
Important Instructions to examiners:

1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance. (Not applicable for subject English and Communication Skills.)
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Question & its Answer	Remark	Total Marks
01A)	**Attempt Any THREE**		**12**
i)	**Compare open loop and close loop control system**		**04**
Ans	(see table below)	**1 mark for each point (Any 04 points)**	

No.	**Open Loop Control System**	**Close Loop Control System**
1	It is simple and economical	It is complex and costlier
2	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
3	It consumes less power	It consumes more power
4	It is more stable	It is less stable
5	It does not require feedback path element	It requires feedback path element
6	It has poor accuracy	It has better accuracy
7	It does not give automatic correction for external disturbances	It gives automatic correction for external disturbances
8	It is more sensitive to noise	It is less sensitive to noise
9	It is dependent on operating condition	It is not dependent on operating conditions
10	Its operation is degraded if non linearity is present	Its operation is not independent on conditions
11	It has slow response	It has fast response

12	It has high bandwidth	It has low bandwidth

ii) Define: a)Poles b) Zeros c)Order of system d) Characteristic equation **04**

Ans Transfer function of standard control system is given as

$$G(s) = \frac{K'(S - Z1)(S - Z2)\ldots.}{S^j(S - P1)(S - P2)\ldots.}$$

a) **Poles: T**he poles of the system are roots of the denominator polynomial of transfer function. i.e. in above transfer function G(s) P_1, P_2,…. Are poles of the system. **1 mark**

b) **Zeros: T**he zeros of the system are roots of the numerator polynomial of transfer function. i.e. in above transfer function G(s), Z_1, Z_2,…. Are zeros of the system. **1 Mark**

c) **Order of system:** It is highest power of 'S' at denominator of closed loop T.F.
In case of electrical circuit network number of energy storing device also give order of system. **1 Mark**

d) **Characteristics Equation:** The characteristics equation of the control system can be obtained by simplifying the denominator of the transfer function. In above transfer function G(s), the characteristics equation can be obtained from by salving equation **1 Mark**
$S^j (S-P^1) (S-P^2) \ldots=0$

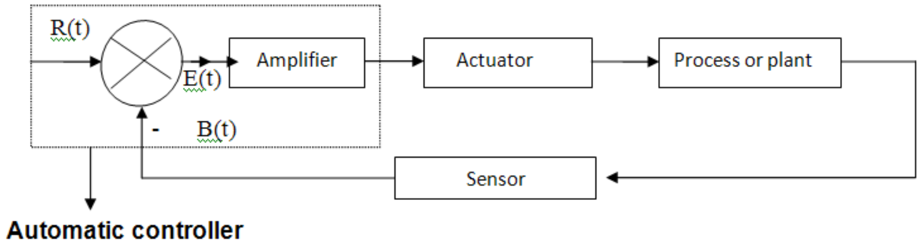
iii) State advantages of PLC **04**

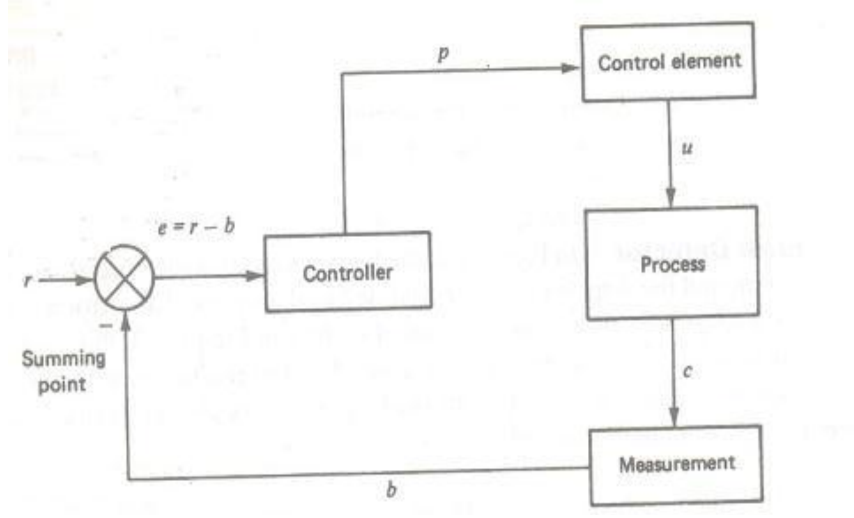
advantages of PLC:

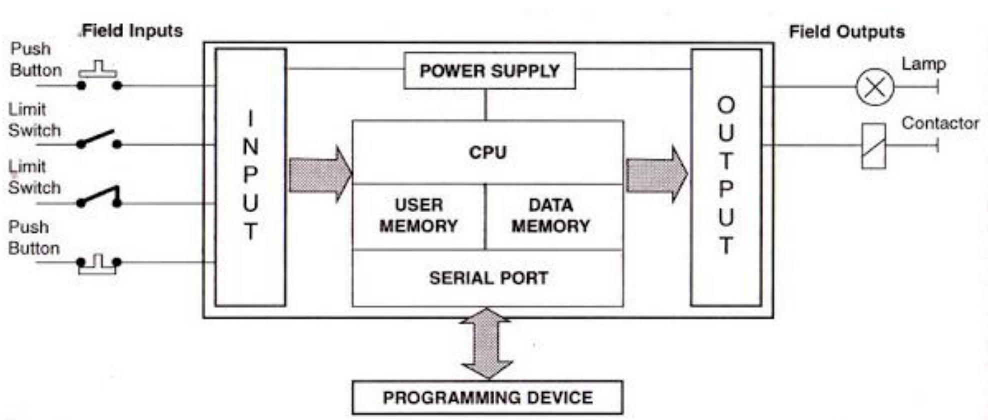
- Reduce human efforts
- Maximum efficiency through machine and logic is controlled by human
- Higher productivity
- Superior quality of end products
- Efficient uses of energy and raw material
- Eliminate the high costs associated with inflexible, relay-controlled systems
- Improved safety in working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

1 mark for each advantage (Any 04 points)

iv) Draw block diagram of Process Control System. State functions of its blocks. **04**

Ans	 **Explanation** - Process control system consists of process or plant ,sensor, error detector, automatic Controller, actuator or control element. **1) Process or plant-** process means some manufacturing sequence. It has 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. **2) 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 loop system. **3) Error detector** – Error detector is summing point whose output is an error signal i.e. e(t) = r(t) - b(t) to controller for comparison & for the corrective action. Error detector compares between actual signal & reference i/p i.e. set point. **4) 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 comprises an error detector and amplifier. **5) Actuator or control element** – Actuator is nothing but pneumatic motor or valve, a hydraulic motor or an electric motor, which produces an input to the plant according to the control signal getting from controller. **OR**	**Diagram – 2 Marks** **Explanation – 2 Marks**	

	 **Explanation :** The block diagram of process control system consists of the following blocks:- **1) Measuring element:** It measures or senses the actual value of controlled variable "c" and converts it into proportional feedback variable b. **2) 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. **3) Controller:** It generates the correct signal which is then applied to the final control element. Controller output is denoted by "p". **4) 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". **5) Process:** Output of control element is given to the process which changes the process variable. Output of this block is denoted by "u".		
Q1B	**Attempt Any ONE.**		**06**
i)	**Draw block diagram of PLC. Describe working of different parts of PLC.**		**06**
Ans.	A simplified block diagram of a PLC shown in Fig. It has three major units. • I/O (Input/Output) Modules. • CPU (Central Processing Units). • Programmer/Monitor.		

	1) I/O Section:- The I/O section establish the interfacing between physical devices in the real world outside the PLC and the digital arena inside the PLC. The input module has bank of terminals for physically connecting input devices, like push buttons, limit switches etc. to a PLC. the role of an input module is to translate signals from input devices into a form that the PLC's CPU can understand. The Output module also has bank of terminals that physically connect output devices like solenoids, motor starters, indicating lamps etc. to a PLC. The role of an output module is to translate signals from the PLC's CPU into a form that the output device can use. The tasks of the I/O section can be classified as: • Conditioning • Isolation • Termination • Indication An electronic system for connecting I/O modules to remotely located I/O devices can be added if needed. The actual operating process under PLC Control can be thousands of feet from the CPU and its I/O modules.  **Block diagram of PLC** **2) CPU Section:-** The Central Processing Unit, the brain of the system is the control portion of the PLC. It has three Subparts. • Memory System • Processor • Power Supply **Memory System:-** The memory is the area of the CPU in which data and information is stored and retrieved. The total memory area can be subdivided into the following four Sections.	**Block Diagram – 2 Marks** **Explanation – 4 Marks**	

<table>
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- I/O Image Memory
- Data Memory
- User Memory
- Executive Memory

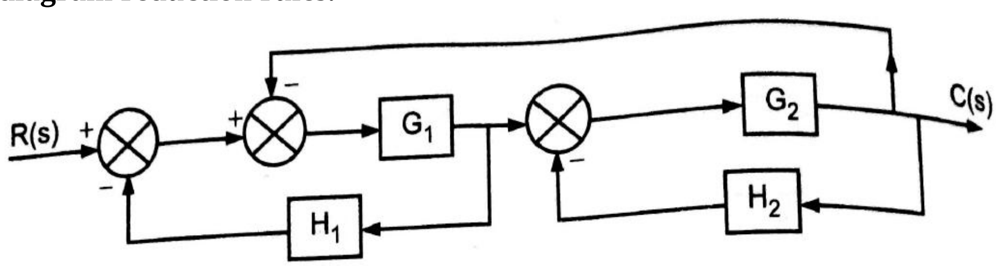
Processor:- The processor, the heart of CPU is the computerized part of the CPU in the form of Microprocessor / Micro controller chip. It supervises all operation in the system and performs all tasks necessary to fulfill the PLC function.

Power Supply:- The power supply provides power to memory system, processor and I/O Modules. It converts the higher level AC line Voltage to various operational DC values.

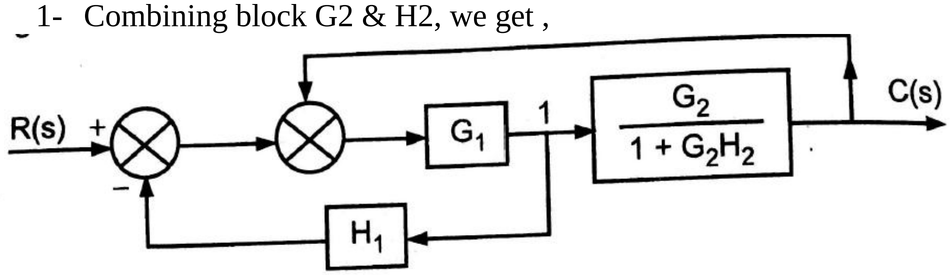
3) Programmer/Monitor:-

The Programmer/Monitor (PM) is a device used to communicate with the circuits of the PLC. The programming unit allows the engineer/technicians to enter the edit the program to be executed. With the help of proprietary software, it allows programmer to write, view and edit the program and download it into the PLC. It also allows user to monitor the PLC as it is running the program. With this monitoring systems, such things as internal coils, registers, timers and other items not visible externally can be monitored to determine proper operation. Also, internal register data can be altered, if required.</td><td></td><td></td></tr>
<tr><td>**ii)**</td><td>

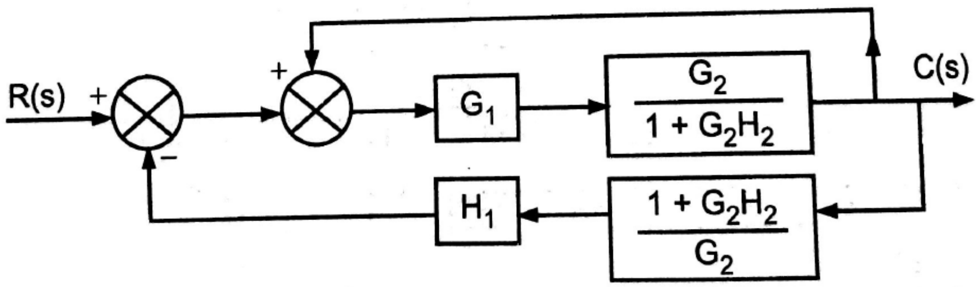
Derive transfer function of block diagram shown in fig. using block diagram reduction rules.


</td><td></td><td>**06**</td></tr>
<tr><td>**Ans.**</td><td>

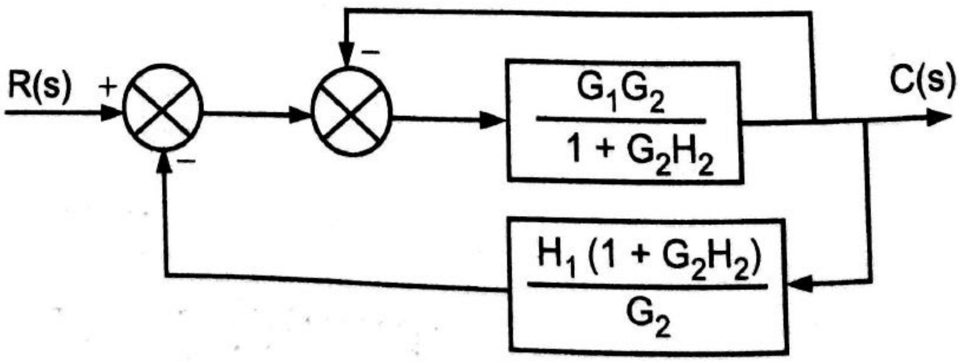
1- Combining block G2 & H2, we get ,


</td><td>**6 marks (Consider stepwise marking – combining blocks,s**</td><td></td></tr>
</table>

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



3- Combining two cascaded blocks, we get

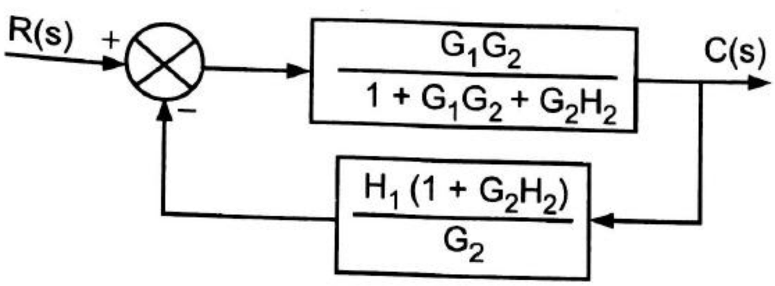


4- Salving unit negative feedback loop i.e. H(s) = 1

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

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

5- After eliminating unity feedback loop we get,



hifting take of points, combining cascade block, feedback gain, final answer etc.)

6- Salving two blocks in parallel we get,

where,

$$G(s) = \frac{1 + G_1G_2}{1 + G_1G_2 + G_2H_2}$$

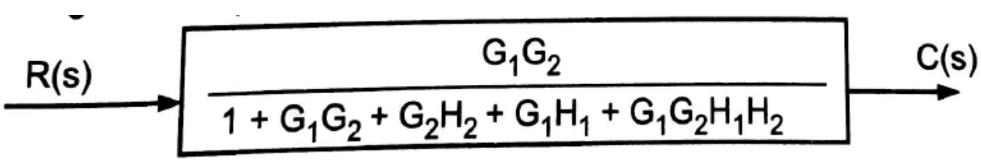
$$H(s) = \frac{H_1\,(1 + G_2H_2)}{G_2}$$

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

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

$$= \frac{G_1G_2}{1 + G_1G_2 + G_2H_2 + G_1H_1 + G_1G_2H_1\,H_2}$$

7- Thus, combining two parallel blocks we get ,



Q2	**Attempt any TWO**		**16**
a)	**A system is given by differential equation** $\frac{d^2y}{dx} + 4.\frac{dy}{dx} + 8.y = 8.x$. **Where y is output and x is input. Determine time domain specification. i) Rise Time ii) Peak Time iii)Settling Time iv) Peak overshoot**		**08**
Ans			

Taking Laplace for zero initial conditions, we get

$$s^2Y(s) + 4sY(s) + 8Y(s) = 8X(s)$$

$$(s^2 + 4s + 8)\,Y(s) = 8X(s)$$

$$\therefore \quad \frac{Y(s)}{X(s)} = \frac{8}{s^2 + 4s + 8}$$

Comparing with standard form, we get

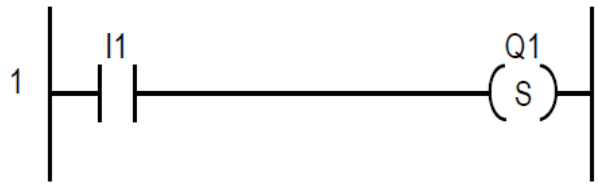
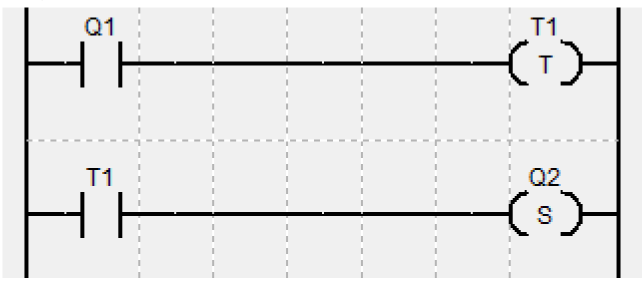
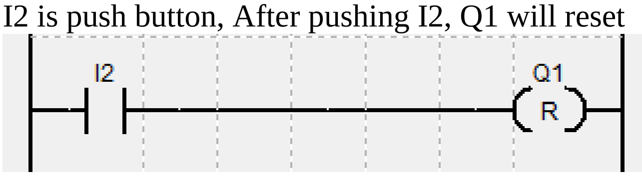
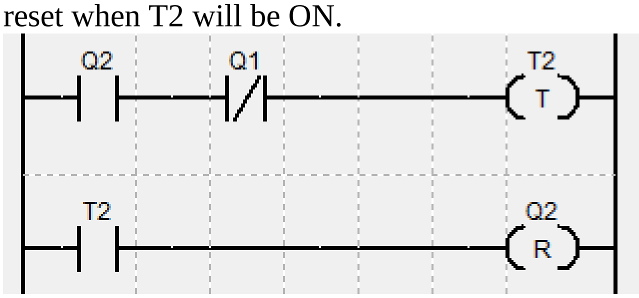
$$\omega_n^2 = 8 \qquad \therefore\ \omega_n = \sqrt{8} = 2.828 \text{ rad/s.}$$

$$2\xi\omega_n = 4 \qquad \therefore\ \xi = \frac{4}{2 \times 2.828} = 0.707$$

Equation – 1 Mark

	$Wd = Wn\sqrt{1-\xi^2} = 2.828\sqrt{1-0.707^2} = 2$ rad/s (ii) Rise time, $t_r = \frac{\pi-\beta}{\omega_d}$ where $\beta = \frac{\sqrt{1-\xi^2}}{\xi} = 0.7853$ $\therefore$ $T_r = \frac{3.14-0.7853}{2} = 1.178$ sec. (iii) Peak time, $t_p = \frac{\pi}{\omega_d} = \frac{3.14}{2} = 1.5707$ sec. (iv) Peak overshoot time, $\%M_p = \frac{4}{\xi\,\omega_n} = 100 \times e^{\frac{-\xi\pi}{\sqrt{1-\xi^2}}}$ or $\%M_p = 100 \times e^{\frac{-0.707\times 3.14}{\sqrt{1-(0.707)^2}}}$ $= 4.321\%$ (v) Settling time, $t_s = \frac{4}{\xi\omega_n} = \frac{4}{\left(\frac{1}{\omega^2}\right)\times\sqrt{8}} = 2$ sec.	**Wn–1 M** **ζ–1M** **Wd–1M** **Tr – 1M** **Tp–1M** **Mp–1M** **Ts–1M**	
b)	**For unity feedback system having open loop transfer function** $G(s) = \frac{K(S+2)}{S(S^3+7S^2+12S)}$ **Find i) Type of System ii) All error coefficients iii) Steady state error for input r(t) = R/2.t^2**		**08**
Ans.	1) 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** 2) Positional error coefficient (K_p) is given by, $K_p = \lim_{s\to 0} G(s).H(s)$ $K_p = \lim_{s\to 0} \frac{K(S+2)}{S^2(S+4)(S+3)}$ $K_p = \infty$ 3) Velocity error coefficient (K_v) is given by,		

	$K_v = \lim_{s \to 0} s.G(s).H(s) = \lim_{s \to 0} \frac{K(S+2)}{S(S+4)(S+3)}$ $K_p = \infty$ 4) Acceleration error coefficient (K_a) is given by, $K_a = \lim_{s \to 0} S^2.G(s).H(s) = \lim_{s \to 0} \frac{K(S+2)}{(S+4)(S+3)}$ $Ka = \frac{K}{6}$ 5) Steady State Error is given as, $ess = \lim_{s \to 0} \frac{s\ .\ X(s)}{1+G(s).H(s)}$ 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 $ess = \lim_{s \to 0} \frac{s\ .\ X(s)}{1+G(s).H(s)} = \lim_{s \to 0} \frac{S . \frac{R}{S^3}}{1+\frac{K(S+2)}{S^2(S+4)(S+3)}}$ $ess = \lim_{s \to 0} \frac{R(S+4)(S+3)}{S^2(S+4)(S+3)+K(S+2)} = \frac{6.R}{K}$		
c)	**Draw ladder diagram for two motor system with following condition** **i) Start switch starts motor 1 ii) 10 seconds later motor 2 starts** **iii) Stop switch stops motor 1 iv) 15 seconds later motor 2 stops**		**08**
Ans.	**i) Start switch starts motor 1**	**01 Mark**	

	1) Start push button, start motor M_1  I1 is push button, Q1 is output relay for motor M_1 **ii) 10 seconds later motor 2 starts** After setting Q1, T1 timer will get on after 10 seconds. After T1 ON Q2 will set.  **iii) Stop switch stops motor 1** I2 is push button, After pushing I2, Q1 will reset  **iv) 15 seconds later motor 2 stops** At Q1 reset & Q2 Set state, T2 timer will get on after 15 seconds. Q2 will reset when T2 will be ON.  **Note: Any relevant ladder logic may considered.**	**03 Mark** **1 Mark** **03 Mark**	
Q. 3	**Attempt any FOUR of the following**		**16**
a)	**Derive transfer function of RC Network.**		**04**
Ans.			

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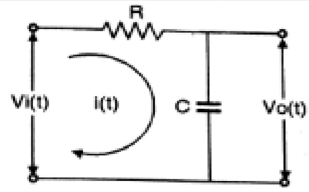


R-C circuit

- 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,

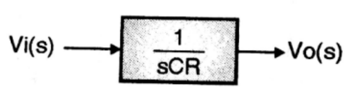
$$V_i(s) = R \cdot sC \cdot V_o(s) + V_o(s)$$

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

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

Where RC is a time constant

- The above system can be represented as shown below,



</td>
<td>
2 marks for transfer function

2 marks For Vi(s) and Vo(s)
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<td>**b)**</td>
<td>**Describe the proportional control action w. r. t. eqn and response. State significance of proportional band.**</td>
<td></td>
<td>**04**</td>
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<tr>
<td>**Ans.**</td>
<td>
Proportional control action-

The output of the controller is proportional to the input error signal.
One to one correspondence exists only for errors in this range.
Proportional mode can be expressed mathematically by-

$$p = K_p\, e(t) + e_0$$
</td>
<td>**Description- 2 Mark,**</td>
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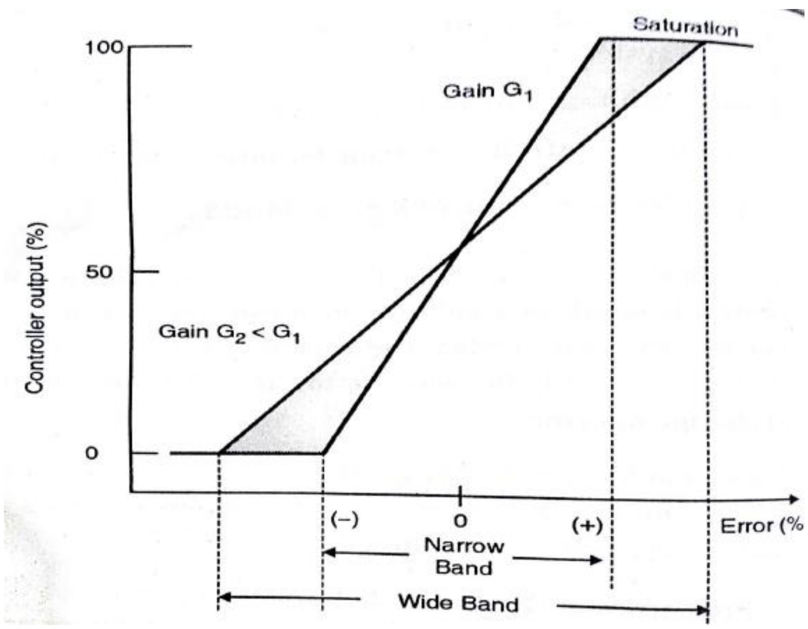
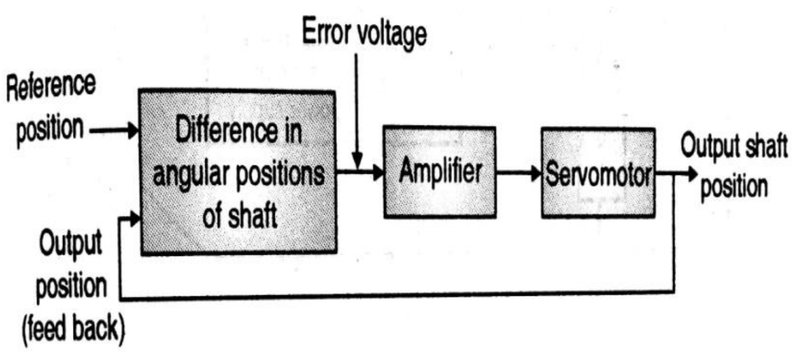
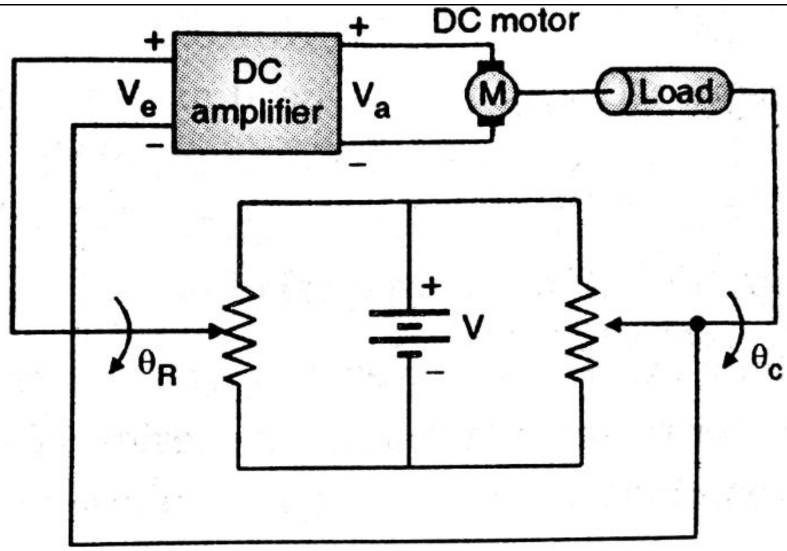
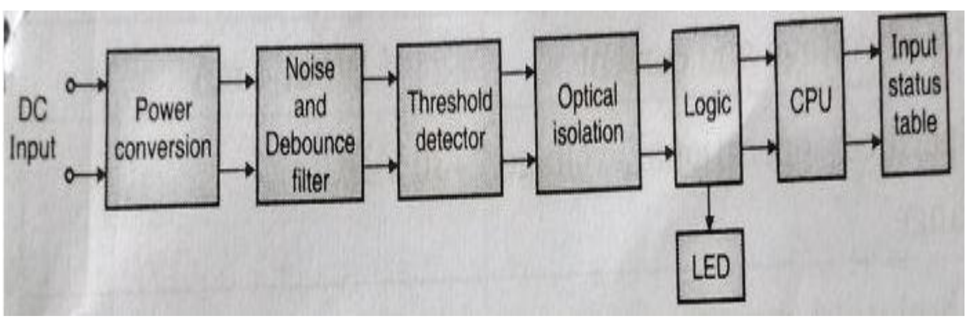
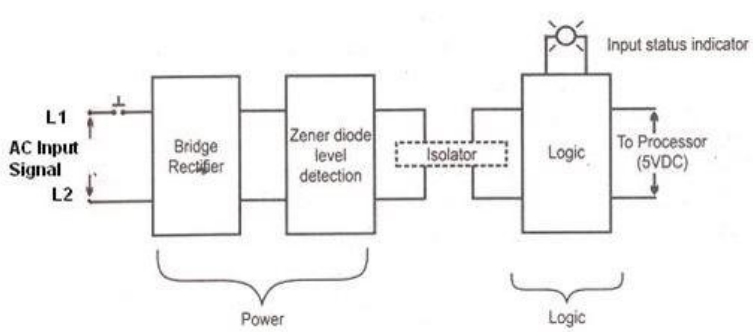
	where, K_p - proportional gain between error and controller output. e_0 - Controller output with no error.  **Fig- Proportional mode controller action** **Proportional Band significance -** The range of error to cover the 0% to 100% controller output is called proportional band. Which specifies the percentage error that result in a 100% change in the controller output.	**Response- 1 Mark** **Significance- 1 Mark.**	
c)	**Draw block diagram of servo system. State function of its component.**		**04**
Ans.	**Definition:** Servo system is one type of feedback control system in which control variable is the mechanical load position &its time derivatives like velocity and acceleration.  **Fig- standard block diagram of Servo system**	**Block diagram- 2 Mark,**	

	 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 systems 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.	**Description-2Mark.**	
d)	**Define the terms-** **i. Stable systems** **ii. Unstable system** **iii. Critically stable** **iv. Conditionally stable**		**04**
Ans.			

	STABLE : 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. UNSTABLE: A linear time invariant system is said to be unstable if following conditions are satisfied: 1.) If for a bonded input it produces unbounded output. 2.) In absence of the input, output may not return to zero it shows certain output without input. CRITICALLY STABLE: A linear time invariant system is said to be critically stable if for a bounded input its output oscillates with constant frequency and amplitude. CONDITIONALLY STABLE: 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.	**1-Mark each**	
e)	**Draw block diagram of DC input module of PLC. Describe its working.**		**04**
Ans.	**Block Diagram-**  **Fig- DC input module of PLC** **OR**  **Block Diagram of input Module**	**02 marks for block diagram**	

<table>
<tr><td></td><td>Working-

Power conversion:
It consists of rectifier which converts the incoming AC signal to a pulsating dc level, which is passed through filter and other logic in order to deliver a clean and denounced dc signal.

Threshold detector:
It detects if monitoring signal has reached or exceeded a predetermine d value. A valid ON sate will be between 80- 132V ac. The upper voltage limit for a valid OFF state is below 20V. The voltage between 20V and 80V is called undefined zone.

Isolation:
It is made up of an optical isolator which separate high voltage from CPU‟ s low voltage control logic.

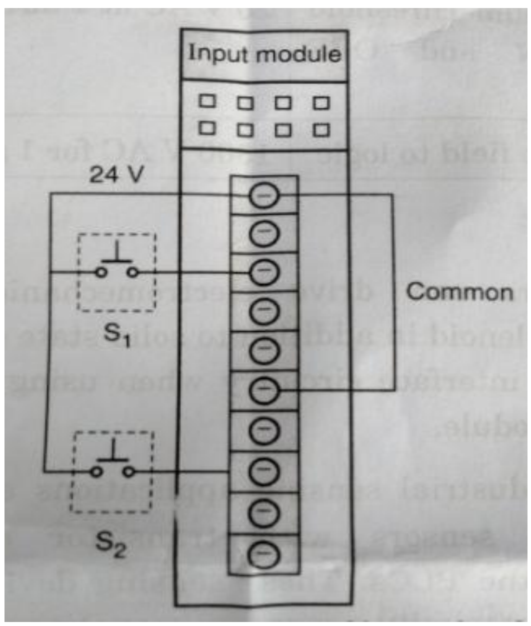
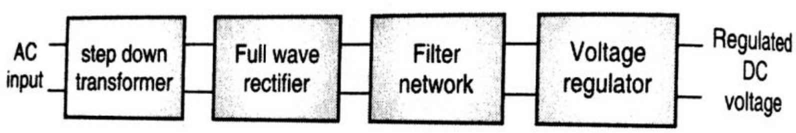
Logic section:
It passes the input signal to the modules input address LED and the CPU.


Fig- wiring of input signal into 24V DC 8 point input</td><td>02 marks for working</td><td></td></tr>
<tr><td>Q. 4</td><td>Attempt any THREE</td><td></td><td>12</td></tr>
<tr><td>i)</td><td>State Routh’s stability criteria. State its advantages.</td><td></td><td>04</td></tr>
<tr><td>Ans.</td><td>Statement-
The necessary & sufficient condition for system to be stable is “All the terms in the first column of routh array must have same sign. There should not be any sign change in the first column of Routh’s array”.</td><td>Stateme nt-02 Marks,</td><td></td></tr>
</table>

	If there are any sign changes existing then, (1) System is unstable (2) The number of sign changes equals the number of roots lying in the right half of the S- plane. **Advantages-** 1. Simple method to determine the stability of system, without actually solving characteristics equation of the system. 2. Range of K (variable gain) can be determined. 3. Number of roots of characteristics equation with positive real parts can be given by this method for unstable system. 4. Relative stability, marginally stability can be determined. 5. No time wastage in solving high order determinants like Hurwitz method. 6. Frequency of sustained oscillation can be determined.	**Advantages- 02 Marks(any 2)**	
ii)	**Draw block diagram of PLC power supply. State functions of its components.**		**04**
Ans.	 **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 or 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.	**Block Diagram- 02 Marks,** **Description- 02 Marks.**	
iii)	**Explain ON/OFF delay timer instruction with diagram.**		**04**
Ans.	Depending on the time delay and 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	**02 marks**	

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 (bit13)**-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 (bit15)**-TT is set when rung conditions are true & 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.

(ii) 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 reset when the rung conditions go true regardless of whether the timer has timed out.

Instruction parameter- Timer TOFF is 3 word element.

02 marks

	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(bit13)-DN is reset when the accumulated value is equal to or greater than the preset value.It is set when rung condition are true.

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

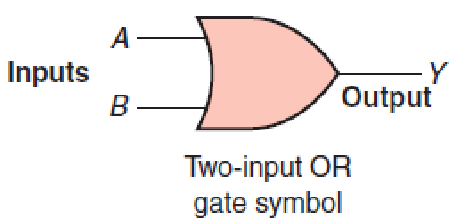
iii) Timer timing bit(bit15)-TT is set when rung conditions are false & the accumulated value is less than the preset value. It is reset when the rung conditions go true or when the done bit is reset.

iv) **Develop ladder diagram for logic operation** **04**

a) OR

b) EX-OR

Ans. **i. OR:** **2 Marks.**

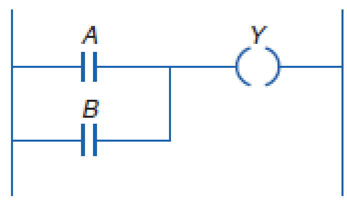


OR truth table

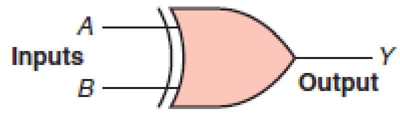
Inputs		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Fig. The OR gate symbol and truth table

Ladder logic program



c) EX-OR: **2 Marks.**

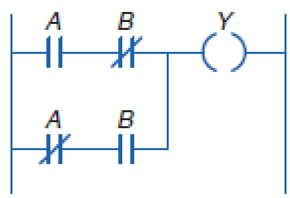


Truth table

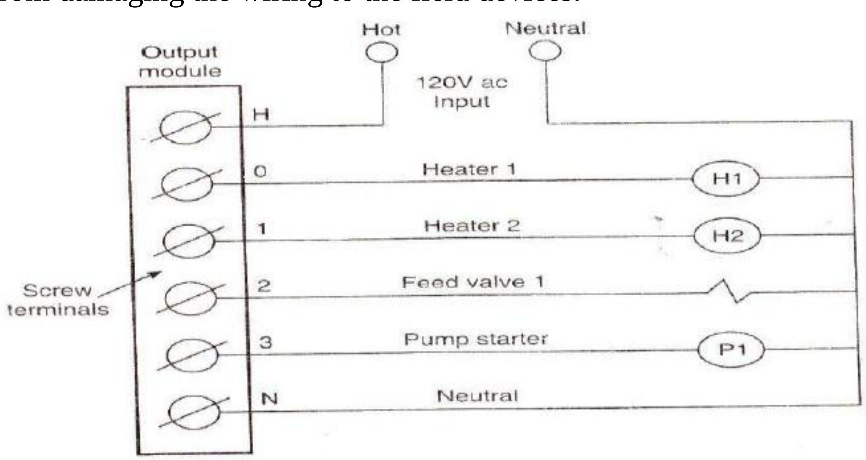
Inputs		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Fig- The EX-OR gate symbol and truth table

Ladder logic program



Q4B	**Attempt any ONE**		**06**
i)	**Describe the wiring details of AC output module of PLC with diagram.**		**06**
Ans.	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.	**Description- 04 Mark,**	



Typical discrete output module wiring diagram

Diagram- 02 Marks

<table>
<tr><td>ii)</td><td>Explain the PD control action w. r. t. eqn and response. State their advantage and drawback.</td><td></td><td>06</td></tr>
<tr><td>Ans.</td><td>

PD control action mode is used in industrial applications. It uses proportional and derivative modes serially. Mathematically it is given by;

$$P = K_p e(t) + K_p K_D \frac{de(t)}{dt} + p(0)$$

Above equation contains three mathematical terms i.e. K_p e (t) indicates the proportional output term, K_p K_D $\frac{de(t)}{dt}$ indicates derivative term and p(0) controller output with no error.

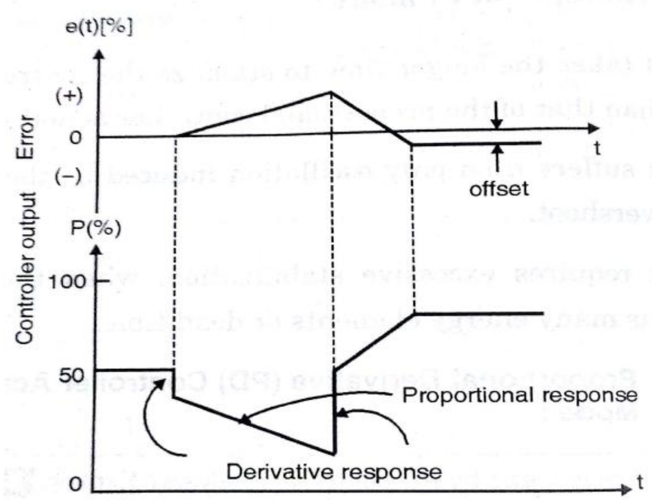


Fig- Proportional-Derivative action.

Advantages-
<ol type="i">
It allows the rise of narrower proportional band with its lesser offset.
Increases the controller gain during the error changes.
Can compensate the rapidly changing error.
Can handle the fast processes.
Can compensate some of the lag in a process.

Disadvantages-

It cannot eliminate offset of proportional controller.
</td><td>Description- 2 Mark,

Response- 2 Mark,

Adv 1 mark

Disadv- 01Mark</td><td></td></tr>
<tr><td>Q. 5</td><td>Attempt any TWO.</td><td></td><td>16</td></tr>
<tr><td>a)</td><td>Consider sixth order system with characteristic equation $s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0$. Determine stability of system using Routh's criterion.</td><td></td><td>08</td></tr>
<tr><td>Ans.</td><td></td><td></td><td></td></tr>
</table>

	(Any relevant method is also applicable but final conclusion should be same) I) Find odd and even coefficients from given characteristic equation & make Routh's array F(s) $= s^6 + 2s^5 + 8s^4 + 12s^3 + 20s^2 + 16s + 16 = 0.$ $a_0 \quad a_1 \quad a_2 \quad a_3 \quad a_4 \quad a_5 \quad a_6$ Hence even coefficients are a_0, a_2, a_4, a_6 i.e 1 ,8, 20, 16. Odd coefficients are a_1, a_3, a_5 i.e 2, 12, 16 Routh's Array s^6 | 1 8 20 16 s^5 | 2 12 16 0 s^4 | 2 12 16 0 s^3 | 0 0 0 0 – sp.case 2 s^2 | s^1 | s^0 | 16 II) Make auxiliary equation of the row which is just above row of zero. $A(s) = 2s^4 + 12s^2 + 16$ III) Take $\frac{dA(s)}{ds}$ $\frac{dA(s)}{ds} = \frac{d(2s^4 + 12s^2 + 16)}{ds}$	**Routh's array -4 marks,** **pply sp case2-2mark,**	

<table>
<tr><td></td><td>

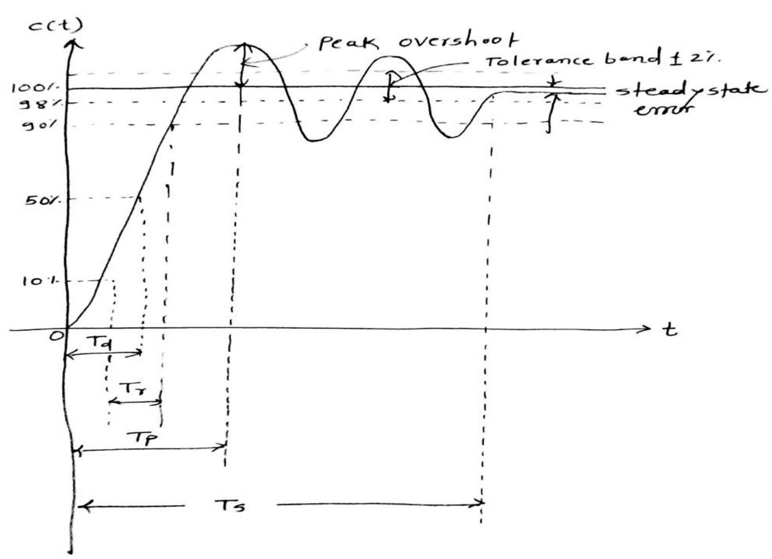
$$\frac{dA(s)}{ds} = 8s^3 + 24s + 0$$

IV) Make Routh's array with new coefficients

s^6	1	8	20	16
s^5	2	12	16	0
s^4	2	12	16	0
s^3	8	24	0	0
s^2	6	16	0	
s^1	2.66	0		
s^0	16			

V) As in first column of Routh's array there is no any sign change .Therefore system is stable.
</td><td>conclusion -2 mark)</td><td></td></tr>
<tr><td>b)</td><td>State output time response relationship of second order system for step input. Give meaning of different terms in it. Show effect of damping on time response with waveforms.</td><td></td><td>08</td></tr>
<tr><td>Ans.</td><td>

- **Output time response relationship of second order system for step input**



</td><td>Diagram of time response-2 mark,</td><td></td></tr>
</table>

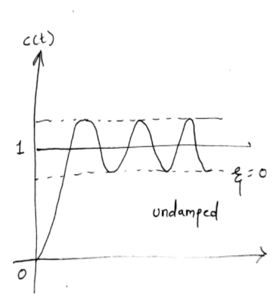
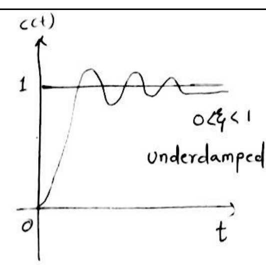
	Where T_d - Delay Time T_r Rise time T_p -Peak time T_s - Settling Time M_p − Peak overshoot 1) **Delay Time** (T_d) − It is the Time required for the response to reach 50 % of the final value in the first attempt. It is given by $Td = \frac{1+0.7\zeta}{\omega_n} sec$ (2) **Rise time** (T_r) -It is the 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 $Tr = \frac{\pi-\theta}{\omega_d} sec$ Where θ must be in radian (3) **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. $Tp = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} sec$ (4) **Settling Time** (T_s) − This is defined as the time required for the response to decrease & stay within specified % of its final value . $Ts = \frac{4}{\zeta\omega_n}$ (5) **Peak overshoot** (M_p) − It is the largest error between reference input & output during the transient period. $\%Mp = \left[e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}\right] * 100$	**Def. of terms-2 mark(formulae are not compulsory),** **effect of**	

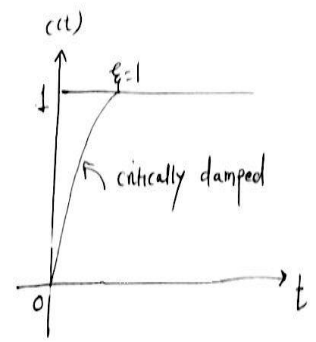
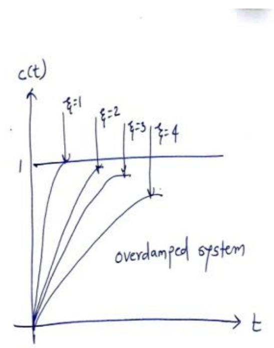
- **Effect of Damping on time response with waveform-**

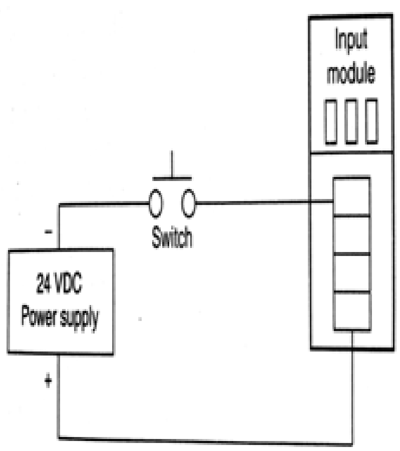
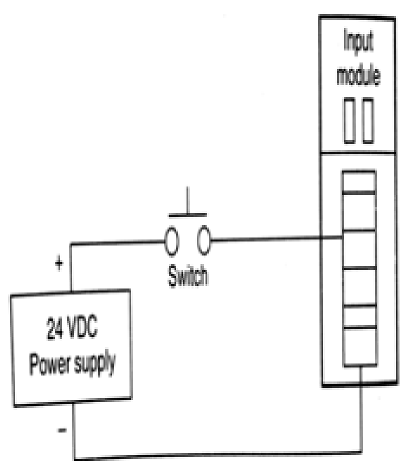
dampin g- 4marks)

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
1	$\zeta = 0$	Purely imaginary	Oscillations with constant frequency & amplitude	Undamped	
2	$0 < \zeta < 1$	Complex conjugates with negative real part	Damped oscillations	Underdamped	

3	$\zeta = 1$	Real, Equal and Negative	Critical & pure exponential	Critically Damped	
4	$1 < \zeta < \infty$	Real, Unequal & Negative	Purely exponential slow & sluggish	Overdamped	

c)	**Describe the concept of sinking and sourcing in D.C input modules .Differentiate between Fixed PLC and Modular PLC.**		**08**
Ans.	**Diagram:**  **fig 1-Sourcing D.C input module with a sinking switch**  **Fig 2 - Sinking D.C input module with a sourcing switch**	**Diagram sourcing- 01 mark** **Diagram Sinking - 01 mark,**	

- **Explanation**

1. Sinking and Sourcing are terms used to describe current flow through a field device in relation to the power supply and the associated input, output point.
2. Solid state input devices with NPN transistors are called "Sinking input device" while input devices with PNP transistor are called "Sourcing input devices".
3. The commonly accepted definition by PLC manufactures about sinking & sourcing input & output circuit is current flows from positive to negative.
4. Basic principle retain to sinking & sourcing circuits.

- NPN transistors are open collector current sinking devices which interface to a sourcing input module.
- PNP transistors are open collector, current sources, which interface to a sinking input module.

5. In fig. no1 current flows from positive terminal of 24 volt DC supply to input module then through switch to negative terminal of supply, hence module acts as sinking device for DC supply but sourcing device for switch.
6. In fig.2 current flows from positive terminal of 24 volt DC supply to switch then input module to negative terminal of supply, as far as input module is concern it act as sinking device for DC switch and sourcing device for 24 volt DC supply.

Explanation-2 marks,

- **Comparison between Fixed PLC and Modular PLC.**

Sr. no	Fixed PLC	Modular PLC
1	Elements are fixed on main board of PLC	Elements are modular form, mounted on chasis(rack)
2	I/O count is 32 or less than 32	I/O count is more than32
3	Small in size	Size is more
4	Easy to install	Complex installation process

01 mark for each point (any 4 points)

5	Memory capacity is less	Memory capacity is more
6	It can not be repaired	It can repaired as modules are in modular form
7	Generally digital devices are connected to it.	Analog & digital devices are connected to it.
8	Cost is less	Cost is more
9	Less input output devices are connected	More input output devices are connected
10	Application-Tea-coffee vending m/c, Washing m/c	Application-Cement, rubber, Chemical fertilizer industries.

Q.6 Attempt any FOUR. **16**

a) Describe PI control action. State their advantages. **04**

Ans. This is composite control mode obtained by combining the proportional mode and the integral mode

ii) The mathematical expression for such a composite control is

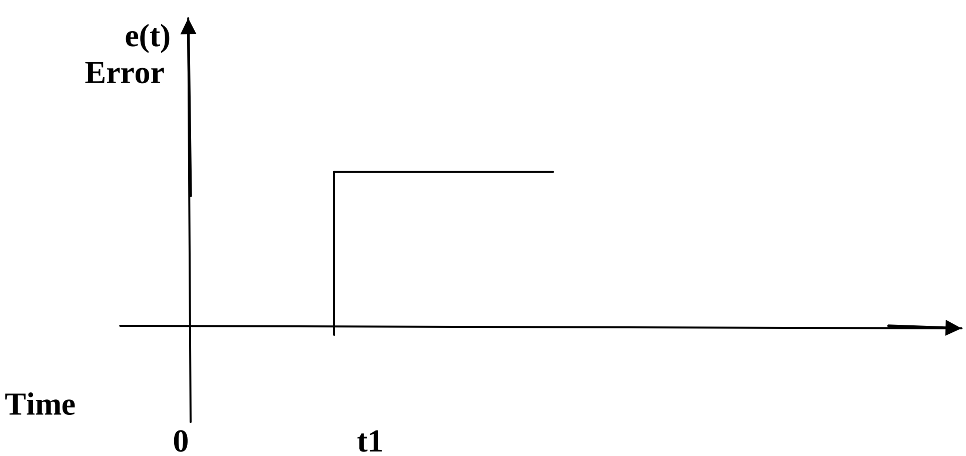
$$P(t) = k_p e(t) + k_p k_i \int_0^t e(t)\,dt + p(0)$$

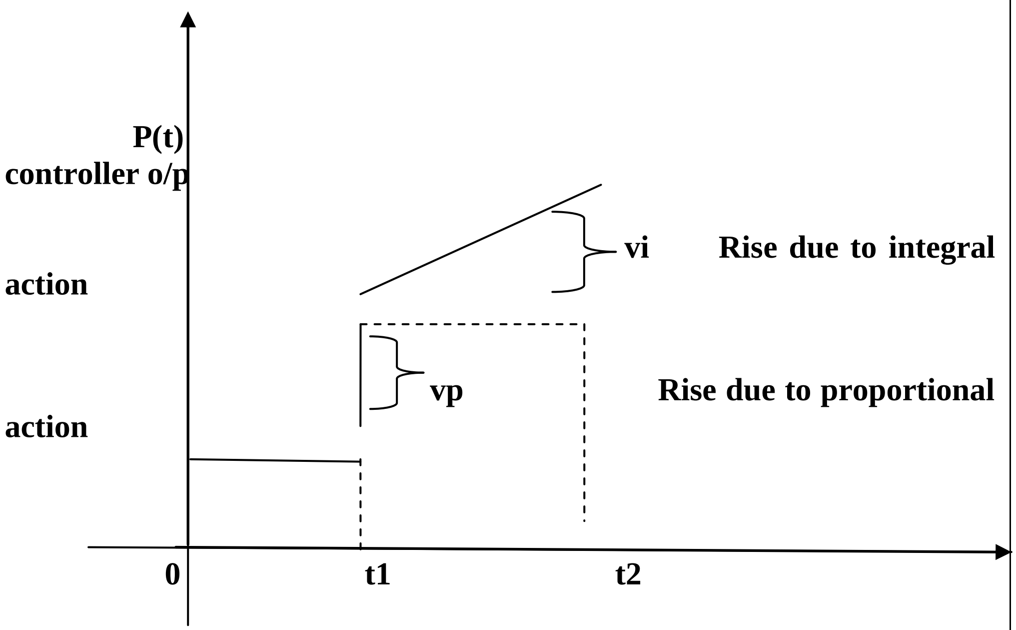
Where $p(0) =$ Initial value of the o/p at t=0

iii) one important advantage of this control is that one to one correspondence of proportional mode is available while the offset gets eliminated due to integral mode ,the integral part of such a composite control provides a reset of the zero error output after a load change occurs

iv) Response of PI mode for direct action of the controller.-As the error changes from zero to positive at that instant t1.,the controller o/p changes but this change due to proportional mode. As the error changes further the controller o/p increases, but this increase is due to integral mode. And as the error becomes constant ,controller o/p remains as it is equal to previous stage.

Describtion-2marks,





Advantages of PI controller

i) It eliminates the offset error that means it improves the steady state accuracy.
ii) It increases the rise time so response becomes slow.
iii) It decreases bandwidth of the system.
iv) It filters out the high frequency noise.

01 mark for each advantage (any 2 points)

b) List different input and output devices used in PLC. **04**

Ans.

Input devices	**Output devices**
Push buttons	A.c motor,D.c motor
temperature switch	Buzzer-Annunciater,Bell,Buzzer,Horn,Siren
limit switch	Relay
pressure switch	Lamp
level switch	Heater coil
thumbwheel switches,	Solenoid valve
Flow switches	Timer
Proximity switches	Contactor, Display.

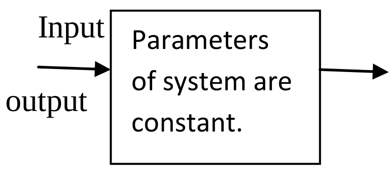
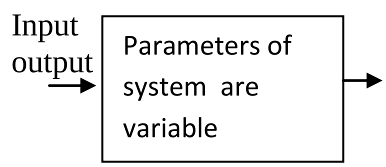
01 mark for each device (Any 2 input and any 2 output devices)

c) Differentiate between linear time invariant and linear time varying system. **04**

Ans.

Sr. No	**Linear time invariant system**	**linear time varying system**

01 mark for each

1	It is defined as system in which parameter does not change with time	It is defined as system in which parameter change with time
2	It is described by linear differential equation with constant variable coefficients	It is described by linear differential equation with variable coefficients.
3	Circuit is easy to design	Design of circuit is complex
4		
5	R-L-C N/W-values of R,L,C component are constant and not function of time.	Space vehicle whose mass decreases with time

point (any 4 points)

d) Draw block diagram of A.C output module of PLC. Describe its working. **04**

Ans. block diagram of A.C output module of PLC:

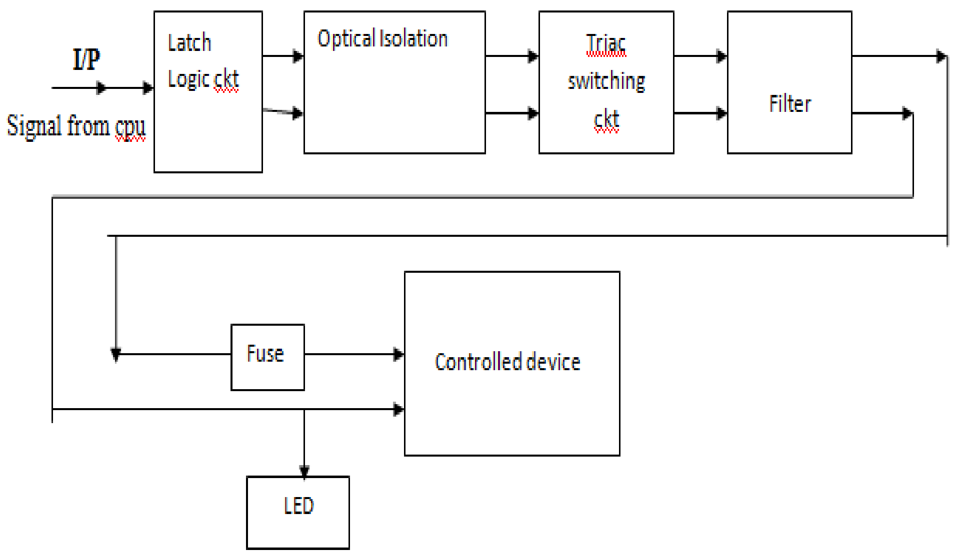


Diagram-2 marks,

Explanation:

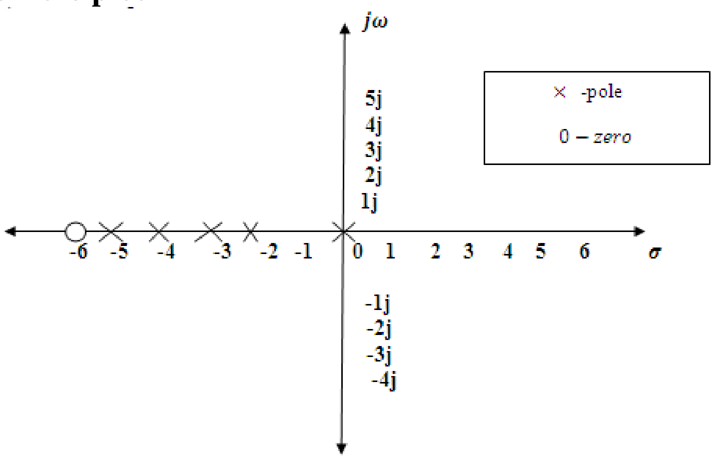
i) Latch logic circuit- Signals from CPU are provided to the latch logic circuit , which is used for low voltage usually 12-18VD.C logic signal sent by CPU from the O/P status table. ON/OFF signal represents the logic value of the output.

ii) Optical Isolation- ON signal from latch circuit is then passed through optical isolation circuit . The block contain switching hardware. It provides electrical separation between CPU &O/P device signal.

iii) Switching circuit -Triac is used as a switching device in A.C O/P

Explanation -2 marks

	module which is basically solid state device. It is used to switch the A.C high voltage & current for controlling the ON or OFF state of the field hardware device. **iv) Filter circuit** Voltage protective circuit such as metal oxide varister (mov) is used to limit peak voltage across the A.C switching hardware to a safe value, which is known as filter circuit. **v) Fuse & LED-** LED provides the indication of the status of the o/p to the operator, which has been directed by CPU to turn ON. Fuse is connected in line of output to protect the A.C Triac switching device from drawing high current **vi) Controlled device-**The devices which is to be controlled is connected at O/P of filter circuit		
e)	**The Transfer Function of system is** $\frac{C(s)}{R(s)} = \frac{k(s+6)}{s(s+2)(s+5)(s^2+7s+12)}$ **Determine poles, zeros and pole –zero plot of system**		**04**
Ans.	**Poles of system is calculated as following:** Characteristic equation of T.F is given as $F(s) = s(s+2)(s+5)(s^2+7s+12)$ Hence $s(s+2)(s+5)(s^2+7s+12) = 0$ Therefore Poles are $s_1 = 0, s_2 = -2, s_3 = -5, s_4 = -4, s_5 = -3$ **ii) Zero of the system is calculated by numerator of T.F.** Hence $k(s+6) = 0$ $s_1 = -6$	**pole - 1marks,** **zero-1 marks**	

	iii) Poles-Zero plot 	**plot-2marks**	