T.Y. Diploma : Sem. V
[ET/EN/EX/EJ/DE/ED/EI]

Control System & PLC

Time: 3 Hrs.] Prelim Question Paper Solution [Marks : 100

Q.1 (a) Attempt any THREE of the following : [12]

Q.1 (a) (i) Compare open loop and close loop control system. [4]

(A)

	Open Loop Control System	Close Loop Control System
(i)	It is simple and economical.	It is complex and costlier.
(ii)	It is easier to construct, as it requires less number of components.	It is not easy to construct, as it requires more number of components.
(iii)	It consumes less power.	It consumes more power.
(iv)	It is more stable.	It is less stable.
(v)	It does not require feedback path element.	It requires feedback path element.
(vi)	It has poor accuracy.	It has better accuracy.
(vii)	It does not give automatic correction for external disturbances.	It gives automatic correction for external disturbances.
(viii)	It is more sensitive to noise.	It is less sensitive to noise.
(ix)	It is dependent on operating condition.	It is not dependent on operating conditions.
(x)	Its operation is degraded if non linearity are present.	Its operation is not independent on conditions.
(xi)	It has slow response.	It has fast response.
(xii)	It has high bandwidth.	It has low bandwidth.

Q.1 (a) (ii) State the advantages of PLC. [4]

(A) Advantages of PLC:

- Reduce human efforts.
- Maximum efficiency through machine and logic is controlled by human.
- Higher productivity.
- Superior quality of end products.
- Efficient uses of energy and raw material.
- Eliminate the high costs associated with inflexible, relay-controlled systems.
- Improved safety in working conditions.
- Easily programmed and have an easily understood programming language.

Q.1 (a) (iii) Consider a system with characteristic equation [4]

$$S^5 + 2S^4 + 2S^3 + 4S^2 + 11S + 10 = 0$$

Determine stability using Routh's criteria.

(A) (i) Firstly Find even and odd coefficient from characteristics equation.

$$S^5 + 2.S^4 + 2.S^3 + 4.S^2 + 11.S + 10 = 0$$

(ii) The routh's array for above characteristics equation is formed as follows

S^5	1	2	11	
S^4	2	4	10	
S^3	0	6	0	Special case
S^2	∞	10		
S^1				
S^0				

Substitute a small positive number ε in place of 0 occurred as first element in a low. Complete the array with this number ε. The examine the sign change by taking $\lim_{\varepsilon \to \infty}$

S^5	1	2	11
S^4	2	4	10
S^3	ε	6	0
S^2	$4\varepsilon - 12/\varepsilon$	10	0
S^1	$\dfrac{\left(24\varepsilon - 72 - 10\varepsilon^2\right)}{4\varepsilon - 12}$	0	0
S^0	10	0	0

To examine sign change

$\lim\limits_{\varepsilon\to\infty} 4\varepsilon - 121\varepsilon$ =8

$\lim\limits_{\varepsilon\to\infty}\left(24\varepsilon - 7\varepsilon - 10\varepsilon\hat{}2\right) / 4\varepsilon - 12$ =6

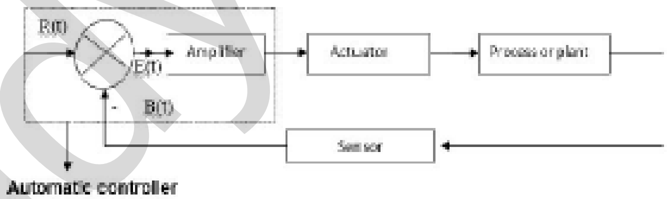
So final Array is

S^5	1	2	11
S^4	2	4	10
S^3	ε	6	0
S^2	∞	10	0
S^1	6	0	0
S^0	10	0	0

Routh's stability criteria states that the elements of 1st column of Routh's array should not have any sign change for the system to be stable. The number of sign changes in the 1st column indicates the number of Poles on RHS which makes the system unstable. Here, No sign changes in the 1st column indicate system is stable.
(Note : Alternative method of Rouths Array by replacing S with 1/Z in the original equation also can be considered n.)

Q.1 (a) (iv) Draw block diagram of process control system. Explain the function of each block. **[4]**

(A)



Explanation : Process control System consists of process or plant, sensor, error detector, automatic Controller, actuator or control element.

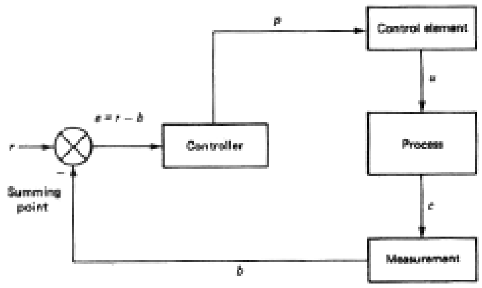
(i) Process or plant : Process means some manufacturing sequence. It is one variable or multivariable output. Plant or process is an important element of process control system in which variable of process is to be controlled.

(ii) Sensor measuring elements : It is the device that converts the output variable into another suitable variable which can acceptable by error detector Sensor is present in F/b path of close lop system.

(iii) Error detector : Error detector is he subtracting summing points whose output is an error signal i.e. e(t) = r(t) to controller for comparison and for the corrective action. Error detector compares between actual signal and reference i/p i.e. set point.

(iv) Automatic Controller : Controller detects the actuating error signal, which is usually at a very low power level, and amplifies it to a sufficiently high level i.e. means automatic controller comprise an error detector and amplifier.

(v) Actuator or control element : Actuator is nothing but pneumatic motor or value, a hydraulic motor or an electric motor, which produces an input to the plant according to the control signal getting from controller.



Explanation : The block diagram of process control system consists of following blocks:–

(i) Measuring element : It measure or senses the actual value of controlled variable "c" and converts it into proportional feedback variable b.

(ii) Error detector : It receives two inputs: set point "r" and controlled variable "p". The output of the error detector is given by e = r − b. "e" is applied to the controller.

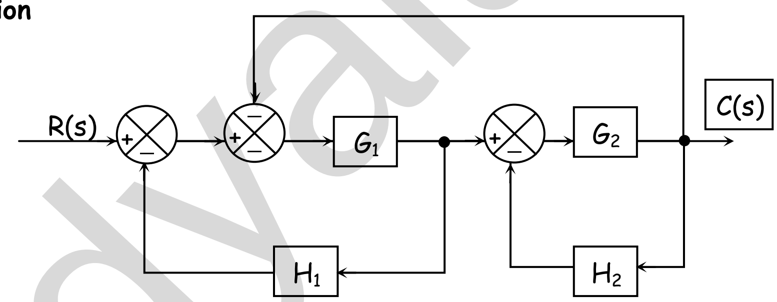
(iii) Controller : It generates the correct signal which is then applied to the final control element. Controller output is denoted by "p".

(iv) Final control element : It accepts the input from the controller which is then transformed into some proportional action performed by the process. Output of control element is denoted by "u".

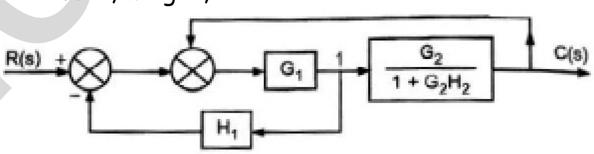
(v) Process : Output of control element is given to the process which changes the process variable. Output of this block is denoted by "u".

Q.1(b) Attempt any ONE of the following : **[6]**

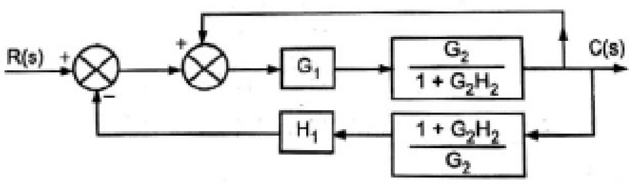
Q.1(b) (i) Derive transfer function of block diagram shown in fig. using block diagram reduction



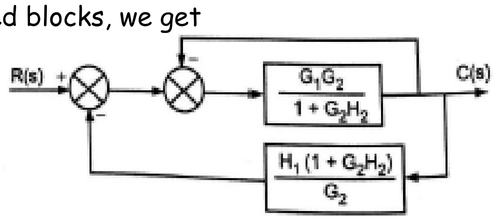
(A) (i) Combining block G2 & H2, we get,



(ii) Shifting take off point '1' after $\frac{G2}{1+G2.H2}$ block we get,



(iii) Combining two cascaded blocks, we get

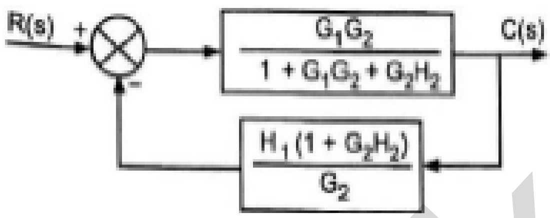


(iv) Salving unit negative feedback loop i.e. H(s) = 1

$$\frac{\frac{G_1G_2}{1+G_2H_2}}{1+\frac{G_1G_2}{1+G_2H_2}} = \frac{G_1G_2}{1+G_2H_2} \times \frac{1+G_2H_2}{1+G_1G_2+G_2H_2}$$

$$= \frac{G_1G_2}{1+G_1G_2+G_2H_2}$$

(v) After eliminating unity feedback loop we get,



(vi) Salving two blocks in parallel we get,

Where, $G(S) = \frac{1+G_1G_2}{1+G_1G_2+G_2H_2}$

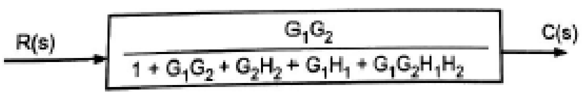
$H(S) = \frac{H_1(1+G_2H_2)}{G_2}$

$$\frac{G(S)}{1+G(S)\cdot H(S)} = \frac{\frac{G_1G_2}{1+G_1G_2+G_2H_2}}{1+\left(\frac{G_1G_2}{1+G_1G_2+G_2H_2}\right)\cdot\left(\frac{H_1+H_1H_2G_2}{G_2}\right)}$$

$$= \frac{\frac{G_1G_2}{1+G_1G_2+G_2H_2}}{\frac{1+G_1G_2+G_2H_2+G_1H_1+G_1G_2H_1H_2}{(1+G_1G_2+G_2H_2)}}$$

$$= \frac{G_1G_2}{1+G_1G_2+G_2H_2+G_1H_1+G_1G_2H_1H_2}$$

(vii)Thus, combining two parallel blocks we get,



Q.1(b) (ii) Explain the memory organization of PLC. **[6]**

(A) Different types of memory that are generally used in PLC s are as follows:

(1) RAM :

(2) ROM: A) EPROM B) EEPROM

In PLC program instructions are stored in the memory.

An internal communication high way also known as a bus system, carries information to and fro from the CPU, Memory and I/O units under the control of CPU Memory unit for storage of program.

The user ladder logic program, is in the memory of PLC.

The main program and other programs are necessary for operation of PLC.

The organization of the data and information in the memory is called memory map There are two types of memory used in PLC: Volatile and non volatile memory , in non volatile memories are generally used for storing user program so that the programs can return during power failure.

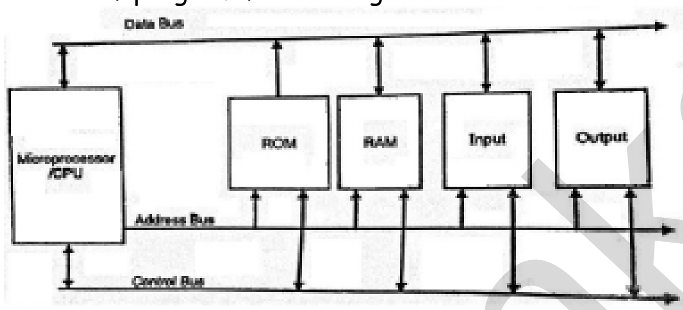
OR

Memory is classified into two types:

1. Storage memory: in storage memory store information on the status of i/o devices, pre assigned value of internal relay status and values for mathematical functions, this is called a data table or register table and stores information in two types: status and numbers,.
Status is stored in the form of ON or OFF and nos are stored in the form of

(i) "s and 0"s is unique bit of memory.

(ii) User memory: in this memory, ladder logic programming is carried out and stored.
User memory consists of program files or register table and holds the complete operation.



Q.2 Attempt any TWO of the following : [16]

Q.2(a) For unity feedback system having open loop transfer function [8]

$$G(S) = \frac{K(S+2)}{S(S^3+7S^2+12S)}$$

Find : (i) Type of system

(ii) All error coefficients

(iii) Steady state error for input r(t) = R/2.t^2

(A) (i) As H(S) = 1, so G(S).H(S) $= \frac{K(S+2)}{S^2(S^2+7S+12)} = \frac{K(S+2)}{S^2(S+4)(S+3)}$

Consider the first term in the S^2 denominator. This gives (n = 2) poles at origin of s-plane. So it is Type 2 system

(ii) Positional error coefficient (K_p) is given by.

$$K_p = \lim_{s\to 0} G(S)\cdot H(S)$$

$$K_p = \lim_{s\to\infty} \frac{K(S+2)}{S^2(S+4)(S+3)}$$

(iii) Velocity error coefficient (K_v) is given by,

$$K_v = \lim_{s\to\infty} s.G(S).H(S) = \lim_{s\to\infty} \frac{K(S+2)}{S(S+4)(S+3)}$$

$$K_p = \infty$$

(iv) Acceleration error coefficient (K_a) is given by,

$$K_a = \lim_{s\to\infty} S^2.G(S).H(S) = \lim_{s\to\infty} \frac{K(S+2)}{(S+4)(S+3)}$$

$$K_a = \frac{K}{6}$$

(v) Steady State Error is given as,

$$ess = \lim_{s\to\infty} \frac{s.X(s)}{1+G(s).H(s)}$$

As $x(t) = R/2.t^2$, so input is parabolic function. For parabolic function steady state error is given as,

$$Ess = R / Ka = \frac{6.R}{K}$$

Or

$X(S) = R/S^3$, we get

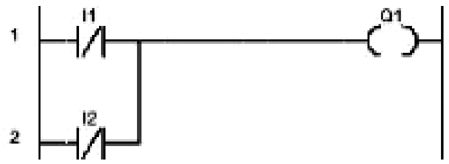
$$ess = \lim_{s\to\infty} \frac{s.X(s)}{1+G(s).H(s)} = \lim_{x\to\infty} \frac{S\frac{R}{S^3}}{1+\frac{K(S+2)}{S^2(S+4)(S+3)}}$$

$$ess = \lim_{s\to\infty} \frac{R(S+4)(S+3)}{S^2(S+4)(S+3)+K(S+2)} = \frac{6.R}{K}$$

Q.2(b) Draw ladder diagram to verify following logic gates truth table : [8]

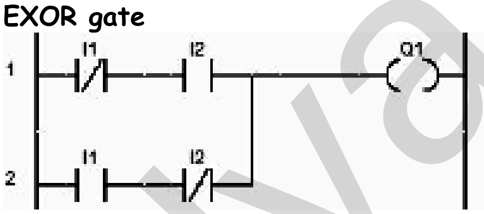
(i) NAND gate (ii) EXOR gate (iii) NOR gate (iv) AND gate

(A) (i) NAND gate



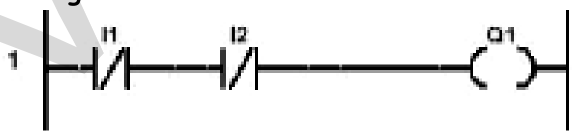
I_1	I_2	Q_1
0	0	1
0	1	1
1	0	1
1	1	0

(ii) EXOR gate



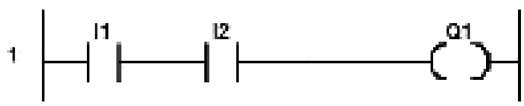
I_1	I_2	Q_1
0	0	0
0	1	1
1	0	1
1	1	0

(iii) NOR gate



I_1	I_2	Q_1
0	0	1
0	1	0
1	0	0
1	1	0

(iv) AND gate



I_1	I_2	Q_1
0	0	0
0	1	0
1	0	0
1	1	1

Q.2(c) Define the time response specifications delay time T_d, rise time T_r, setting time T_s and peak overshoot M_p. **[8]**

(A) 1. Delay Time T_d = It is the Time required for the response to reach 50 % of the final value in the first attempt it is given by

$$T_d = \frac{1+0.7\zeta}{w_n}$$

2. Rise time Tr= It is the time required for the response to rise from 10% to 90% of the final value for overdamped systems & 0 to 100 % of the final value for under damped systems. It is given by

$$T_r = \frac{\pi-\theta}{w_d}$$

where θ must be in radian

3. Setting Time T_s = This is defined as the time required for the response to decrease and stay within specified % of its final value.

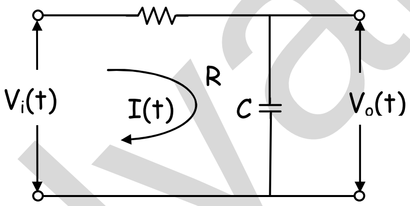
$$T_s = \frac{4}{\zeta w_n}$$

4. Peak overshoot Mp = it is the largest error between reference input and output during the transient period.

Q.3 Attempt any FOUR of the following : **[16]**

Q.3(a) Derive transfer function of RC Network. **[4]**

(A)



- Transfer function of the circuit is defined as,

$$L\frac{\{Output\}}{\{Input\}} = \frac{L\{V_o(t)\}}{L\{V_i(t)\}} = \frac{V_o(s)}{V_i(s)}$$

From figure apply KVL to input loop we get,

$$V_i(t) = R_i(t) + \frac{1}{C}\int i(t)dt$$

$$V_o(t) = \frac{1}{C}\int i(t)\,dt$$

- Neglecting initial conditions, taking Laplace of V_i (t) and V_o (t) we get,

$$V_i(s) = R \cdot I(s) + \frac{1}{sC}\cdot I(s)$$

$$V_o(s) = \frac{1}{sC}\cdot I(s)$$

$$I(s) = sC \cdot V_o(s)$$

Substituting value of I(s) in Equation (1.6.9) we get,

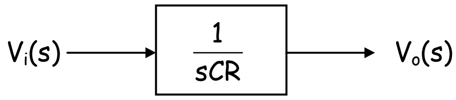
$$V_i(s) = R \cdot sC \cdot V_o(s) + V_o(s)$$

$$V_i(s) = V_0(s)\,[1 + sCR]$$

$$\frac{V_o(s)}{V_i(s)} = \frac{1}{[1 + sCR]}$$

Where RC is a time constant

- The above system can be represented as shown below,



Q.3(b) Draw block diagram of servo system. State function of its component. [4]

(A) Servo system is one type of feedback control system in which control variable is the mechanical load position and its time derivatives like velocity and acceleration.

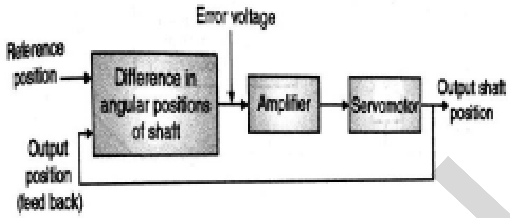


Fig. : Standard block diagram of Servo system

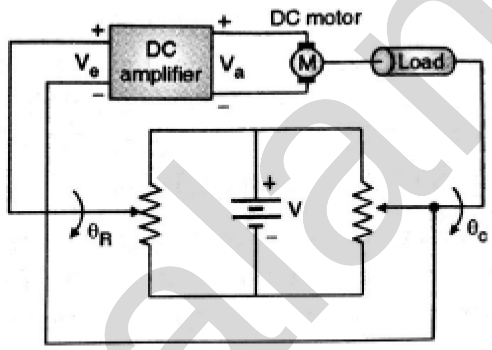


Fig. : DC Servo system

Explanation :

- The standard block diagram of servo system consists of error detector, amplifier, motor as controller, load whose position is to be changed.
- Servo systems is to be divided into two type
  (a) DC servo system (b) AC servo system
- DC servo system consists of potentiometer as a error detector, DC amplifier, DC motor, DC gear system and the DC load whose position is to be changed.
- In DC servo system potentiometer has two input i.e one is reference input and another is actual load position. Potentiometer finds the error between two positions.
- The errors between two positions is given to DC amplifier which amplify the error.
- Output of DC amplifier is given to DC motor &finally DC motor change the position of DC load. In this way servo system is used to change the load position with help of motor &error detector.

Q.3(c) Define the terms: [4]

(i) Stable system **(ii) Unstable system**

(iii) Critical stable system **(iv) Conditionally stable system**

(A) **(i) Stable system** : A linear time invariant system is said to be stable if following conditions are satisfied :

(1) When the system is excited by a bounded input, output is also bounded and controllable.

(2) In the absence of the input, output must tend to zero irrespective of the initial condition.

(ii) Unstable system : A linear time invariant system is said to be unstable if following conditions are satisfied :
(1) If for a bounded input it produces unbounded output.
(2) In absence of the input, output may not return to zero it shows certain output without input.

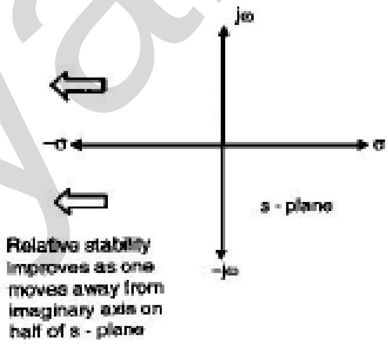
(iii) Critical stable system : A linear time invariant system is said to be critically stable if for a bounded input its output oscillates with constant frequency and amplitude.

(iv) Conditionally stable system : A linear time invariant system is called as conditionally stable system if the stability of system depends on certain conditions of parameters of the system.

Q.3(d) Define : (i) Stability (ii) Relative stability [4]

(A) (i) Stability :
- The system is said to be stable if it produces bounded output for a bounded input.
- It is used to define usefulness of the system.
- The stability implies that the system performance should not change even if there is small change in system input. Any control system must be stable.
- The system is said to be stable if poles of closed loop TF of the system lies in left half of s-plane.
- The system is said to be unstable if poles closed loop TF of the system lies in right half of s-plane.

(ii) Relative stability :
- It is a quantitative measure of how fast the transient die out in the system.
- Relative stability may be measured by relative settling times of each root or pair of roots.
- The settling time of a pair of complex conjugate poles is inversely proportional to the real part of the root.
- As the root moves further away from the imaginary axis the relative stability of the system improves.



Relative stability improvement area.

Q.3(e) Define scan time of PLC. Explain the significance of scan time. [4]

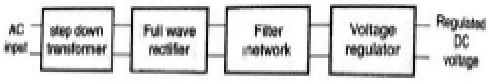
(A) Scan time :
- The time taken by PLC to get from one I/O update to the next is marks known as PLC scan time.
- It is typically measured in milliseconds (ms).
- PLC scan time depends on number of inputs, output and program size (total memory used.).
- So it may be different for different program (PLC).

Significance :
- Less scan time means faster PLC action.
- It indicates the speed of CPU.
- It indicates the speed of execution.

Q.4(a) Attempt any THREE of the following : [12]

Q.4(a) (i) Draw block diagram of PLC power supply. State functions of its component. [4]

(A)



Block diagram of power supply

Description :

- The power supply of PLC consists of step down transformer which operates with 120V AC input followed by rectifier circuit which converts the AC input to pulsating DC, this signal is filtered with filter circuit. Specific DC voltage level is achieved by regular circuit.
- Power supply unit provides specific power to different parts of the PLC. In most of the PLC power supply is inbuilt structure of sometime it may separate module, each rack must have its own power supply.
- PLC power supply converts the AC voltage supply which is usually 115 V AC or 240V AC, into low level DC voltage which is required for different parts of PLC like I/O module, CPU.

Q.4(a) (ii) Explain ON/OFF delay timer instruction with diagram. [4]

(A) Depending on the time delay ad operation there are two types of timers

PLC timer – (i) ON delay timer

(ii) OFF delay timer

On Delay timer

- This instruction counts time interval when conditions preceding it in the rung are true. Produces an output when accumulated reaches the preset value.
- Use Ton instruction to turn an output on or off after the timer has been on for a preset time interval. The Ton instruction begins to count time base intervals when the rung conditions become true.
- The accumulated value is reset when the rung condition go false regardless of whether the timer has timed out

Instruction parameter– Timer TON is 3 word element.

	15	14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	
word 0	TT/EN	TT/EN DN	16 bit
word 1	preset value		16 bit
word 2	Accumulator value		16 bit

Status bit explanation

(i) Timer done bit (bit 13)- DN is set when the accumulated value is equal to or greater than the preset value. It is reset when rung condition become false.

(ii) Timer enable bit (bit 14)- EN is set when rung condition are true. It is reset when rung condition become false.

(iii) Timer timing bit (bit 15)- TT is set when rung conditions are true and the accumulated value is less than the preset value. It is reset when the rung conditions go false or when the done bit is set.

OFF delay timer

- This instruction counts time interval when conditions preceding it in the rung are false. Produces low output when accumulated value reaches the preset value.
- Use Toff instruction to turn an output on or off after the timer has been off for a preset timer has been off for a preset time intervals. The Toff instruction begins to count time base intervals when the rung makes a true to false to transition.

- As long as rung conditions remains false the timer increments its accumulated value each scan until it reaches the preset value. The accumulated value is rest when the rung conditions go true regardless of whether the timer has time out.

Instruction parameter- Timer TOFF is 3 word element.

	15	14 13 12 11 10 9 8 7 6 5 4 3 2 1 0	
word 0	TT/EN	TT/EN DN	16 bit
word 1	preset value		16 bit
word 2	Accumulator value		16 bit

Status bit explanation

(i) Timer done bit (bit 13)- DN is reset when the accumulated value is equal to or greater than the preset value. It is set when rung condition are ture.

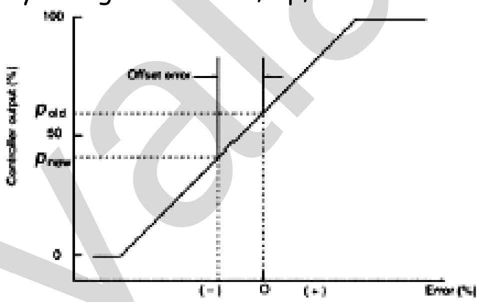
(ii) Timer enable bit (bit 14)- EN is set when rung condition are true. It is reset when rung condition become false.

(iii) Timer timing bit (bit 15)- TT is set when rung conditions are false and the accumulated value is less than the preset value. It is reset when the rung conditions go true or when the done bit is reset.

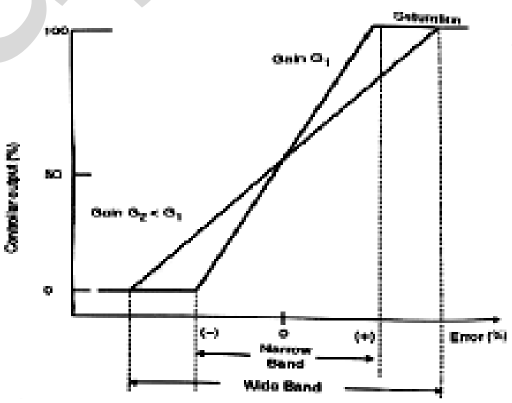
Q.4(a) (iii) Explain the offset in proportional controller. Draw the response of proportional controller. [4]

(A) Offset in proportional controller

- Proportional controller produces a permanent residual error in the operating point of the controlled variable when a change is occurring.
- This error is referred as Offset.
- It can be minimized by a larger constant, Kp, which also reduces the proportional band.



Response of proportional controller



Q.4(a) (iv) List any four specifications of AC input module. [4]

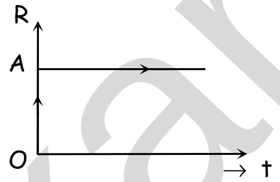
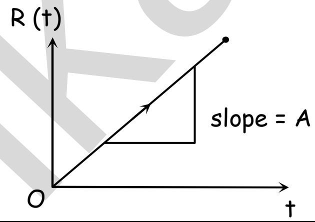
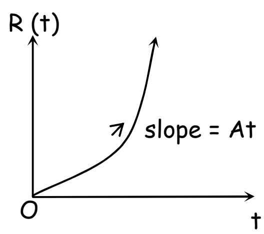
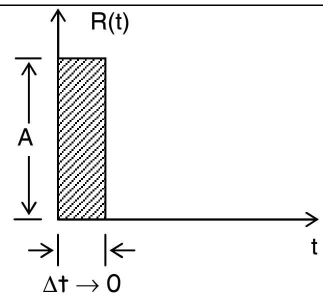
(A)

Item	Typical Value for 120/230V AC
Rated voltage and current	120V at 64mA 230V at 9 mA

Specified operational voltage range	264 V AC
Signal delay	15.0 ms ON to OFF or OFF to ON
Logic 1 minimum (Threshold values for ON and OFF conditions)	790 V AC at 2.5 mA
Logic 0 minimum (Threshold values for ON and OFF conditions)	20 V AC at 1 mA
Isolation between field to logic	1500 V AC for 1 sec.

Q.4(a) (v) Write the Laplace transform for the following input signal. **[4]**
(i) step (ii) ramp (iii) parabolic (iv) impulse

(A)

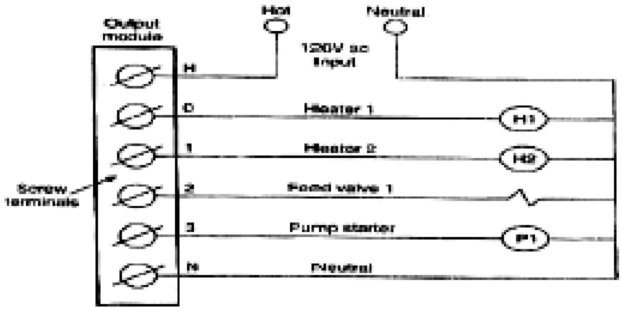
Standard test input	Laplace Representation	Waveforms
Step input (position function) r(t)	L.T of r(t) = R(s) = A/s	
Rampinput (Velocity function) r(t)	L. T of r(t) = R(s) = A/s^2	
Parabolic input (Acceleration r(t) function)	L. T of r(t) = R(s) = A/s^2	
Impulse input r(t)	L. T of r(t) = R(s) = 1 if A = 1	

Q.4(b) Attempt any ONE of the following : **[6]**

Q.4(b) (i) Describe the wiring details of AC output module of PLC with diagram. **[6]**

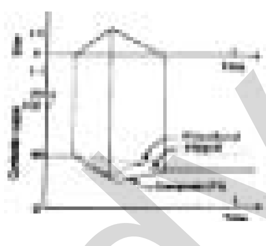
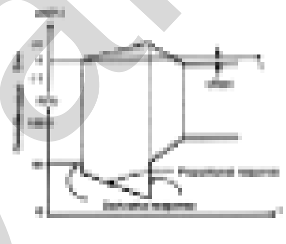
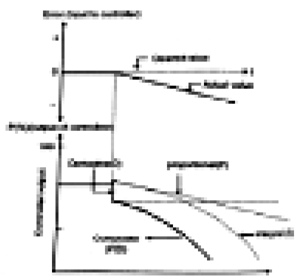
(A) The below fig show the basic field wiring for digital 120V AC output module. The Wiring diagrams show how wires of output devices are connected to screw terminals of PLC modules. As per the wiring diagram, User has to connect the wires of input and output devices to PLC or Module.

It can be thought of as a simple switch power can be provided to control the output device. During normal operation, processor sends the output state that was determined by logic diagram of output module. The module then switches the power to the field devices. A fuse is normally provided in that the output circuit of the module to prevent excessive current from damaging the wiring to the field devices.



Typical discrete output module wiring diagram

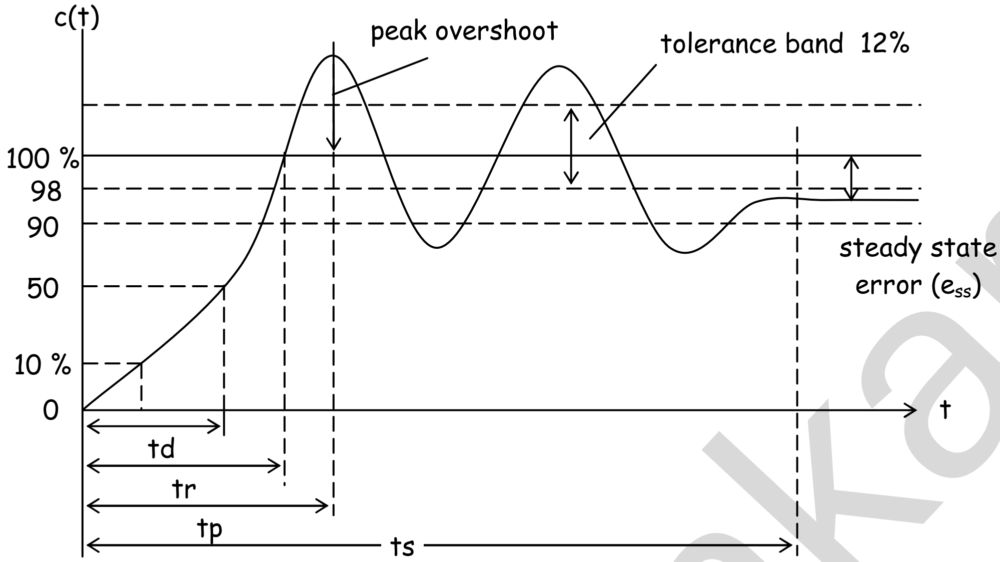
Q.4(b) (ii) Compare PL, PD and PID controller (four points). **[6]**
(A)

	PI	PD	PID
1)	It is the combination of Proportional control and integral control action.	It is the combination of Proportional control and derivative control action.	It is the combination of Proportional control, integral control and derivative control action.
2)	The proportional controller stabilizes the gain but produces steady state error and integral control minimize the error.	The proportional controller stabilizes the gain but produces steady state error and derivative control minimize the error.	The proportional controller stabilizes the gain but produces steady state error and integral and derivative control minimizes the error.
3)	$P = K_p \cdot C_p + K_p K_i \int_p^t c_p(t)\,dt + p_1(0)$	$P = K_p \cdot e_p + K_p K_p \frac{d}{dx}(e\,p) + P_{(0)}$	$P(t) = K_p\, e(t) + K_p K_i \int_0^t e(t)dt + K_p K_d \frac{de(t)}{dt} + p(0)$
4)			
5)	It eliminate steady state error.	It compensate rapidly changing error.	It eliminate steady state and rapidly changing error.
6)	It stabilize controller gain.	It increase controller gain during error change.	The gain of controller is stable.
7)	It require Expensive stabilization when process has many energy storage elements.	It cannot eliminate offset of proportional controller.	More effective for control process when many energy storage element than PI.
8)	It is used in control system with large load changes.	It is used in temperature cascade systems and batch neutralization.	A PID controller can be used for regulation of speed, temperature, flow, pressure and other process variables.

Q.5 Attempt any TWO of the following : [16]

Q.5(a) State output time response relationship of second order system for step input. Give meaning of different terms in it. Show the effect of damping on time response with waveforms. [8]

(A) Output time response relationship of second order system for step input



Where

T_d – Delay Time
T_T – Rise time
T_r – Peak time
T_S – Settling Time
M_P – Peak overshoot

(i) Delay Time (T_d) : It is the Time required for the response to reach 50% of the final value in the first attempt. It is given by

$$T_d = \frac{1+0.7\varsigma}{\omega_n}$$

(ii) Rise time (T_r) : It is the time required fro the response to rise from 10% to 90% of the final value for overdamped system and 0 to 100% of the final value for under damped systems. It is given by

$$T_r = \frac{\pi-\theta}{\omega_d}\text{sec}$$

Where θ must be in radian

(iii) Peak time (T_p) : It is the time required for the response to reach its peak value.

Or

The time at which response undergoes the first overshoot, which is always peak overshoot.

$$T_p = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n\sqrt{1-\varsigma^2}}\text{sec}$$

(iv) Settling Time (T_S) : This is defined as the time required for the response to decrease and stay within specified % of its final value.

$$T_S = \frac{4}{\varsigma\omega_n}$$

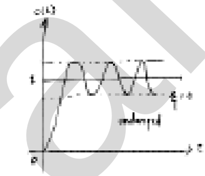
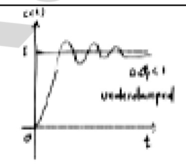
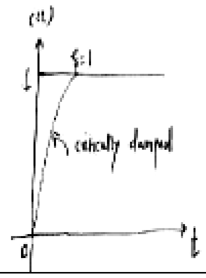
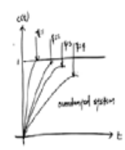
(v) Peak overshoot (M_P) : It is the largest error between reference input and output during the transient period.

$$\%M_P = \left[e^{\frac{-\pi\varsigma}{\sqrt{1-\varsigma^2}}} \right] \times 100$$

Effect of Damping on time response with waveform

Damping : Every system has tendency to oppose the oscillatory behavior of the system which is called as damping.

Damping ratio (ζ) : The damping is measured by a factor or a ratio called damping ratio of the system.

	Range of ζ	Type of close loop poles	Nature of response	System classification	Response waveform
(i)	$\zeta = 0$	Purely imaginary	Oscillations with constant frequency and ampliude	Undamped	
(ii)	$0 < \zeta$	Complex conjugates with negative real part	Damped oscillations	Underdamped	
(iii)	$\zeta = 1$	Real, Equal and Negative	Critical and pure exponential	Critically Damped	
(iv)	$1 < \zeta < \infty$	Real, Unequal and Negative	Purely exponential slow and sluggish	Overdamped	

Q.5(b) (i) Define critically stable and conditionally stable system. [8]
(ii) For the characteristic equation $S^4 + 20KS^3 + 5S^2 (10 + K) S + 15 = 0$. Determine the value of K for stable system.

(A) **(i) Critically stable system**: A linear time invariant system is called as critically stable system if it generates oscillations with constant amplitude and frequency for a bounded input.

Conditionally stable system: a linear time invariant system is called as Conditionally stable system if the stability of such system depends on condition of parameters of the system.

(ii) For the characteristic equation $S^4 + 20KS^3 + 5S^2 + (10+K)S + 15 = 0$ determine value of K for stable system.

From the given characteristic equation we can write Routh's array

S^4	1	5	15
S^3	20k	10+k	0
S^2	$\frac{99k-10}{20k}$	15	0

S^1	$\dfrac{980k-590\,lt^2-100}{99t-10}$	0
S^0	15	0

Consider Row S^2

99K – 10 / 20K >0

99K – 10 > 0

99K > 0

K > 10/99

K > 0.1

So value of K for stability should be greater than 0.1

Q.5(c) T.F. of a second order system is given by $\frac{C(s)}{R(s)} = \frac{2s}{s^2+6s+2s}$. Find out T_r, T_p, T_s and % Mp for unit step input. **[8]**

(A) In above problem, assume "25" in place of "2s" in numerator and denominator;

[1 mark for each parameter Means for ω_n, ξ, θ, ωd, Tr, Tp, Ts, and % Mp]

Then solve as follows:

Comparing the given equation with the standard form of second order equation.

$$\frac{C(S)}{R(S)} = \frac{\omega n^2}{\omega_n^2 + 2\xi\omega_n s + s^2} = \frac{25}{s^2+6s+25}$$

we get, $\omega_n^2 = 25$

Therefore, ω_n = 5rad/sec

$2\xi\omega_n = 6$, $\xi = 0.6$

$$\theta = \tan^{-1}\left(\frac{\sqrt{1-\xi^2}}{\xi}\right) = \tan^{-1}\left(\frac{\sqrt{1-0.6^2}}{0.6}\right) = 0.9272\text{rad}$$

$$\omega_d = \omega_n\sqrt{(1-\xi^2)} = 5\sqrt{(1-0.6^2)} = 4 \text{ rad/sec}$$

$$T_r = \frac{\pi-\theta}{\omega_d} = \frac{\pi-0.9272}{4} = 0.5535\text{sec}$$

$$T_p = \frac{\pi}{w_d} = \frac{\pi}{4} = 0.785\text{sec}$$

$$T_s = \frac{4}{\xi w_n} = 1.33\text{sec}$$

$$\%M_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}} * 100 = 9.48\%$$

Q.6 Attempt any FOUR of the following : **[16]**

Q.6(a) State Routh's criteria. Describe different cases to find stability of system (any two). **[4]**

(A) The necessary and sufficient condition for system to be stable is "All the not be any sign change in the first column of Routh's array".

If there are any sign changes existing then,

(i) System is unstable

(ii) The number of sign changes equals the number of roots lying in the right half of the S-plane.

Case 1:

If first element of any row in the Routh's array is zero, while the rest of row has at least one non zero term then due to this the next row element becomes infinite and Routh's test fails.

E.g. Characteristics equation
$F(S) = S^5 + S^4 + + 2S^3 + 2S^2 + 3S + 5 = 0$
For this equation Routh's array is,

S^5	1	2	3
S^4	1	2	5
S^3	0	-2	0
S^2	∞		

If all the element of a row are zero then due to this the elements of the next row.
E.g. Characteristics equation
$F(S) = S^5 + S^4 + + 3S^3 + 3S^2 + 3S + 3 = 0$
For this equation Routh's array is,

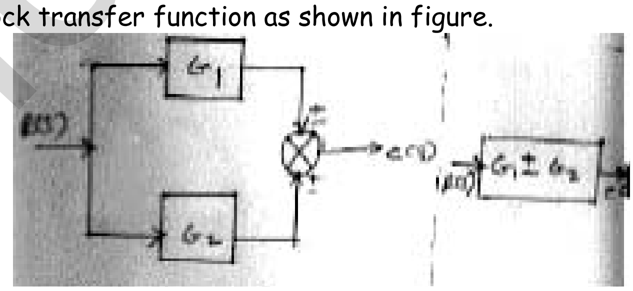
S^5	1	3	3
S^4	1	3	3
S^3	0	3	← Row of zero

Here, a row S^3 has all zero element, Routh's array test break down.
To overcome a problem an auxiliary equation with polynomials is formed from the co-efficient of the S^4 - row which is given by
$A(S) = S^4 + 3S^2 + 3.$
Differentiate this equation w.r.t S
$\frac{d\,A(S)}{dS} = 4S^3 + 6S + 0 = 4S^3 + 6S$
Zeros in S^3 row are now replaced by the co-efficient 4 and 6.

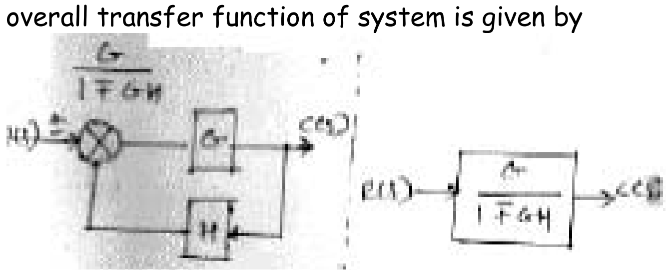
Q.6(b) State and explain any two rules of block diagram reduction. **[4]**

(A) **(i) Blocks in series or cascade :** When two or more blocks are in series with each other then these blocks can be combine to form a single block.
The overall transfer function of a resultant block is given be multiplication of individual block

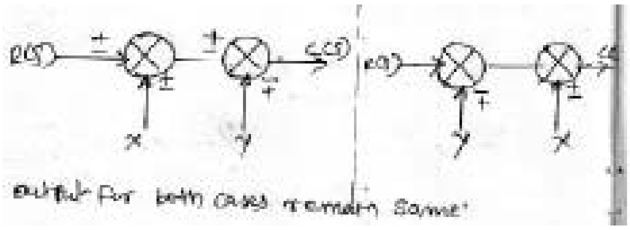
(ii) Blocks in parallel : When two or more blocks are in parallel with each other then these blocks can be combine to form a single block.
The overall transfer function of a resultant block is given by addition or difference of individual block transfer function as shown in figure.



(iii) Removal of minor or simple feedback loop : When a minor loop is present in a given system the minor feedback loop is converted into single functional block as shown in figure. The overall transfer function of system is given by



(iv) Interchange of summing points: When two or more summing point are directly connected with each other, then these summing points can be interchanged. The output remains same in this case.

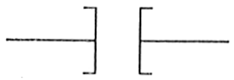


Q.6(c) Explain Relay instruction of PLS. [4]

(A) Relay instruction

- Representation of contacts and coils are the basic symbols of the logic ladder diagram instruction set.
- The three fundamental symbols used to translate relay control logic to contact symbolic logic are :
  1) EXAMINE IF CLOSED, 2) EXAMINE IF OPEN and 3) OUTPUT ENERGIZE

1.



Symbol

- This symbol represents normally open relay contact. For this instruction we ask the processor to EXAMINE IF (contact is) CLOSED.
- Typically represents any input to the control logic
  Has a bit level address
  The status bit will be either 1 (ON) or 0 (OFF)
  The status bit is examined for an ON condition
  If the status bit is 1 (ON) then
  The instruction is TRUE
  If the status bit is 0 (OFF) then
  Then instruction is FALSE

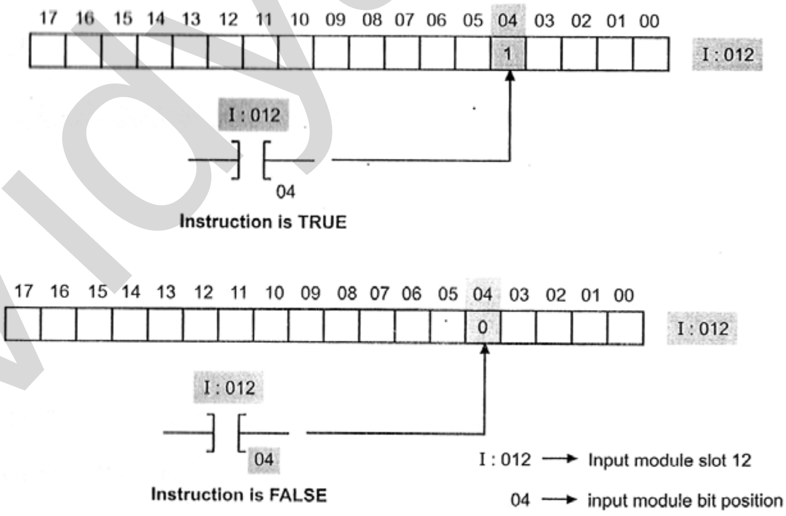
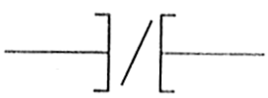


Fig. 1 : Examine If Closed (XIC) Instruction

2.



Symbol

- This represents normally closed relay contact.
- For this instruction, we ask processor to EXAMINE IF (the contact is) OPEN.

Typically represents any input
to the control logic
Has a bit–level address
The status bit will be either
1 (ON) or 0 (OFF)
The status bit is examined for
an OFF condition
If the status bit is 0 (OFF), then
the instruction is TRUE
If the status bit is 1 (ON), then
the instruction is FALSE.

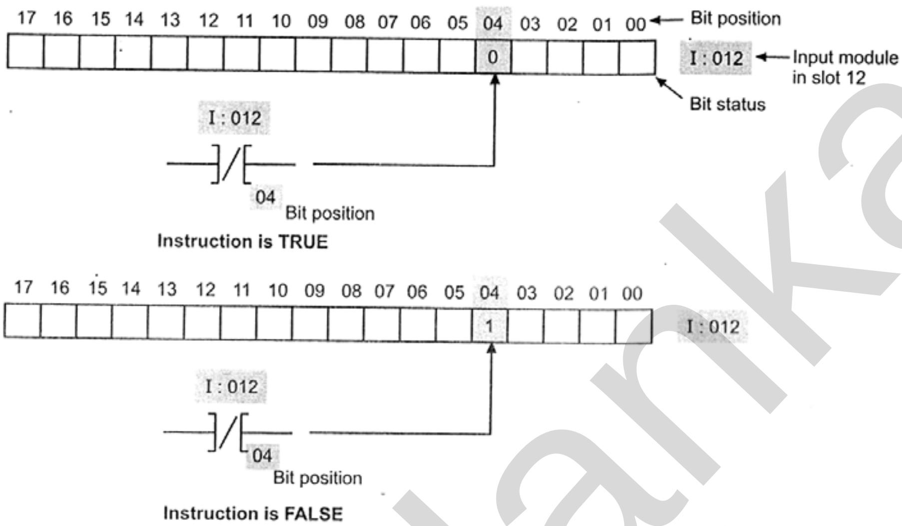
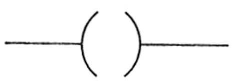


Fig. 2 : Examine if open (X10) instruction

3.



Symbol

- Symbol represents relay coil.
- The processor makes this instruction true (represents energizing a coil) when there is a path of true XIC and XIO instruction in the rung.

Typically represents any output that
is controlled by some combination of
input logic.
If any left to right path of input
conditions is True, the output is
energized (ON).
The status bit of the addressed
OUTPUT ENERGIZE instruction
is set to 1 (ON) when the rung
is TRUE.
The status bit of the addressed
OUTPUT ENERGIZE instruction
Is reset to 0 (OFF) when the
rung is FALSE

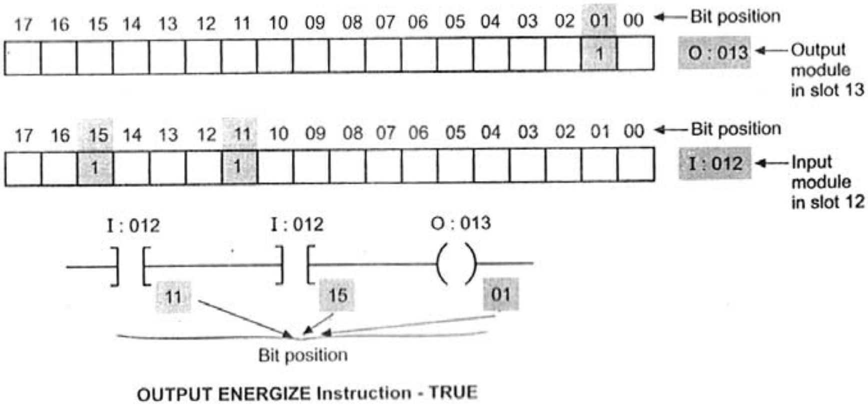


Fig. 3 : Output Energinze instruction – True

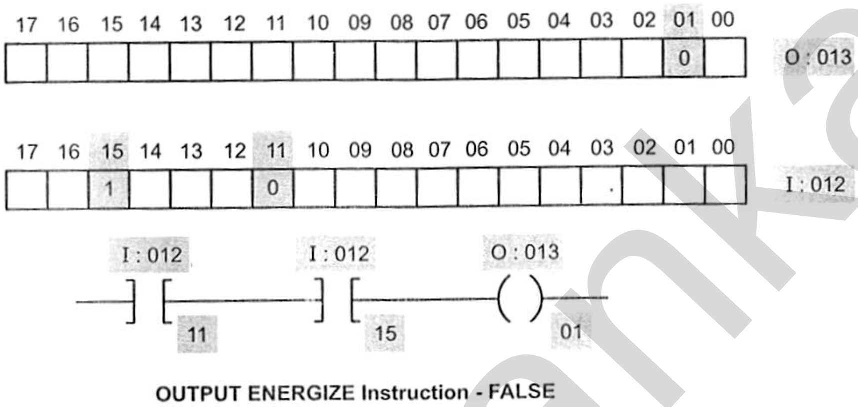


Fig. 4 : Output Energize (OTE) Instruction

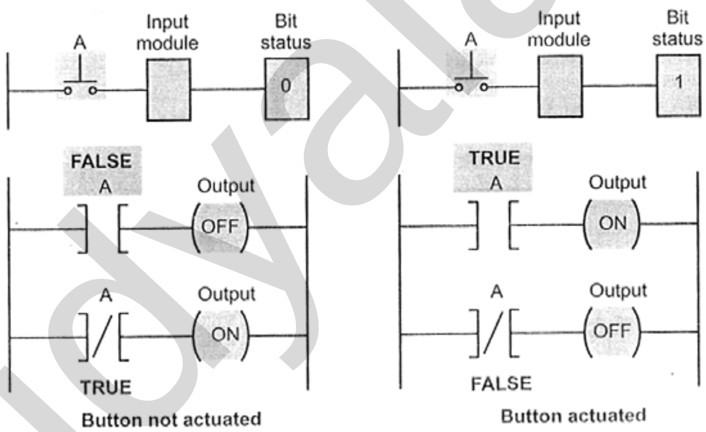
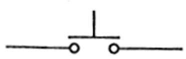
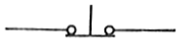
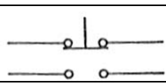
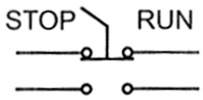
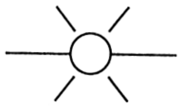


Fig. 5 : Status Bit Examples

Q.6(d) Draw any four ladder diagram symbols. [4]

(A) Ladder Diagram Symbols :

No.	Component	Symbol	Use
1)	Momentary push button switches.		All are used in automotive and electronic equipment applications.
	Normal open push button.		
	Normally closed push button.		
	Single push button with N/O and N/C contacts		

2)	Selector switches Open when the selector is turned to the left and closed when turned to right.		Selector switch is also known as rotary switch. An automobile ignition and an oscilloscope vertical gain and time base switches.
	Top contacts are closed when turned to left and open when selector turned to right. Bottom contact works opposite.		
3)	Limit Switch		Mechanically operated limit switch is the switch on the refrigerator door that turns ON the light inside.
	N/O		
	N/C		
4)	Indicator lamps		To indicate the ON position of the system (LEDs are used).

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