC servo motor?

EXPERIMENT - 4

EFFECT OF VARIOUS CONTROLLERS ON A SECOND ORDER SYSTEM

4.1 AIM:

To study the steady state performance of an analog P, PI & PID controller using simulated system.

4.2 APPARATUS:

S. No.	Equipment	Quantity
1	PID Controller	1
2	Patch Chords	As Required

4.3 THEORY

Proportional Controllers

With **proportional controllers** there are two conditions and these are written below:

1. Deviation should not be large; it means there should be less deviation between the input and output.
2. Deviation should not be sudden.

Now we are in a condition to discuss proportional controllers, as the name suggests in a proportional controller the output (also called the actuating signal) is directly proportional to the error signal. Now let us analyze proportional controller mathematically. As we know in proportional controller output is directly proportional to error signal, writing this mathematically we have,

$$A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_p \times e(t)$$

Where, K_p is proportional constant also known as controller gain. It is recommended that K_p should be kept greater than unity. If the value of K_p is greater than unity, then it will amplify the error signal and thus the amplified error signal can be detected easily.

Integral Controllers

As the name suggests in integral controllers the output (also called the actuating signal) is directly proportional to the integral of the error signal. Now let us analyze integral controller mathematically. As we know in an integral controller output is directly proportional to the integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt$$

Removing the sign of proportionality we have,

$$A(t) = K_i \times \int_0^t e(t)dt$$

Where K_i is integral constant also known as controller gain. Integral controller is also known as reset controller.

Derivative Controllers

We never use derivative controllers alone. It should be used in combinations with other modes of controllers because of its few disadvantages which are written below:

1. It never improves the steady state error.
2. It produces saturation effects and also amplifies the noise signals produced in the system.

Now, as the name suggests in a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal. Now let us analyze derivative controller mathematically. As we know in a derivative controller output is directly proportional to the derivative of the error signal, writing this mathematically we have,

$$A(t) \propto \frac{de(t)}{dt}$$

Removing the sign of proportionality we have,

$$A(t) = K_d \times \frac{de(t)}{dt}$$

Where, K_d is proportional constant also known as controller gain. Derivative controller is also known as rate controller.

Proportional and Integral Controller

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have,

$$A(t) \propto \int_0^t e(t)dt + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_i \int_0^t e(t)dt + K_p e(t)$$

Where, K_i and k_p proportional constant and integral constant respectively.

Advantages and disadvantages are the combinations of the advantages and disadvantages of proportional and integral controllers.

Proportional and Derivative Controller

As the name suggests it is a combination of proportional and a derivative controller the output (also called the actuating signal) is equal to the summation of proportional and derivative of the error signal. Now let us analyze proportional and derivative controller mathematically. As we know in a proportional and derivative controller output is directly proportional to summation of proportional of error and differentiation of the error signal, writing this mathematically we have,

$$A(t) \propto \frac{de(t)}{dt} + A(t) \propto e(t)$$

Removing the sign of proportionality we have,

$$A(t) = K_d \frac{de(t)}{dt} + K_p e(t)$$

Where, K_d and k_p proportional constant and derivative constant respectively.

4.4 BLOCK DIAGRAM:

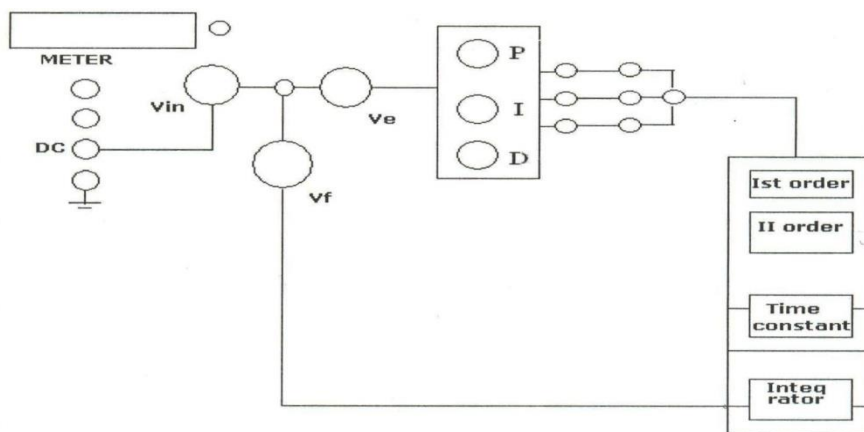


Fig – 4.1 Block diagram Effect of P, PI, PID Controller on a second order system

4.5 PROCEDURE:

1. Make the connections as per the block diagram.
2. Set input DC amplitude to 1V.
3. Adjust I, D to Zero.
4. For various values of P, measure V_f , V_i and V_e using meter provided on the kit and note down the readings.

4.6 TABULAR COLUMN:

P Controller		(Variable Proportionate gain)		
S. No.	P	V_i	V_f	V_e
1				
2				
3				
4				

PI Controller (Constant Proportionate gain and Variable Integral gain)

P =

S. No.	I	V _i	V _f	V _e
1				
2				
3				
4				

PID Controller (Constant Proportionate gain & Integral gain and Variable Differential gain)

P =

I =

S. No.	D	V _i	V _f	V _e
1				
2				
3				
4				

4.7 RESULT:

4.8 PRE LAB VIVA QUESTIONS:

1. What is a controller?
2. What is the difference between a compensator and controller?
3. Write a brief note about Proportional Controller.
4. Write a brief note about Derivative Controller.
5. Write a brief note about Integral Controller.

4.9 LAB ASSIGNMENTS:

1. To observe open loop performance of building block and calibration of PID Controls.
2. To study P, PI and PID controller with type 0 system with delay.
3. To study P, PI and PID controller with type 1 system.

4.10 POST LAB VIVA QUESTIONS:

1. Write a brief note about PID Controller.
2. Compare the performance of PI and PD controller.
3. Which controller is used for improving the transient response of the system?
4. Which controller is used for improving the steady state response of the system?
5. What is the purpose of PID controller?

EXPERIMENT - 5

COMPENSATOR

5.1 AIM:

To study of Lag, Lead, Lead - Lag compensation networks.

5.2 APPARATUS:

S.No.	Equipment	Quantity
1	Lead-Lag network study unit	1
2	C.R.O	1

5.3 THEORY

INTRODUCTION TO LEAD-LAG COMPENSATION

Generally the purpose of the Lead-Lag compensator is to create a controller which has an overall magnitude of approximately 1. The lead-lag compensator is largely used for phase compensation rather than magnitude. A pole is an integrator above the frequency of the pole. A zero is a derivative above the frequency of the zero.

Adding a pole to the system changes the phase by -90 deg and adding a zero changes the phase by +90 deg. So if the system needs +90 deg added to the phase in a particular frequency band then you can add a zero at a low frequency and follow that zero with a pole at a higher frequency.

Lead or Lag Control

Lead and lag control are used to add or reduce phase between 2 frequencies. Typically these frequencies are centered around the open loop crossover frequency. A lead filter typically has unity gain (0 dB) at low frequencies while the lag provides a non unity gain at low frequencies.

$$C(s) = \frac{\tau_1 s + 1}{\tau_2 s + 1}$$

where

$\tau_1 > \tau_2$ makes this a lead filter and

$\tau_1 < \tau_2$ makes this a lag filter.

Lead-Lag Control

This is an extension of the Lead and Lag network described above. We can always stick a gain in front of something so reformulate $C(s)$ above to look like this

$$C(s) = k \frac{\tau_a s + 1}{\tau_b s + 1}$$

Then a lead-lag controller would have the form

$$C(s) = k \left(\frac{\tau_a s + 1}{\tau_b s + 1} \right) \left(\frac{\tau_c s + 1}{\tau_d s + 1} \right)$$

where

k is a gain,

$\tau_a > \tau_b$ makes the first part a lead filter and

$\tau_c < \tau_d$ makes the last part a lag filter.

5.4 CIRCUIT DIAGRAM:

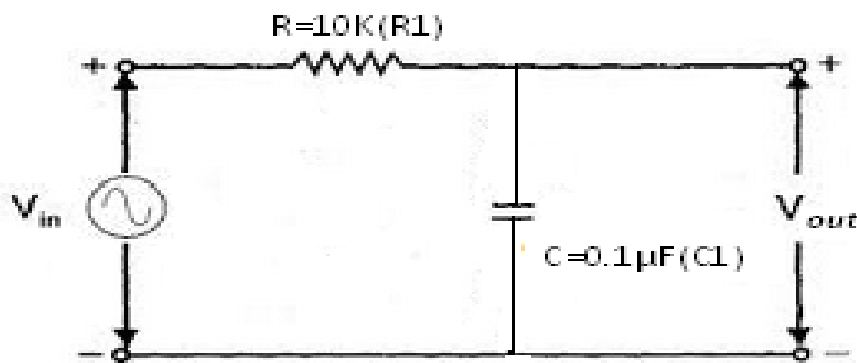


Fig – 7.1 Lag Compensation Network

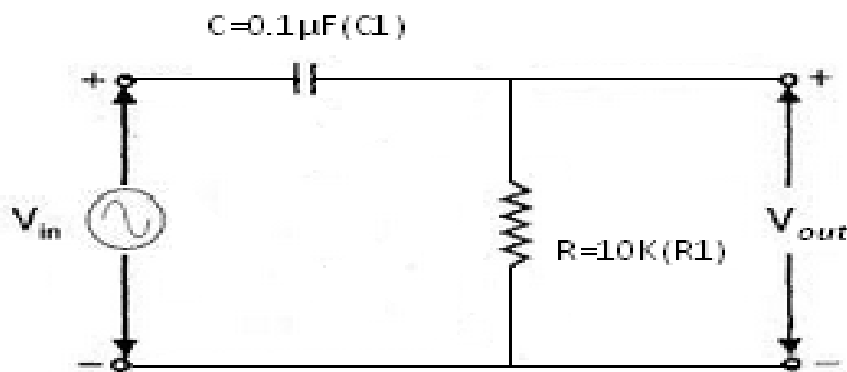


Fig – 7.2 Lead Compensation Network

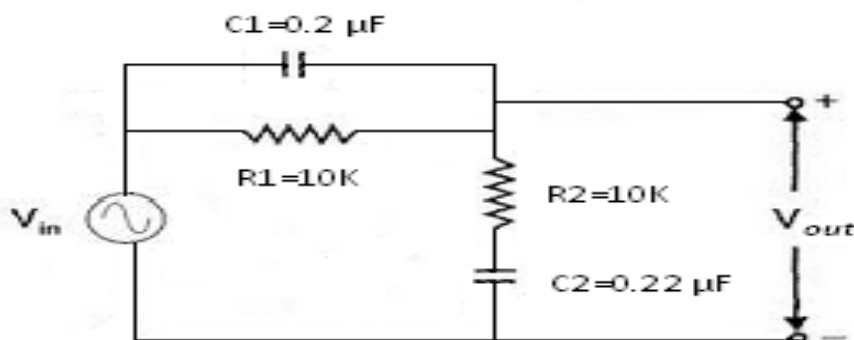


Fig – 7.3 Lag-Lead Compensator Network

5.5 PROCEDURE:

1. Switch on the main supply to unit observes the sine wave signal by varying the frequency and amplitude potentiometer.
2. Now make the network connections for Lag, Lead and Lead-Lag networks connect the sine wave output to the networks input.
3. Note down the peak actuator input using digital voltmeter provided, now the meter will shows peak voltage.
4. Set the amplitude of sine wave to some value ex: 3 Volts peak, 4Volts Peak etc.,
5. Now vary the frequency and note down frequency, phase angle difference and output voltage peak for different frequencies and tabulate all the readings.
6. Calculate the theoretical values of phase angle difference and gain compare these values with the practical values.
7. Plot the graph of phase angle versus frequency (phase plot) and gain versus frequency (magnitude plot).
8. Repeat the same for different values of R and C.
9. Repeat the same for different sine wave amplitude.
10. Repeat the same experiment for lead and lag-lead networks.

FORMULAE

Lag Network

Phase angle, $\Phi = \tan^{-1}\omega RC$

$$\text{Gain} = \frac{1/RC}{\sqrt{\omega^2 + (1/RC)^2}}$$

FORMULAE

Lead Network

Phase angle, $\Phi = \tan^{-1}\left(\frac{1}{\omega RC}\right)$

$$\text{Gain } G_c = (j\omega) = \frac{V_{\text{out}}}{V_{\text{in}}} = \frac{j\omega RC}{1 + j\omega RC}$$

$$\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R}{Z} \quad Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$V_{\text{in}} = V$$

FORMULAE

Lag-Lead Network

$$R_1 C_1 = \tau_1, \quad R_2 C_2 = \tau_2$$

$$\beta = \frac{R_1 + R_2}{R_2} > 1$$

$$\beta = \frac{10k + 10k}{10k} = 2.0$$

$$\alpha = \frac{R_2}{R_1 + R_2} \quad 0.5 < 1$$

The transfer function of such a compensator is given by

$$G(s) = \frac{\left(s + \frac{1}{\tau_1}\right)\left(s + \frac{1}{\tau_2}\right)}{\left(s + \frac{1}{\beta\tau_1}\right)\left(s + \frac{1}{\alpha\tau_2}\right)}$$

(lag) (lead)

CALCULATIONS:

$$R_1C_1 = \tau_1 = 0.002, \quad R_2C_2 = \tau_2 = 0.002$$

$$\omega_0 = \frac{1}{\sqrt{\tau_1 \times \tau_2}}$$

The frequency at which phase angle zero is $\omega_0 = \frac{1}{\sqrt{\tau_1 \times \tau_2}}$

$$\omega_0 = 2\pi f = 500$$

$$f = 500/6.28 = 80\text{Hz}$$

5.6

TABULAR COLUMN:

Lag Network

S.No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}
1				
2				
3				

TABULAR COLUMN:

Lead Network

S. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}
1				
2				
3				

TABULAR COLUMN:

Lag-Lead Network

S. No.	Frequency (Hz)	Phase angle Φ in degrees	Output voltage V_O (Volts)	Gain = V_o/V_{in}
1				
2				
3				

5.7 RESULT:

5.8 PRELAB QUESTIONS:

1. Write a brief note about Lag Compensator.
2. Write a brief note about Lead Compensator.
3. Write a brief note about Lag Lead Compensator.
4. Which compensation is adopted for improving transient response of a negative unity feedback system?

5.9 LAB ASSIGNMENTS:

1. To study the open loop response on compensator and Close loop transient response.
2. The max. phase shift provided for lead compensator with transfer function $G(s)=(1+6s)/(1+2s)$

5.10 POSTLAB QUESTIONS:

1. Which compensation is adopted for improving steady response of a negative unity feedback system?
2. Which compensation is adopted for improving both steady state and transient response of a negative unity feedback system?
3. What happens to the gain crossover frequency when phase lag compensator is used?
4. What happens to the gain crossover frequency when phase lead compensator is used?
5. What is the effect of phase lag compensation on servo system performance?

EXPERIMENT - 6

TEMPERATURE CONTROLLER

6.1 AIM:

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

6.2 APPRATUS:

S.NO	Equipment	Quantity
1	Temperature control kit	1
2	Oven	1
3	Patch Cards	As Required
4	Stop Watch	1

6.3 THEORY

Proportional-Response

The proportional component depends only on the difference between the set point and the process variable. This difference is referred to as the Error term. The proportional gain (K_c) determines the ratio of output response to the error signal. For instance, if the error term has a magnitude of 10, a proportional gain of 5 would produce a proportional response of 50. In general, increasing the proportional gain will increase the speed of the control system response. However, if the proportional gain is too large, the process variable will begin to oscillate. If K_c is increased further, the oscillations will become larger and the system will become unstable and may even oscillate out of control.

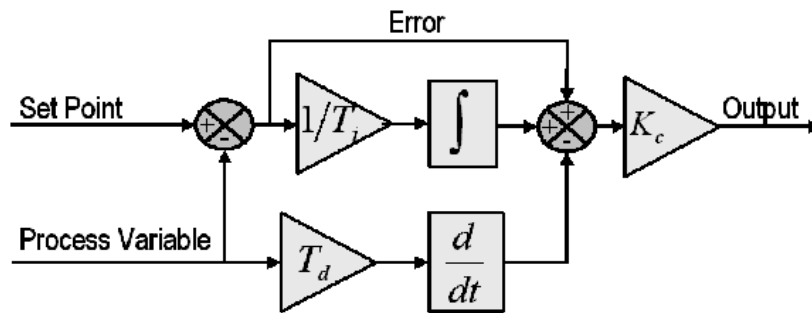


Figure 6.1: Block diagram of a basic PID control algorithm.

Integral-Response

The integral component sums the error term over time. The result is that even a small error term will cause the integral component to increase slowly. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero. Steady-State error is the final difference between the process variable and set point. A phenomenon called integral windup results when integral action saturates a controller without the controller driving the error signal toward zero.

Derivative-Response

The derivative component causes the output to decrease if the process variable is increasing rapidly. The derivative response is proportional to the rate of change of the process variable. Increasing the derivative time (T_d) parameter will cause the control system to react more strongly to changes in the error term and will increase the speed of the overall control system response. Most practical control systems use very small derivative time (T_d), because the Derivative Response is highly sensitive to noise in the process variable signal. If the sensor feedback signal is noisy or if the control loop rate is too slow, the derivative response can make the control system unstable

6.4 CIRCUIT DIAGRAM:

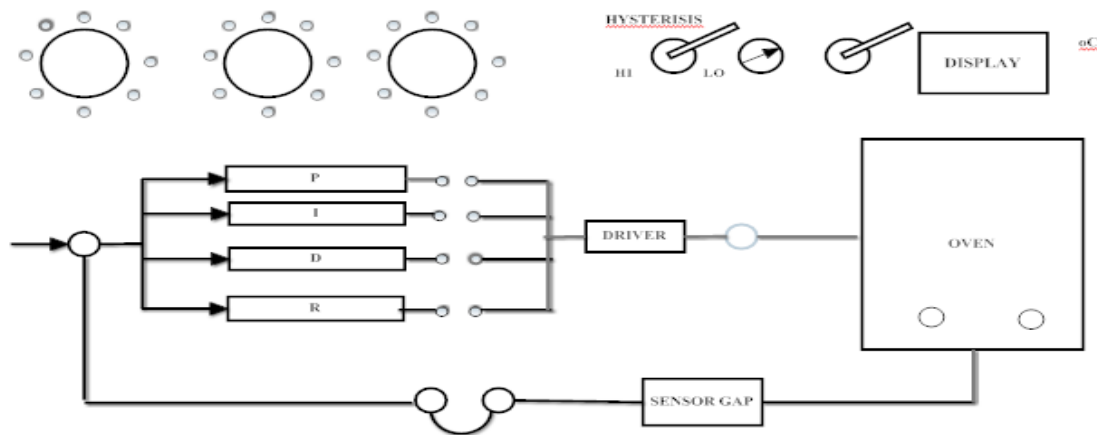


Fig – 6.2 Block Diagram of Temperature Control Systems

6.5 PROCEDURE:

Proportional controller:

1. Keep S1 switch to wait position and allow oven to cool to room temperature. Short the feedback terminals.
2. Keep S2 to set position and adjust the reference potentiometer to desired output temperature say 60° by seeing on the digital display.
3. Connect the 'P' output to the driver, input of P,I,R must be disconnected from drive input and set 'p' potentiometer value to '1'.
4. Switch S2 to measure and S1 to run position and record oven temperature every 30 sec for about 20 min.
5. Plot the graph between temperature and time on graph sheet.

PI Controller:

1. Starting with cool oven, keep switch S1 to wait connect P,I output to drive input and disconnect R&D outputs and short feedback terminals.
2. Set P and I potentiometer to 0.5, 1.
3. Select and set desired temperature to 60° .
4. Keep switch S1 to run position and record the temperature readings every 15/30 sec about 20 min.

5. Plot the graph between temperature and time.

PID Controller:

1. Starting with cool oven, keep switch S1 to wait.
2. Connect P, I, D to driver input and disconnect R output, short feedback terminals.
3. Set P, I, D potentiometer to 0.5, 1.
4. Select and set the desired temperature to 60°.
5. Keep switch S1 to RUN position and record the temperature readings every 15/30 sec about 20 min.

6.6 TABULAR COLUMN:

Time in (sec)	Temperature in degrees		
	P	PI	PID

6.8 RESULT:

6.9 PRE LAB VIVA QUESTIONS:

1. What is control system?
2. Define closed loop and open loop control system.
3. What are the different types of controllers do we have?
4. Define P controller, PI controller and PID controller?

6.10 POST LAB VIVA QUESTIONS:

1. What is a driver circuit?
2. What are the applications of temperature controller system?
3. Which controller is most effective among P, PI, PID and why?
4. Define gain.

EXPERIMENT - 7

DESIGN AND VERIFICATION OF OP-AMP BASED PID CONTROLLER

7.1 AIM:

To design and verify op-amp based PID Controller

7.2 APPARATUS:

S. NO	Devices	Quantity
1	OP-AMP based trainer kit	1
2	MATLAB 16a Software	1
3	Personal Computer	1

7.3 CIRCUIT DIAGRAM:

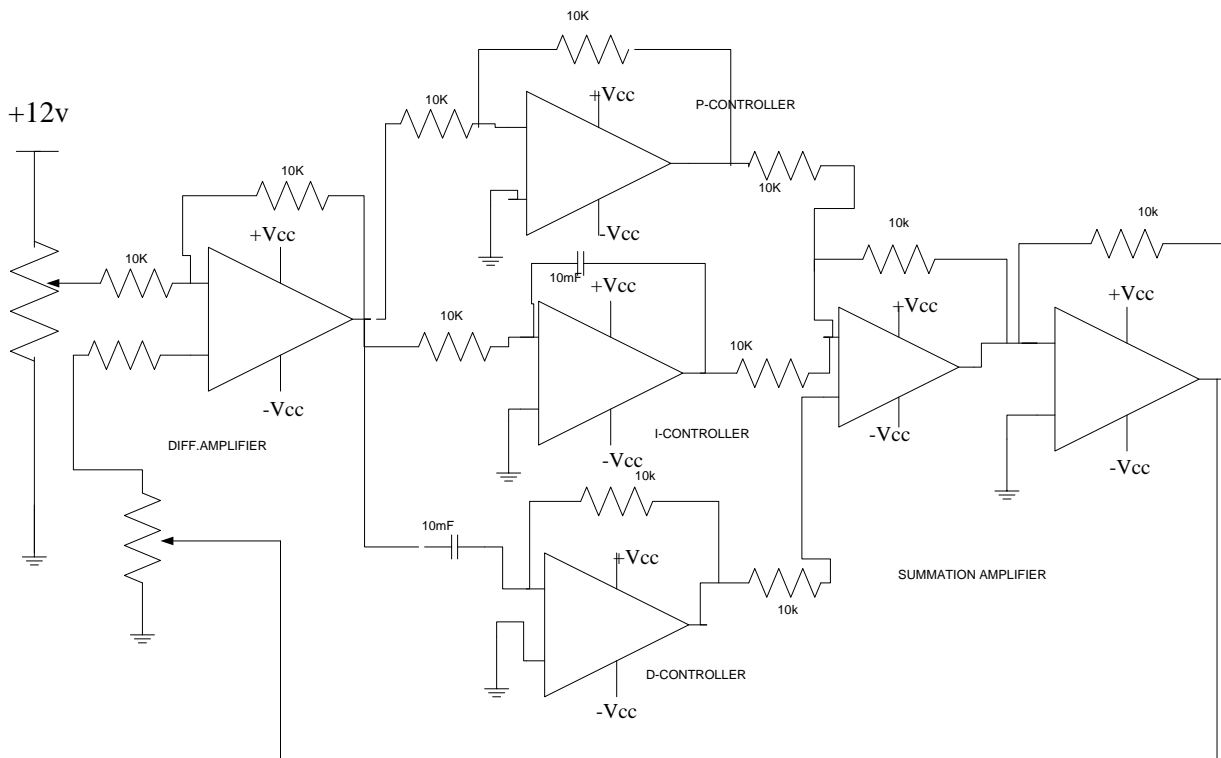
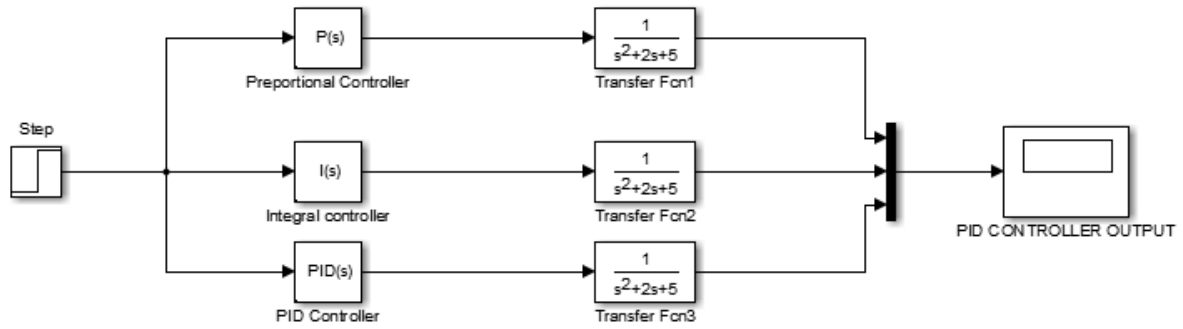


Fig 7.1 CIRCUIT DIAGRAM OF OP-AMP BASED PID CONTROLLER

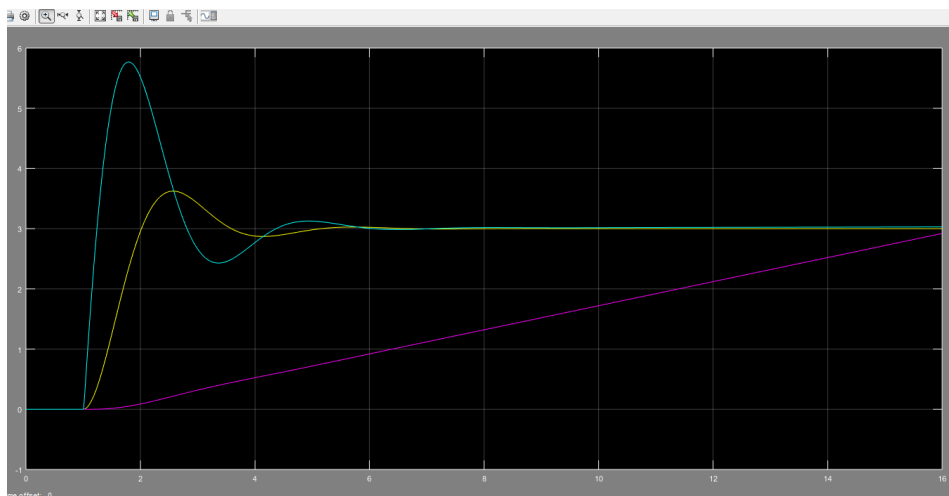
7.4 SIMULINK MODEL:



7.4 PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Connect a step function to controller and observe the output. Change the P, I and D settings and observe the output. Record the results.
3. Record your observations.

7.5 EXPECTED OUTPUT:



7.6 RESULT:

EXPERIMENT - 8

STABILITY ANALYSIS USING DIGITAL SIMULATION

8.1 AIM:

To analyze frequency response of a system by plotting Root locus, Bode plot and Nyquist plot using MATLAB software.

8.2 APPRATUS:

S. No.	Equipment	Quantity
1	MATLAB 16a Software	1
2	Personal Computer	1

8.3 THEORY

ROOT LOCUS

The root locus technique in control system was first introduced in the year 1948 by Evans. Any physical system is represented by a transfer function in the form of

$$G(s) = k \times \frac{\text{numerator of } s}{\text{denominator of } s}$$

We can find poles and zeros from $G(s)$. The location of poles and zeros are crucial keeping view stability, relative stability, transient response and error analysis. When the system put to service stray inductance and capacitance get into the system, thus changes the location of poles and zeros. In **root locus technique in control system** we will evaluate the position of the roots, their locus of movement and associated information. These information will be used to know about the system performance.

BODE PLOTS

Bode plots were first introduced by H.W. Bode, when he was working at Bell labs in the United States. Bode plots are the most widely used means of displaying and communicating frequency response information. There are many reasons for that. Bode' plots are really log-log plots, so they collapse a wide range of frequencies (on the horizontal axis) and a wide range of gains (on the vertical axis) into a viewable whole. In Bode' plots, commonly encountered frequency responses have a shape that is simple. That simple shape means that laboratory measurements can easily be discerned to have the common factors that lead to those shapes. For example, first order systems have two straight line asymptotes and if you take data and plot a Bode' plot from the data, you can pick out first order factors in a transfer function from the straight line asymptotes.

NYQUIST PLOT

The stability analysis of a feedback control system is based on identifying the location of the roots of the characteristic equation on s-plane. The system is stable if the roots lie on left hand side of s-plane. Relative stability of a system can be determined by using frequency response methods like Nyquist plot and Bode plot. Nyquist criterion is used to identify the presence of roots of a characteristic equation in a specified region of s-plane.

8.4 PROCEDURE:

1. Click on MATLAB icon.
2. From FILE menu click on NEW button and select SCRIPT to open Untitled window
3. Enter the following program in untitled window.

8.5 PROGRAM:

For Root Locus Plot

```
%Root Locus Plot
clear all;
clc;
disp('Transfer Function of given system is : \n');
num = input ('Enter Numerator of the Transfer Function:\n');
den = input ('Enter Denominator of the Transfer Function : \n');
G = tf(num,den);
figure(1);
rlocus(G);
```

For Bode Plot

```
%Bode Plot
clear all;
clc;
disp('Transfer Function of given system is : \n');
num = input ('Enter Numerator of the Transfer Function : \n');
den = input ('Enter Denominator of the Transfer Function : \n');
G = tf(num,den);
figure(2);
bode(G);
%margin(G); It can be used to get Gain Margin, Phase Margin etc
[Gm,Pm,Wpc,Wgc] = margin(G);
disp('Phase Cross Over frequency is : \n');
Wpc
disp ('Gain Cross Over frequency is : \n');
Wgc
disp('Phase Margin in degrees is : \n');
Pm
disp('Gain Margin in db is : \n');
Gm = 20*log(Gm)
Gm
if (Wgc<Wpc)
```

```

        disp('Closed loop system is stable')
    else
    if (Wgc>Wpc)
        disp('Closed loop system is unstable')
    else
        disp('Closed loop system is Marginally stable')
    end
end

```

For Nyquist Plot

```

% Nyquist Plot
Clear all;
clc;
disp(' Transfer function of given system is \n');
num = input (' enter numerator of Transfer function: \n ');
den = input (' enter denominator of Transfer function: \n ');
G= tf (num, den)
figure(1);
nyquist (G);
%margin(G);
[gm, pm, wpc, wgc] = margin (G)
Disp (' gain margin in degrees is: \n')
end

```

1. Save the above program by clicking on SAVE button from FILE menu (or) Ctrl+S
2. Run the program by clicking RUN button (or) F5 and clear the errors (if any).
3. Observe the output on the MATLAB Command Window and plots from figure window.

8.6 MODEL GRAPHS:

OUTPUT

```

Phase Cross Over frequency is:
Wpc =
Gain Cross Over frequency is :
Wgc =
Phase Margin in degrees is :
Pm =
Gain Margin in db is :
GM =

```

8.7 THEORETICAL CALCULATION:

1. Phase Margin

1. For a given Transfer Function $G(s)$, get $G(j\omega)$ by placing $s = j\omega$.
2. Separate Magnitude and Phase terms from $G(j\omega)$.
3. Equate magnitude of $G(j\omega)$ to **ONE** and get ω value, this ω is called Gain Cross Over Frequency (ω_{gc})
4. Substitute ω_{gc} in place of $G(j\omega)$, get the phase angle (ϕ).
5. Now Phase margin (PM) = $180 + \phi$

2. Gain Margin

1. For a given Transfer Function $G(s)$, get $G(j\omega)$ by placing $s = j\omega$
2. Separate Magnitude and Phase terms from $G(j\omega)$.
3. Equate imaginary part to **ZERO** and get ω value, this ω is called Phase Cross Over Frequency (ω_{pc})
4. Substitute ω_{pc} in real part, get the corresponding gain (K).
5. Now Gain Margin (GM) = $20 \log_{10} (1/K)$

3. Maximum Allowable Gain

1. For a given Transfer Function $G(s)$, place K in the numerator and get the characteristic equation $Q(s) = 1 + G(s)$.
2. Get $Q(j\omega)$ by placing $s = j\omega$.
3. Separate imaginary and real terms from $Q(j\omega)$.
4. Equate imaginary part to **ZERO** and get ω values, these values called Imaginary Cross Over points.
5. Substitute ω_{pc} in real part and equate real part of $G(j\omega)$ to **ZERO** and get the corresponding gain (K).
6. This gain is called maximum Allowable Gain (K_{max}) or Limiting value of the Gain for stability.

8.8 TABULAR COLUMN:

Specification	Gain Margin (GM) and Gain Cross Over Frequency (ω_{gc})	Phase Margin (PM) and Phase Cross Over Frequency (ω_{pc})	Maximum allowable gain (K_{max})
From MATLAB			
Theoretical			

8.9 RESULT:

8.10 PRE LAB VIVA QUESTIONS

1. What is gain margin and phase margin?
2. What is gain cross over frequency and phase crossover frequency?
3. What are the different types of stability conditions?
4. What are the advantages and disadvantages of root locus, bode & nyquist plot?
5. What are the advantages of frequency response analysis?

8.11 LAB ASSIGNMENTS

1. For the above function, if a pole is added, how the stability will be effected for all the plots?
2. For the above function, if a pole is removed, how the stability will be effected for all the plots?
3. For the above function, if a zero is added, how the stability will be effected for all the plots?
4. For the above function, if a zero is removed, how the stability will be effected for all the plots

8.12 POST LAB VIVA QUESTIONS

1. What is complementary Root Loci?
2. What are contours?
3. How can you analyze the stability of system with bode, nyquist?

EXPERIMENT - 9

STATE SPACE MODEL FOR CLASSICAL TRANSFER FUNCTION USING MATLAB

9.1 AIM:

To Transform a given Transfer Function to State Space Model and from State Space Model to Transfer Function using MATLAB.

9.2 APPRATUS:

S.No.	Equipment	Quantity
1	MATLAB 16a Software	1
2	Personal Computer	1

9.3 THEORY

State-space models

State-space models are models that use state variables to describe a system by a set of first-order differential or difference equations, rather than by one or more nth-order differential or difference equations. State variables $x(t)$ can be reconstructed from the measured input-output data, but are not themselves measured during an experiment.

The state-space model structure is a good choice for quick estimation because it requires you to specify only one input, the model order, n . The model order is an integer equal to the dimension of $x(t)$ and relates to, but is not necessarily equal to, the number of delayed inputs and outputs used in the corresponding linear difference equation.

9.4 PROCEDURE:

1. Click on MATLAB icon.
2. From FILE menu click on NEW button and select SCRIPT to open untitled window.
3. Enter the following program in untitled window.

9.5 PROGRAM:

For Transfer Function to State Space Model:

```
% Transfer Function to State Space Model
Clear all;
clc;
disp('Transfer Function of given system is : \n');
Num = [2 3 2];
Den = [2 1 1 2 0];
sys = tf(num,den);
Disp('Corresponding State Space Model A,B,C,D are: \n');
[A,B,C,D] = tf2ss(num,den)
A
```

B
C
D

9.6 PROGRAM

For State Space Model to Transfer Function:

```
%State Space Model to Transfer Function
Clear all;
clc;
disp('A,B,C,D Matrices of given State Space Model are :: \n');
A = [1 2;3 4 ]
B = [1;1]
C = [1 0]
D = [0]
[num,den] = ss2tf(A,B,C,D);
Disp('And corresponding Transfer Function is : \n ');
Sys = tf(num,den);
Sys
```

1. Save the above program by clicking on SAVE button from FILE menu (or) Ctrl+S
2. Run the program by clicking RUN button (or) F5 and clear the errors (if any).
3. Observe the output from on the MATLAB Command Window.

OUTPUT

Transfer Function to State Space Model

Transfer Function of given system is
Transfer Function:

$$2s^2 + 3s + 2$$

$$\frac{2s^2 + 3s + 2}{2s^4 + s^3 + s^2 + 2s}$$

Corresponding State Space Model A, B, C, D are:

```
A =   -0.5000 -0.5000   -1.0000  0
      1.0000  0         0         0
      0         1.0000  0         0
      0         0         1.0000  0
B =   1
      0
      0
      0
C =   0   1.0000   1.5000   1.000
D =   0
```


OUTPUT

State Space Model to Transfer Function

A, B, C, D Matrices of given State Space Model are :

$$A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

$$B = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

$$C = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

$$D = 0$$

and corresponding Transfer Function is:

$$\frac{s^2}{s^2 - 5s - 2}$$

9.7 RESULT:

9.8 PRE LAB VIVA QUESTIONS:

1. What are the advantages & disadvantages of state space analysis?
2. What are the disadvantages of transfer function?
3. What are the different functions in MATLAB?
4. What is workspace and command window?

9.9 LAB ASSIGNMENTS:

1. $\frac{8s + 1}{9s^3 + s^2 + s + 2}$ formulate state space model?
2. $\frac{s^4 + s^3 + s^2 + s + 1}{9s^3 + s^2 + s + 2}$ formulate state space model?
3. $\frac{s}{9s^3 + s^2 + s + 2}$ formulate state space model?

9.10 POST LAB VIVA QUESTIONS

1. How to call MATLAB in batches?
2. Explain Handle graphics in MATLAB?
3. Explain the following commands:
Acker, Bode, Ctrl, Dstep, Feedback, Impulse, Margin, Place, Rlocus, stairs

EXPERIMENT 10

LADDER DIAGRAMS USING PLC

10.1 AIM

To Study And Develop Logic Diagrams Using Programmable Logic Controller

10.2 APPARATUS:

S. No	Name Of Equipment	Quantity
1	Delta make PLC Trainer kit	1
2	PC with WPL soft installed	1
3	RS232 Cable	1

10.3 THEORY

Monitoring and inspection of several processes is becoming dominant part of the automation technique in any industry. So the automation is basically the delegation of human control function to technical equipment's for increasing productivity and quality, reducing costs, increasing safety in working conditions PLC forms one of the computerized machines and hence regarded as the heart of automated control system. The first PLC came into existence which was MODICON 084" and since the Dick Morley was one of the dedicated members working with the association so he is credited with the invention of PLC and known as "father of PLC".

The control panel consists of thousands of wires which interconnects many relays to operate the various machines. So in case of error, machines have to be stopped and complete rewiring is required which is not only hectic job but also costs more. Also time was wasted in finding out errors and even distance control was not possible. Because of such problems the relays were replaced by PLCs

Ladder diagrams are specialized schematics commonly used to document industrial control logic systems. They are called "ladder" diagrams because they resemble a ladder, with two vertical rails (supply power) and as many "rungs" (horizontal lines) as there are control circuits to represent. If we wanted to draw a simple ladder diagram showing a lamp that is controlled by a hand switch, it would look like this:

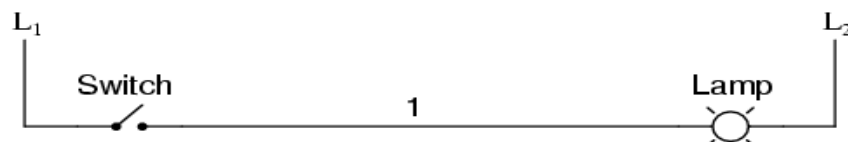


Figure 10.1

The "L₁" and "L₂" designations refer to the two poles of a 220 V Single phase AC supply, unless otherwise noted. L₁ is the "live" conductor, and L₂ is the grounded ("neutral") conductor. These designations have nothing to do with inductors, (just to make things clear). The actual transformer or generator supplying power to this circuit is omitted for simplicity.

10.4 PROCEDURE:

- 1 Click on the WPL soft
- 2 Goto File→New , a window appears on your screen, select required PLC model→SS2→given the file name and program title.
- 3 After selecting the appropriate PLC model, you will get two windows , one ladder diagram mode and other one is instruction list mode.
- 4 Now users has to choose the editing mode of their interests to proceed with the program editing.
- 5 Select ladder diagram mode and enter the ladder logic in the ladder diagram mode using ladder tool bar provided NC,NO contacts.
- 6 Select simulator icon from WPL bar and compile the code set the program to online (or) offline mode.
- 7 Dump the program from PC to PLC using icon provided on WPL bar.
- 8 Run the program.

10.5 EXAMPLES

(a) EXAMPLE 10.1:

CONTROL PURPOSE: Turn on the switch, the light will be ON; turn off the switch, the light will be OFF.

DEVICES:

Devices	Function
X0	Switch-on button. X0 will be ON when pressed
X1	Switch-off button. X1 will be ON when pressed
Y0	Indicator

CIRCUIT DIAGRAM:

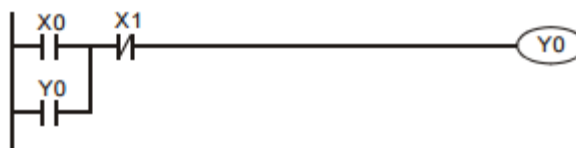


Figure 10.1 COMMON LATCHED CIRCUIT

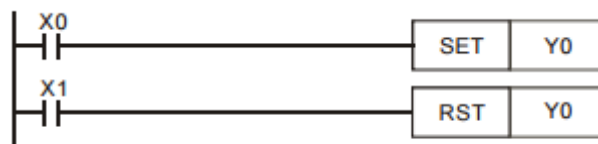


Figure 10.2 LADDER DIAGRAM

PROGRAM DESCRIPTION FOR FIG.10.2:

- In the above examples, when X0 goes from OFF to ON, Y0 will stay in ON state.
- When X1 goes from OFF to ON, Y1 will stay in OFF state. When X0 and X1 are enabled at the same time, it will be “Stop First”, that is, Y1 and the indicator will be OFF.

(b) EXAMPLE 10.2:

CONTROL PURPOSE: Setting the light ON by pressing the switch for the 1st time, the 3rd time, 5th time, etc.; setting the light OFF by pressing the switch for the 2nd time, 4th time, 6th time, etc. Restoring the indicator to the state before power off when the device is powered up again.

DEVICES:

Devices	Function
X1	X1 Light switch. X1 will be ON when the button is pressed
M10	Trigger pulse for one scan cycle
M512	If X1 is pressed for odd number of times, M512 ON, M513 = OFF.
M513	If X1 is pressed for even number of times, M512 = OFF, M513 = ON.
Y1	Indicator

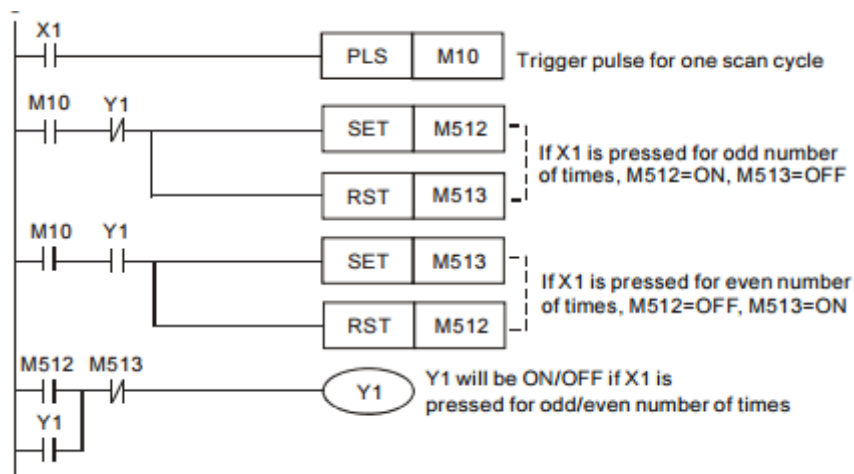


Figure 10.3 LADDER DIAGRAM

PROGRAM DESCRIPTION FOR FIG.10.3:

- Pressing X1 for the 1st time (or odd number of times): When the switch X1 is pressed, X1 will be ON and the [PLS M10] instruction will be executed for triggering M10 to be ON for one scan cycle. In this case, M10 is ON and Y1 is OFF, SET and RST instructions at line 2 will thus be executed. On the contrary, SET and RST instructions at line 3 will not be executed due to the open loop of Y1. At line 4, coil Y1 is ON because of the results of Line 2: M512 is ON and M513 is OFF. When the 2nd scan cycle is started, SET/RST at both line 2 and line 3 will not be executed because M10 is OFF in this scan cycle. As a result, the light will be ON until the switch is pressed next time.

- Pressing X1 for the 2nd time (or even number of times):
When the switch X1 is pressed again, X1 will be ON and M10 will be ON for one scan cycle. According to the result of pressing X1 for the first time, the state of Y1 has been ON. SET/RST instructions at line 3 will thus be executed. In addition, SET/RST instructions at line 2 won't be executed due to the open loop of Y1. In this case, M513 will be ON and M512 will be OFF. When the 2nd scan cycle is started, SET/RST at both line 2 and line 3 will not be executed because M10 is OFF in this scan cycle. As a result, the light will remain OFF until the switch is pressed next time.
- Alternate output(ON/OFF) function can also be performed by using API 66 ALT instruction.
[To get PLS instruction Click on application instruction(F6)]

(C) EXAMPLE 10.3:

CONTROL PURPOSE: Usually very large motors require lubrication oil to be supplied through a lubrication pump for avoiding damage to the bearings and the motor. So, it is required to switch on lubricating oil pump before the main motor pump is made on.

DEVICES	FUNCTION
X0	Lubricating Oil pump START button. X0 will be ON when pressed
X1	Main motor START button. X0 will be ON when pressed
X2	Lubricating Oil pump STOP button. X2 will be ON when pressed.
X3	Main motor STOP button. X3 will be ON when pressed.
Y0	Lubricating Oil pump motor
Y1	Main motor

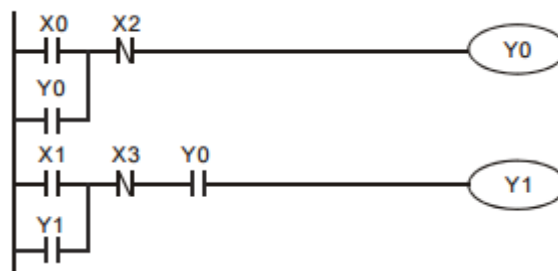


Figure 10.4 LADDER DIAGRAM

PROGRAM DESCRIPTION FOR FIG.10.4:

- When X0 is set on, lubricating oil pump motor gets on.
- When x1 is on main motor gets on ad to switch of main motor press X2.
- To switch of both the motors press X2.

EXPERIMENT - 11
TRUTH TABLES USING PLC

11.1 AIM:

Study and develop the ladder program using PLC

11.2 APPARATUS:

S. No	Name of the equipment	Quantity
1	PLC Trainer Kit	1
2	Personnel Computer	1

11.3 CIRCUIT DIAGRAM:

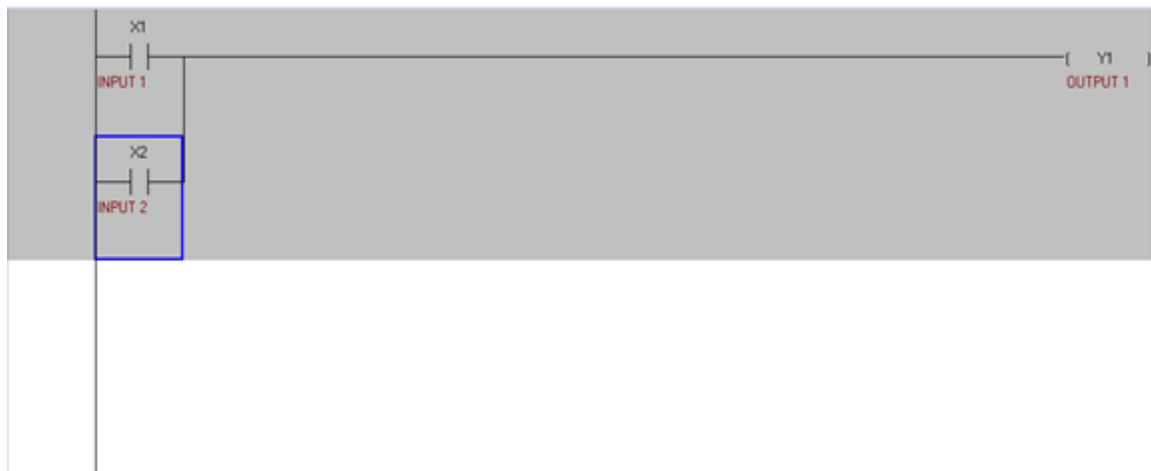


Figure 11.1 Ladder Diagram of OR gate in PLC

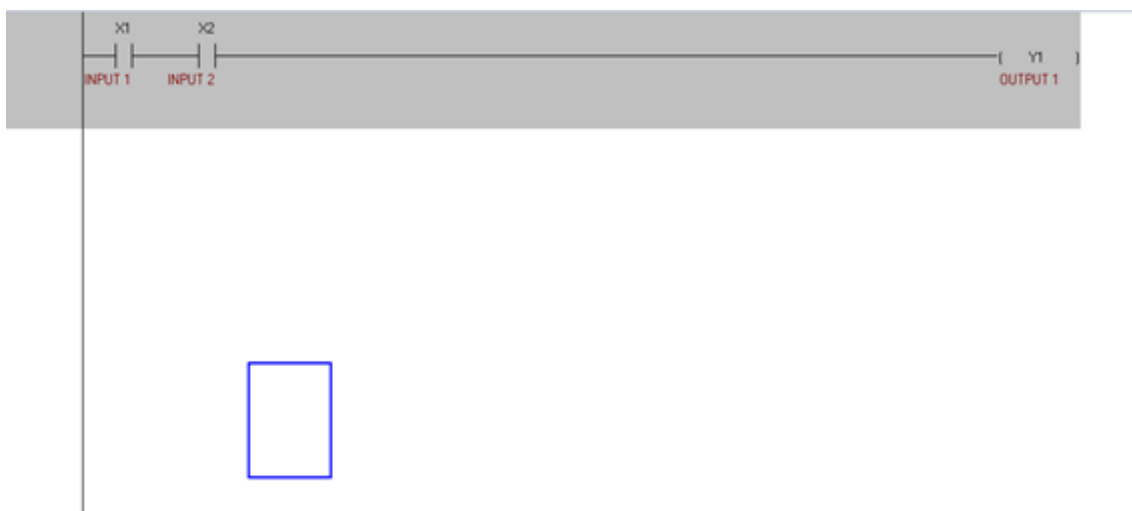


Figure 11.2 Ladder Logic For AND gate In PLC

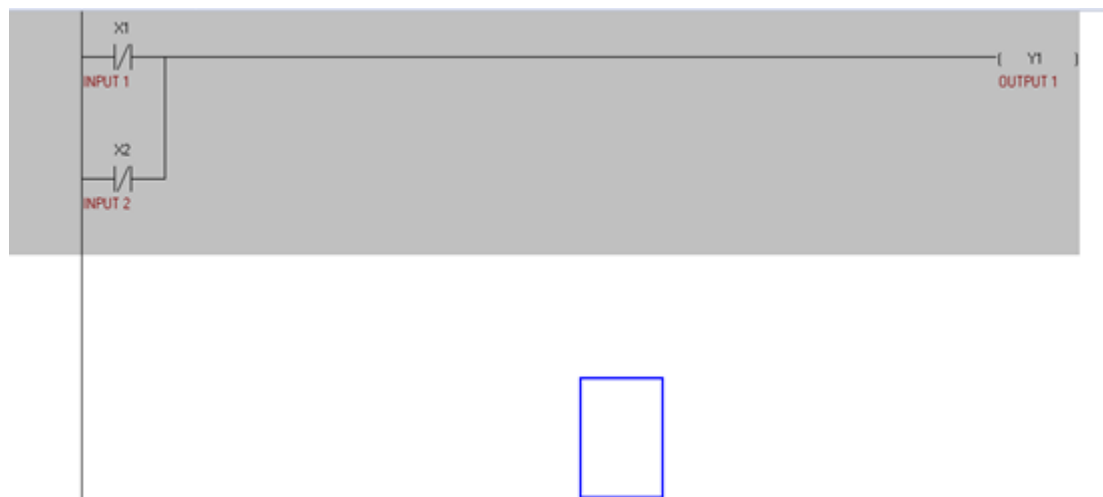


Figure 11.3 Ladder Logic for NAND gate In PLC

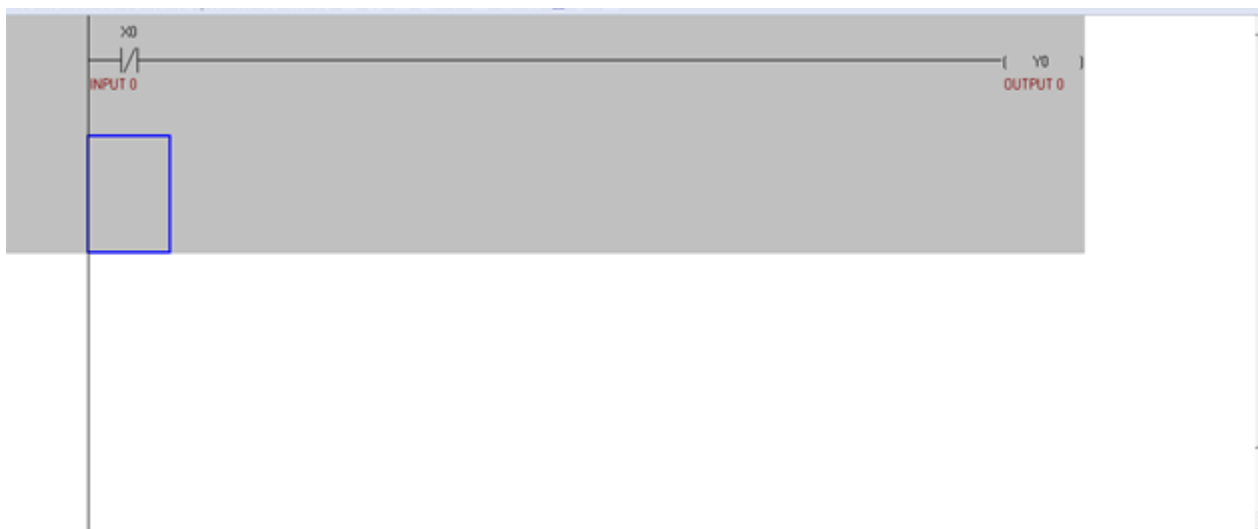


Figure 11.4 Ladder Logic for NOT gate in PLC

11.4 PROCEDURE:

- 1 Click on the WPL soft
- 2 Goto File→New , a window appears on your screen, select required PLC model→SS2→given the file name and program title.
- 3 After selecting the appropriate PLC model, you will get two windows , one ladder diagram mode and other one is instruction list mode.
- 4 Now users has to choose the editing mode of their interests to proceed with the program editing.
- 5 Select ladder diagram mode and enter the ladder logic in the ladder diagram mode using ladder tool bar provided NC,NO contacts.
- 6 Select simulator icon from WPL bar and compile the code set the program to online (or) offline mode.
- 7 Dump the program from PC to PLC using icon provided on WPL bar.
- 8 Run the program.

11.5 RESULT:

11.6 PRE LAB VIVA QUESTIONS

1. What is PLC?
2. Write down two advantages of PLC.
3. Differentiate between normally ON and normally OFF switch.
4. Distinguish between Timers and counters.
5. What is Latches?

11.7 POST LAB VIVA QUESTIONS:

1. What is the function of MCR (Master Control Relay)?
2. Where in the PLC memory is each timer storing its data?
3. How does the operation of an OFF -delay timer differ from that of an on-delay timer?
4. How does each type of timer get reset back to zero?
5. How long of a time period can a timer time? What is the maximum “count” value for a timer?

EXPERIMENT - 12

IMPLEMENTATION OF COUNTER

12.1 AIM:

To implement a counter using Programmable logic control.

12.2 APPARATUS:

S. NO	Name of Equipment	Quantity
1	PLC trainer kit	1
2	PC installed with WPL SOFT	1

12.3 CIRCUIT DIAGRAM

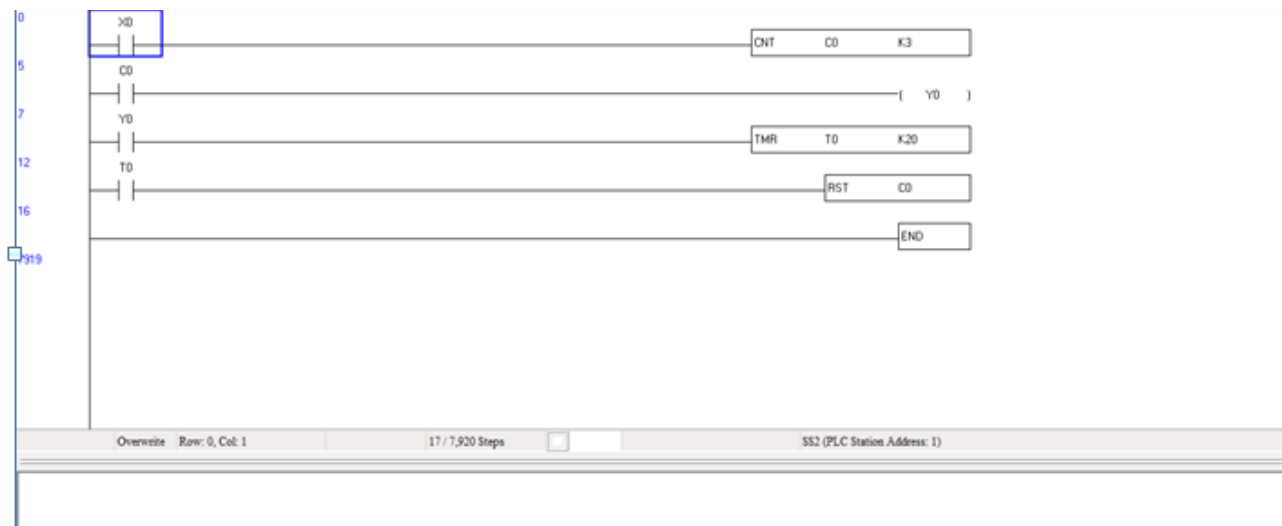


Fig.12.1. Ladder diagram of counter

12.4 PROCEDURE

1. Click on the WPL soft
2. Goto File→New , a window appears on your screen, select required PLC model→SS2→given the file name and program title.
3. After selecting the appropriate PLC model, you will get two windows , one ladder diagram mode and other one is instruction list mode.
4. Now users has to choose the editing mode of their interests to proceed with the program editing.
5. Select ladder diagram mode and enter the ladder logic in the ladder diagram mode using ladder tool bar provided NC,NO contacts.
6. Select simulator icon from WPL bar and compile the code set the program to online (or) offline mode.
7. Dump the program from PC to PLC using icon provided on WPL bar.
8. Run the program.

12.6 RESULT:

EXPERIMENT - 13

BLINKING LIGHTS USING PLC

13.1 AIM:

To implement a ladder logic for blinking of lights using plc

13.2 APPRATUS:

S. No.	Equipment	Quantity
1	Delta make plc trainer kit	1
2	PC installed with WPL Soft	1
3	RS232 cable	1

13.3 CIRCUIT DIAGRAM:

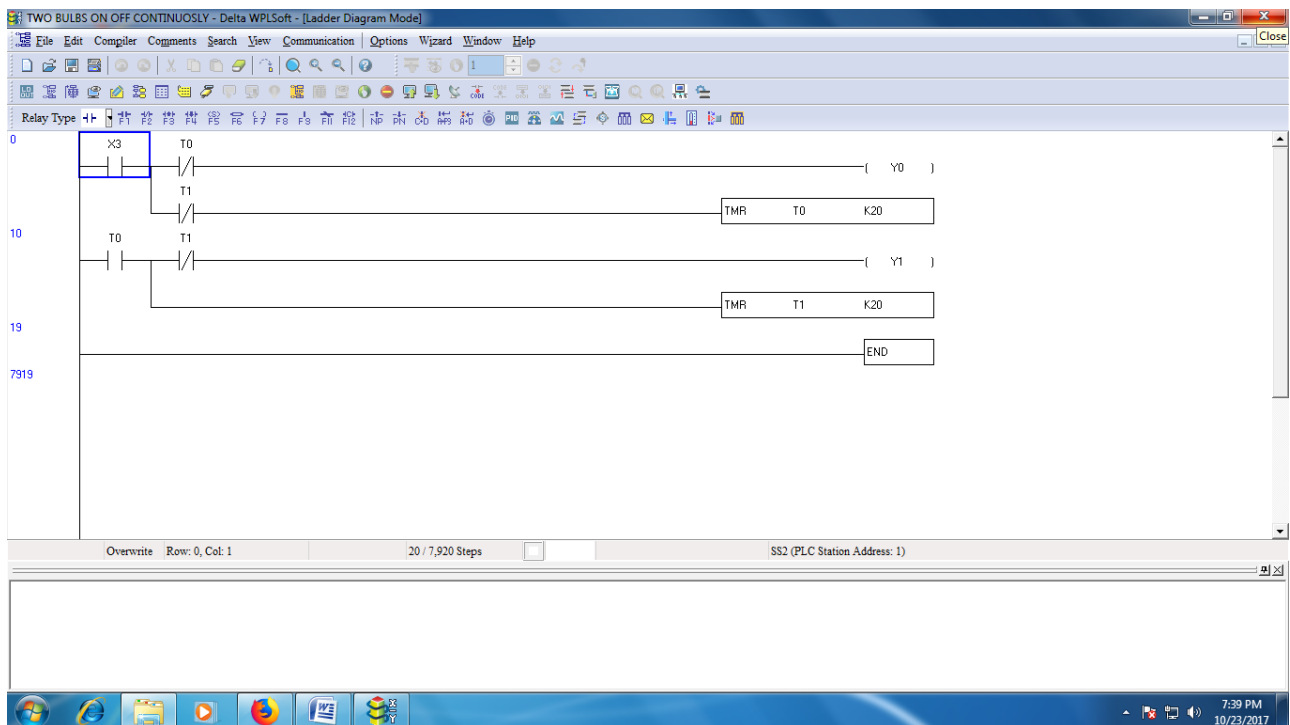


Figure 13.1 Ladder diagram for Blinking of two lights continuously

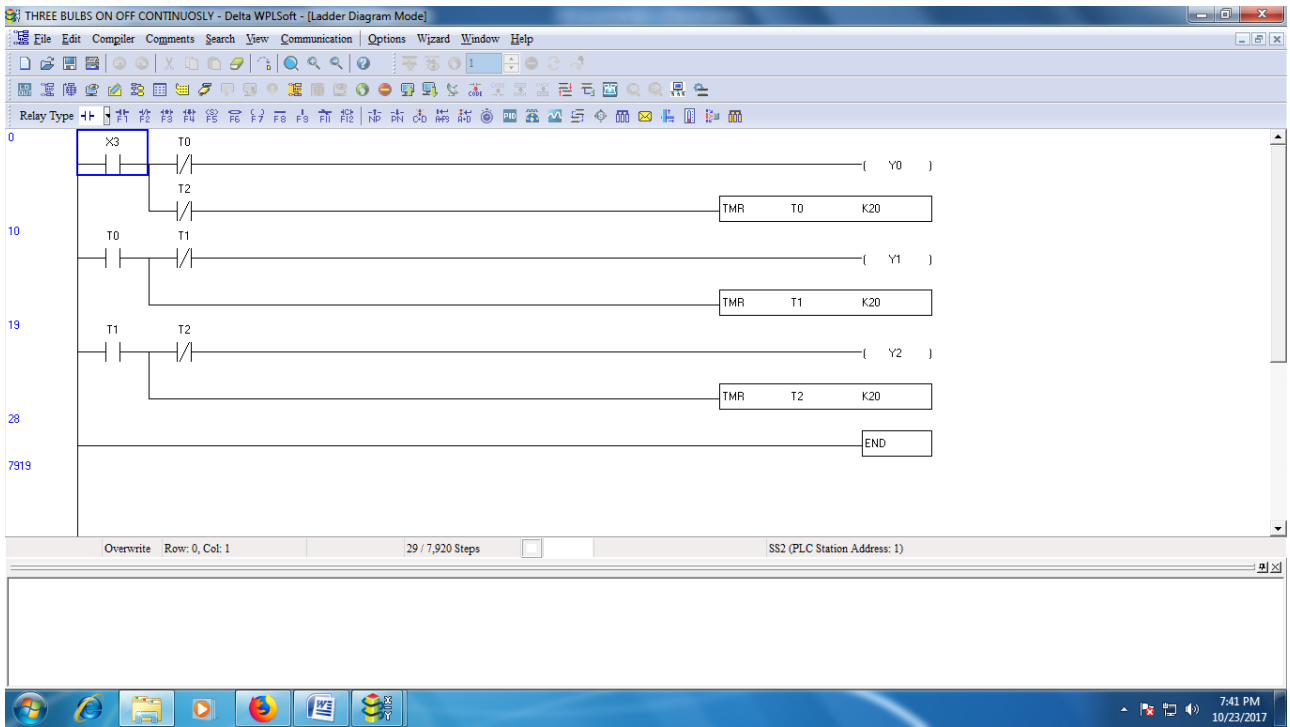


Figure 13.2 Ladder diagram for Blinking of three lights continuously

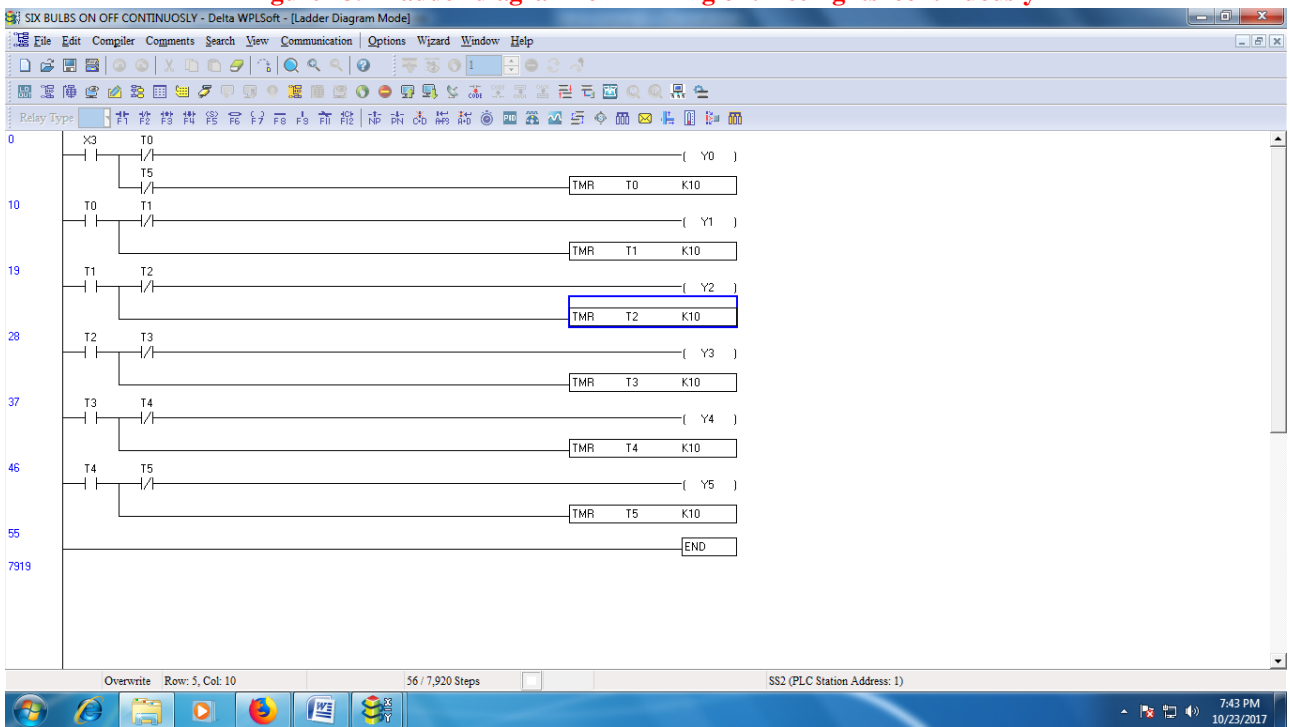


Figure 13.3 Ladder diagram for Blinking of six lights continuously

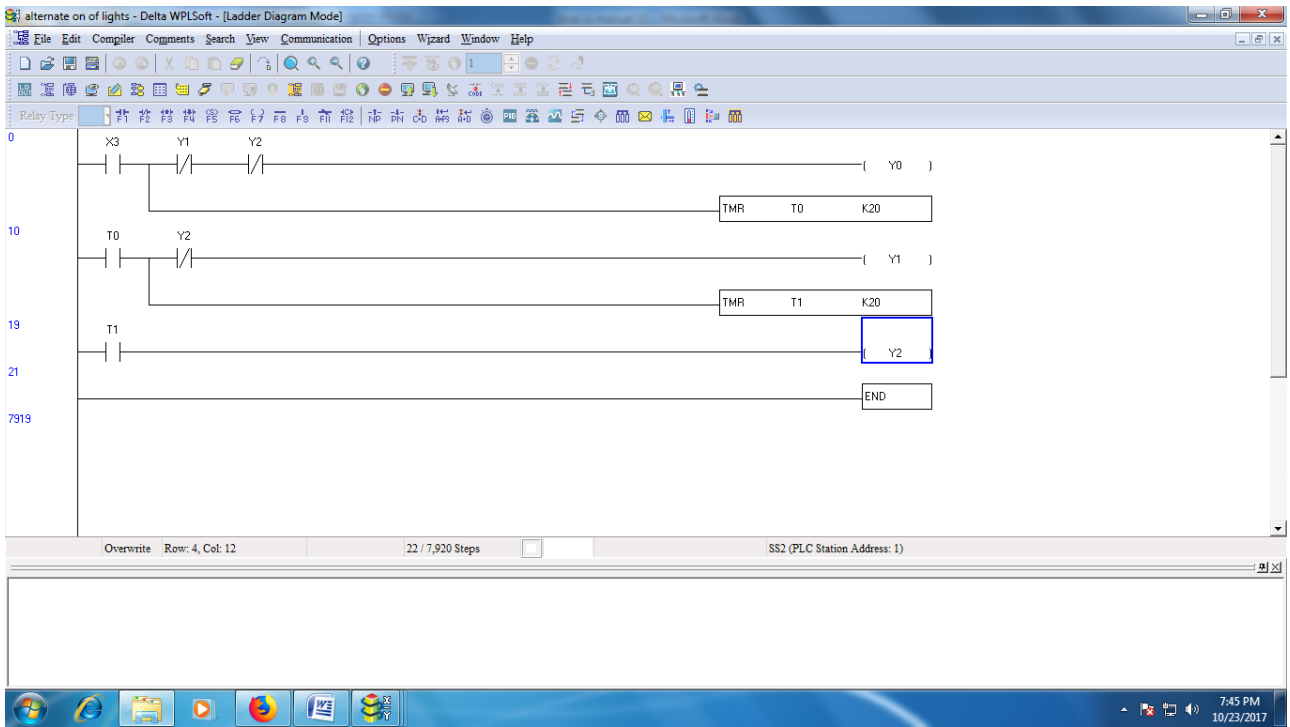


Figure 13.3 Ladder diagram for alternate blinking of three lights with two timers

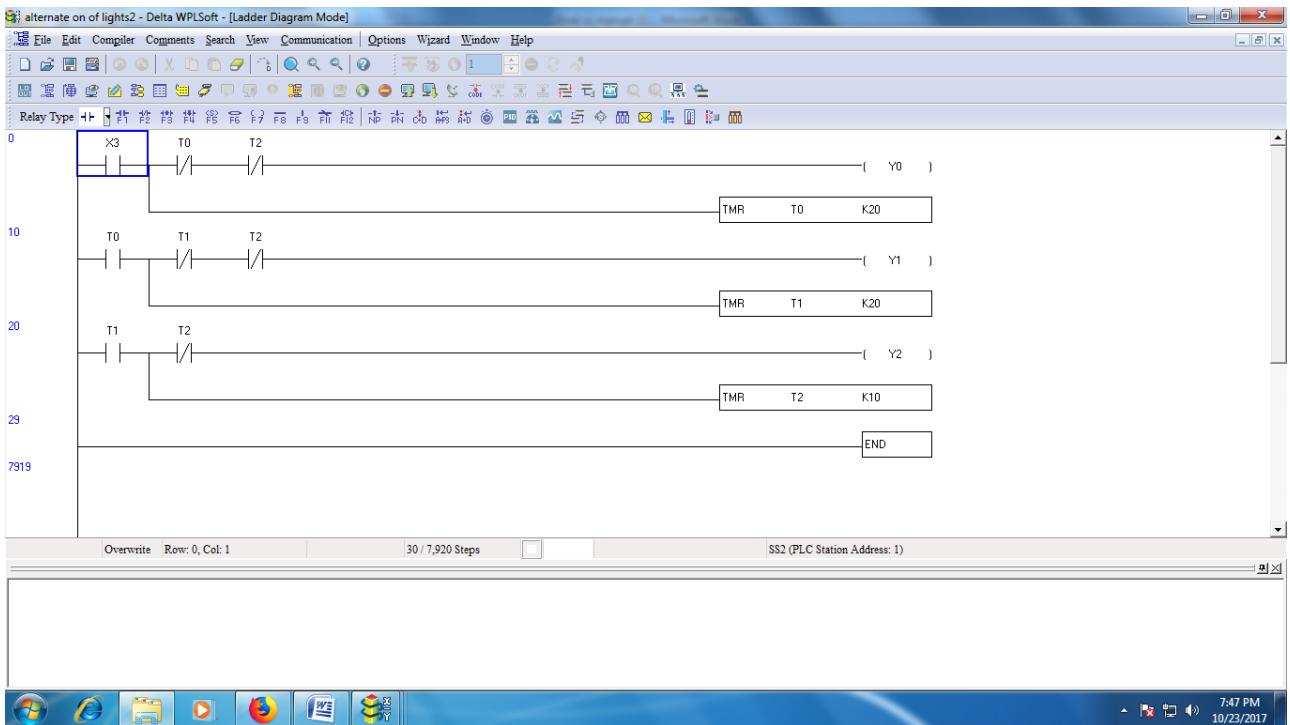


Figure 13.4 Ladder diagram for alternate blinking of three lights with three timers

CONTROL PURPOSE:

Turning on/off the lights and alternately for 20 sec when the switch is turned ON.

Turning off all color lights when the switch is turned off.

13.3 PROCEDURE:

- 1 Click on the WPL soft
- 2 Goto File→New, a window appears on your screen, select required PLC model→SS2→given the file name and program title.
- 3 After selecting the appropriate PLC model, you will get two windows , one ladder diagram mode and other one is instruction list mode.
- 4 Now users has to choose the editing mode of their interests to proceed with the program editing.
- 5 Select ladder diagram mode and enter the ladder logic in the ladder diagram mode using ladder tool bar provided NC,NO contacts.
- 6 Select simulator icon from WPL bar and compile the code set the program to online (or) offline mode.
- 7 Dump the program from PC to PLC using icon provided on WPL bar.
- 8 Run the program.

13.5 RESULT:

]

EXPERIMENT - 14
WATER-LEVEL CONTROL USING PLC

14.1 AIM:

To Control water-level using Programmable Logic Controller

14.2 APPRATUS:

S. No.	Equipment	Quantity
1	Delta make plc trainer kit	1
2	PC installed with WPL Soft	1
3	RS232 cable	1

14.3 THEORY

A simplified approach for speed control of a separately excited DC motor using Programmable Logic Controller (PLC) is presented. This approach is based on providing a variable dc voltage to armature circuit of dc motor from a fixed dc supply voltage via a PLC which is used as a dc/dc chopper.

The methods of speed control of DC motors are normally simpler and less expensive than that of ac drives. Due to the commutators, dc motors are not suitable for very high speed applications and require more maintenance than ac motors. Controlled rectifiers provide a variable dc output voltage from a fixed ac voltage, whereas choppers can provide a variable dc voltage from a fixed dc voltage. Due to their ability to supply a continuously variable dc voltage, controlled rectifiers and dc choppers made a revolution in modern industrial control equipment and variable-speed drives. A Programmable Logic Controller (PLC) is an industrially hardened computer-based unit that performs discrete or continuous control functions in a variety of processing plant and factory environments. In the world of control, the use of PLC is ever increasing. Industrial process control is one of the very important areas where the PLC is extensively used.

LADDER CIRCUIT

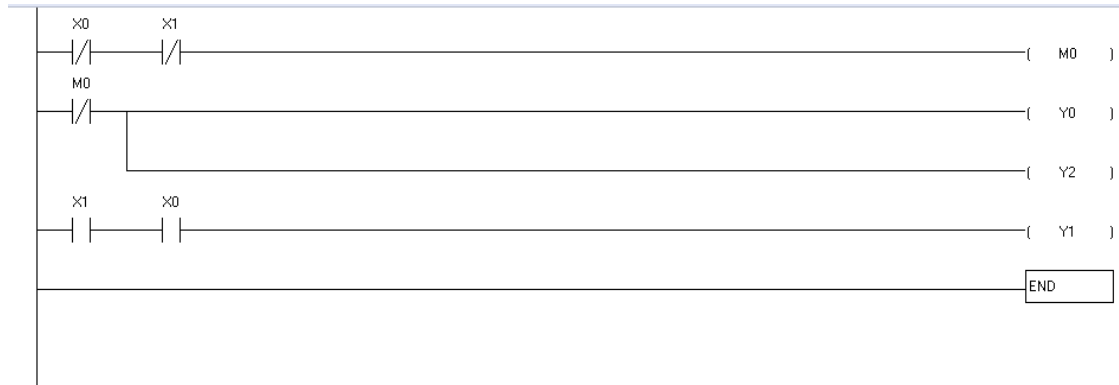


Fig 14.1 Ladder Diagram

14.4 PROCEDURE:

- 1 Click on the WPL soft
- 2 Goto File→New , a window appears on your screen, select required PLC model→SS2→given the file name and program title.
- 3 After selecting the appropriate PLC model, you will get two windows , one ladder diagram mode and other one is instruction list mode.
- 4 Now users has to choose the editing mode of their interests to proceed with the program editing.
- 5 Select ladder diagram mode and enter the ladder logic in the ladder diagram mode using ladder tool bar provided NC,NO contacts.
- 6 Select simulator icon from WPL bar and compile the code set the program to online (or) offline mode.
- 7 Dump the program from PC to PLC using icon provided on WPL bar.
- 8 Run the program.

14.5 RESULT:

ABOUT PLC

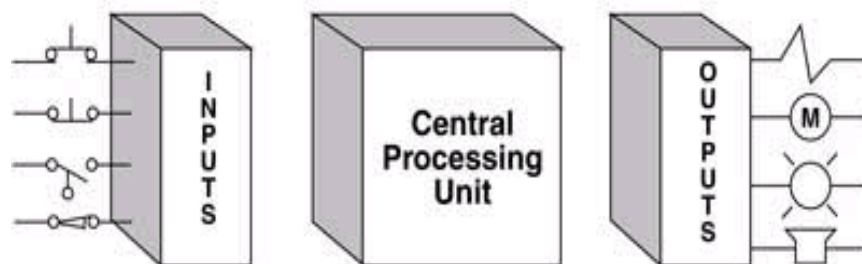
PROGRAMMABLE LOGIC CONTROLLERS(PLC)

Programmable Logic Controllers (PLCs) are most widely used robust industrial controllers which are capable of delivering automatic control functions based on input from sensors. It consists of various modules like CPU, analog I/O, digital I/O and communication modules. It allows the operator to program a control function or strategy to perform certain automatic operation on process. The plc is being used in many automation processes and several areas of industries. The main task involved with the PLC is the controlling of any operation which is acquired through programming. Its usage is noticed in areas like envelope monitoring, machines protection, smoke detection, system interlocking indicators etc.

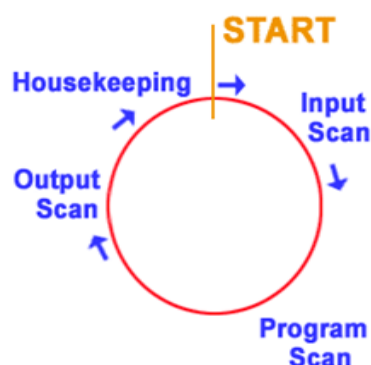
Inside PLC:

The Central Processing Unit, the CPU, contains an internal program that tells the PLC how to perform the following functions:

- Execute the Control Instructions contained in the User's Programs. This program is stored in "non-volatile" memory, meaning that the program will not be lost if power is removed
- Communicate with other devices, which can include I/O Devices, Programming Devices, Networks, and even other PLCs.
- Perform Housekeeping activities such as Communications, Internal Diagnostics, etc.



There are four basic steps in the operation of all PLCs; Input Scan, Program Scan, Output. These steps are continually processed in a loop Scan, and Housekeeping. These steps continually take place in a repeating loop.



Four Steps In The PLC Operations:

1.Input Scan

Detects the state of all input devices that are connected to the PLC

2.Program Scan

Executes the user created program logic

3.Output Scan

Energizes or de-energize all output devices that are connected to the PLC.

4. Housekeeping

This step includes communications with programming terminals, internal diagnostics, etc.

Programming Language is Used to Program A PLC?

While Ladder Logic is the most commonly used PLC programming language, it is not the only one. Ladder Diagram (LD) Traditional ladder logic is graphical programming language. Initially programmed with simple contacts that simulated the opening and closing of relays, Ladder Logic programming has been expanded to include such functions as counters, timers, shift registers, and math operations. The following table lists of some of languages that are used to program a PLC.

What Are Input/Output Devices?

INPUTS	OUTPUTS
Switches and Pushbuttons	Valves
Sensing Devices	Motor Starters
Limit Switches	Solenoids
Photoelectric Sensors	Acuators
Proximity Sensors	Horns and Alarms
Level Switches	Stack lights
Temperature Switches	Counter/Totalizer
Vacuum Switches	Pump
Float Switches	Printers and Fans

What do I need to Consider When Choosing A PLC?

There are many PLC systems on the market today. Other than cost, you must consider the following when deciding which one will best suit the needs of your application.

- Will the system be powered by AC or DC voltage?
- Does the PLC have enough memory to run my user program?
- Does the system run fast enough to meet my application's requirements?
- What type of software is used to program the PLC?
- Will the PLC be able to manage the number of inputs and outputs that my application requires?
- If required by your application, can the PLC handle analog inputs and outputs, or maybe a combination of both analog and discrete inputs and outputs?
- How am I going to communicate with my PLC?
- Do I need network connectivity and can it be added to my PLC?

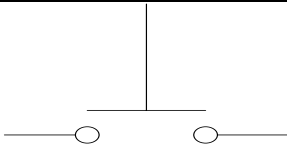
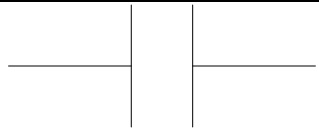
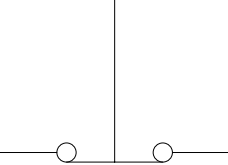
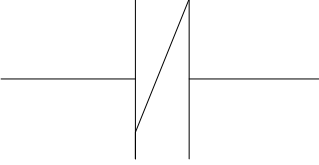
- Will the system be located in one place or spread out over a large area?

PLC Acronyms

The following table shows a list of commonly used Acronyms that you see when researching or using your PLC.

ASCII	American Standard Code for Information Interchange
BCD	Binary Coded Decimal
CSA	Canadian Standards Association
DIO	Distributed I/O
EIA	Electronic Industries Association
EMI	Electro Magnetic Interference
HMI	Human Machine Interface
IEC	International Electro technical Commission
IEEE	Institute of Electrical and Electronic Engineers
I/O	Input(s) and/or Output(s)
ISO	International Standards Organization
LL	Ladder Logic
LSB	Least Significant Bit
MMI	Man Machine Interface
MODICON	Modular Digital Controller
MSB	Most Significant Bit
PID	Proportional Integral Derivative (feedback control)
RF	Radio Frequency
RIO	Remote I/O
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
TCP/IP	Transmission Control Protocol / Internet Protocol

Representation of electrical circuit symbol in ladder diagram contact:

Electrical circuit symbol	Ladder diagram contact	Comment
		NO contact
		NC contact