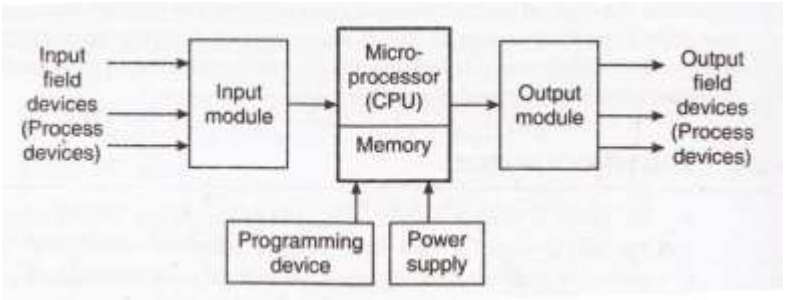
SUMMER– 19 EXAMINATION

Subject Name: Control system and PLC **Model Answer Subject Code:** 17536

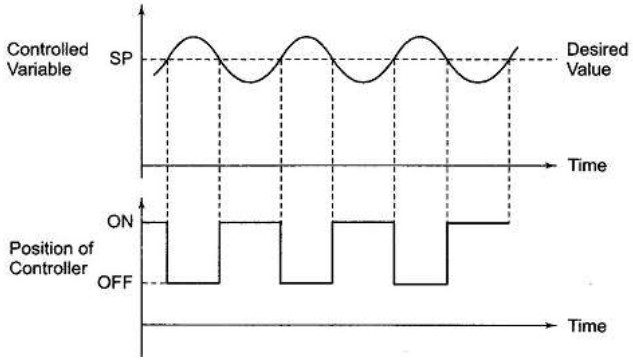
Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given moreImportance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in thefigure. The figures drawn by candidate and model answer may vary. The examiner may give credit for anyequivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constantvalues 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.	Sub Q. N.	Answers	Marking Scheme
1	**(A)**	**Attempt any THREE of the following:**	**12- Total Marks**
	(a)	**Foe a control system, characteristics equation is given by** **$S^5+S^4+3S^3+9S^2+16S+10=0$.** **Determine stability using Routh criteria.**	**4M**
	Ans:	The routh array is, S^5 | 1 3 16 S^4 | 1 9 10 S^3 | -6 6 0 S^2 | 10 10 0 S^1 | 12 S^0 | 10 One element in first column of routh array is negative	**Array : 3M** **Stability : 1M**

		Hence, system is unstable	
	(b)	**Draw the block diagram of PLC and state the function of each block.**	**4M**
	Ans:	 • **Power supply**: - It converts AC line voltages to DC voltage • **Processor**: - This is microprocessor that controls and supervises the entire process. It is the controller of a PLC. • **Memory**: - It contains the program of logic, sequencing and other input & output operation. System program is stored in ROM and application program is stored in RAM. • **Programming Device**: - The basic elements of programming device are keyboard, visual display, and microprocessor and communication cable. The most common programming devices are:- Handle held programming unit, Industrial Programming terminal and Personal Computer. • **Input Module**: - It serves link between input field devices and PLC's CPU. • **Output Module**: - It serves as the link between PLCs CPU and hardware output field devices	**Block diagram : 2M** **Explanation : 2M**
	(c)	**Give classification of control system & define linearity in control system.**	**4M**
	Ans:	**Control system are classified as** **1. Depending on hierarchy** i) Open Loop System ii) Closed Loop System **2. Depending on number of inputs and outputs** i) SISO control system ii) MIMO control system **3. Depending on type of damping** i) Undamped control system	**Classification (any 3) : 3M** **Definition : 1M**

		ii) Underdamped control system iii) Overdamped control system **4. Depending on main purpose of application** i) Position control system ii) Velocity control system iii) Temperature control system **Or** **Control systems are classified as** • Linear/nonlinear • Open loop/closed loop • Time varying/time in varying **Linearity:** A linear system is one whose differential equation consisting of the dependent variables and their derivatives in first degree. **Or:** Linear system is one which obeys superposition theorem.	
(d)		**State the principle of ON-OFF control. Write it's standard equation & define neutral zone.**	**4M**
Ans:		**Principle of ON-OFF control** : The On Off Controller or two position controller. When the measured variable is below the set point, the controller is ON and the output signal has maximum value. When the measured variable is above the set point, the controller is OFF and output is zero.	**Principle : 2M** **Equation : 1M** **Neutral Zone : 1M**



O /P equation of ON-OFF controller

P (t) = 0% (OFF) for ep < 0

100% (ON) for ep > 0

Where

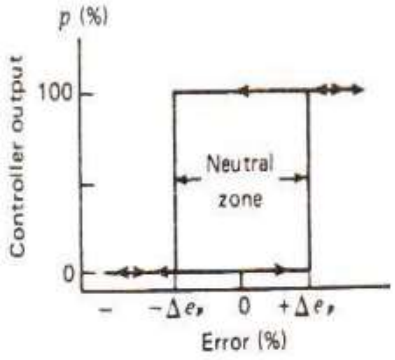
p (t) – Controlled output

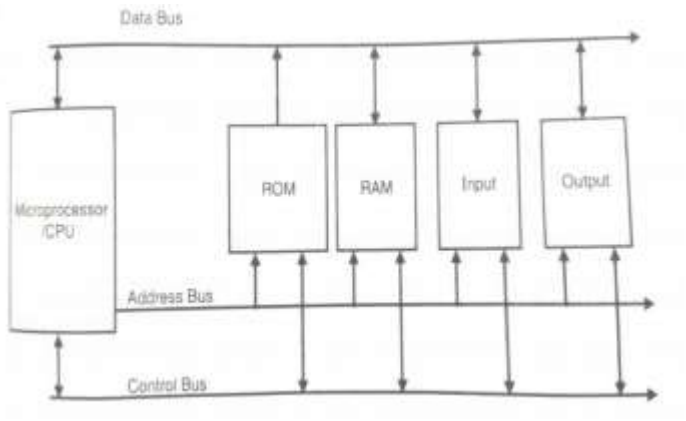
ep - Error based on % of span

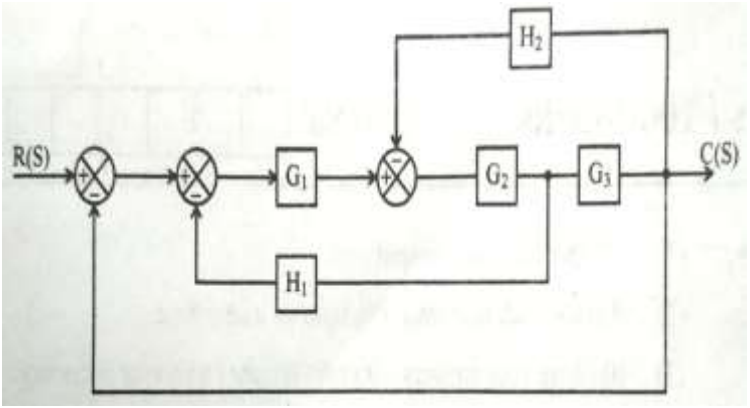
Neutral Zone: In any practical implementation of the two position controller, there is an overlap as e_P increases through zero or decreases through zero. In this span, no change in controller output occurs. This is shown in the fig. which plots p versus ep for two position controller. We see that until an increasing error changes by Δep above zero, controller output will not change state. In decreasing, it must fall Δep below zero before the controller changes to the zero percentage rating. The range 2Δep, which is referred to as the neutral zone.

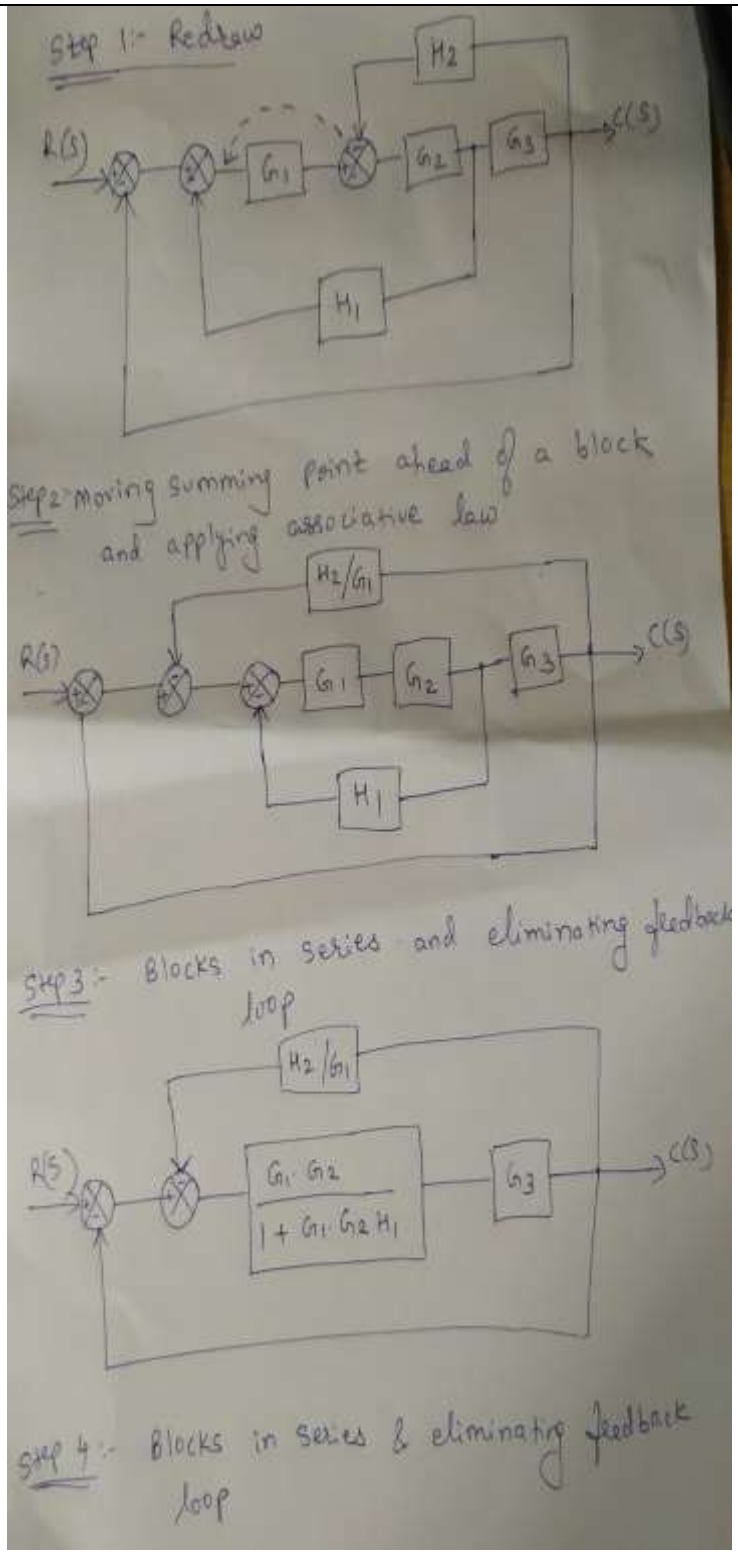
Or:

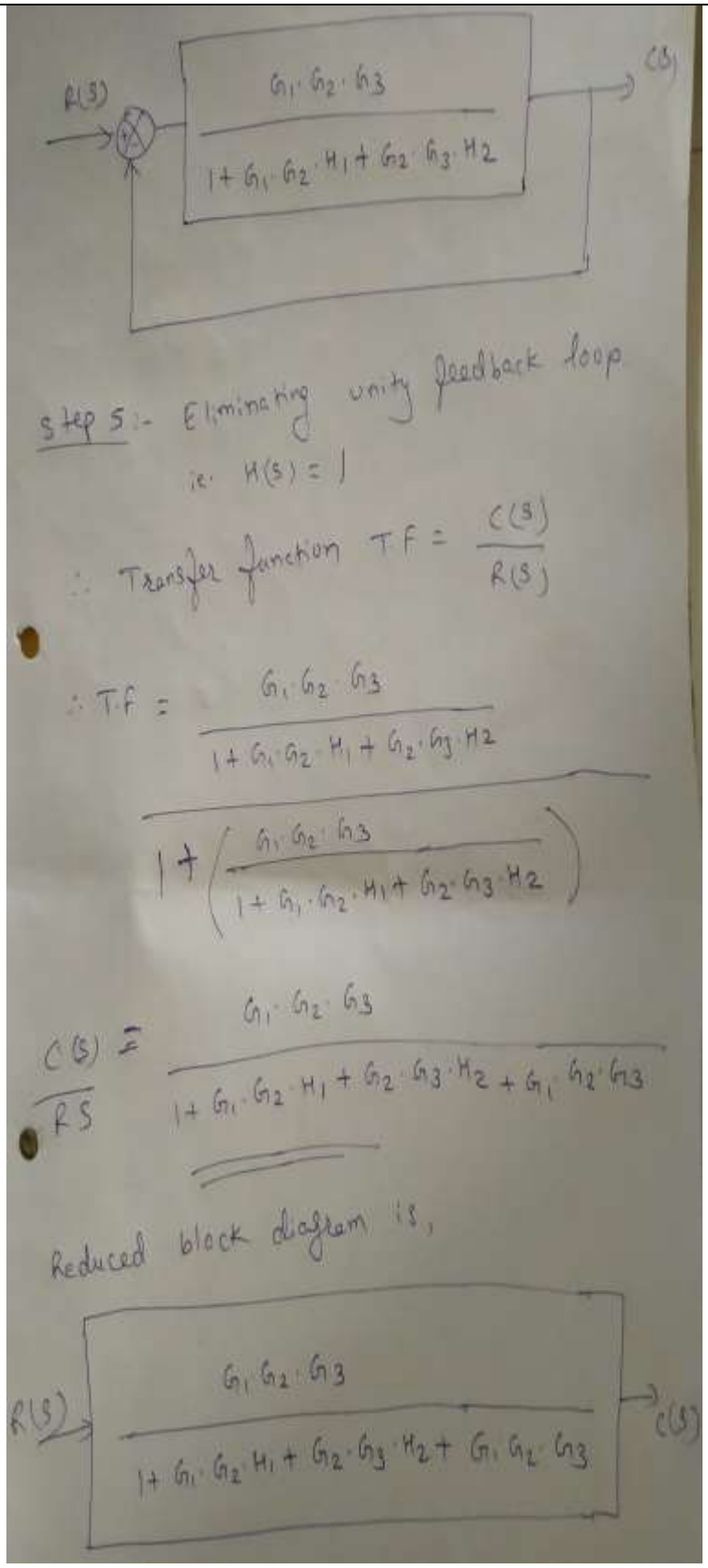
Neutral Zone: it is the range of error in ON-OFF controller for which the controller output remains constant.



(B)	**Attempt any ONE of the following:**	**06- Total Marks**
(a)	**Explain CPU & Memory related to CPU used in PLC.**	**6M**
Ans:	**CPU Section**:- Central Processing Unit (CPU) controls and supervises all operations within the PLC, carrying out programmed instructions stored in the memory. An internal communications highway, or bus system, carries information to and from the CPU, memory and I/O units, under control of the CPU. **Memory** :-  Different types of memory that generally used in PLC are as follows 1. Random Access memory -i)NOVRAM 2. Read only memory -i)PROM ii)EPROM iii)EEPROM	**CPU : 2M** **Memory : 4M**

		1. Random Access memory-RAM is volatile memory means as the power is lost, it's memory erased. But if CPU has battery backup, the information in RAM can not be erased. RAM memory is used to save input data and output information. **i) NOVRAM**- It is one of the type of RAM. NOVRAM is the combination of EEPROM and RAM. When power is go off, the contents of RAM memory are quickly stored in the EEPROM. And the stored data can be read from RAM when power is again restored. **2. ROM**-It is non volatile memory, and used for storing users program so that the program can retain during power failure. **i) PROM**-It is the type of ROM .It is similar to ROM except that it may be programmed once and once only by the user. To change the program in a programmed PROM, throw it away and replace it with a new unprogrammed PROM. **ii) EPROM**- It is the type of ROM. The erasable programmable read-only memory (EPROM) is a PROM that can be erased. The data in the EPROM can be erased by focusing the UV light for a few minutes on the top of EPROM. Thus it is also called as UVPROM. **iii) EEPROM**- It is the type of ROM. The electrically erasable programmable read only memory is similar to the EPROM .Instead of UV light exposure for erasure, an electrical signal is applied to the chip. The speed of erasing of EEPROM is greater than EPROM.	
	(b)	**Determine the transfer function of the given block diagram using block reduction rules.** 	**6M**

	Ans:		**Each step : 1M** **Final answer : 1M**



Step 5:- Eliminating unity feedback loop

ie. $H(S) = 1$

$\therefore$ Transfer function $TF = \frac{C(S)}{R(S)}$

$$\therefore TF = \frac{\frac{G_1 G_2 G_3}{1 + G_1 G_2 H_1 + G_2 G_3 H_2}}{1 + \left(\frac{G_1 G_2 G_3}{1 + G_1 G_2 H_1 + G_2 G_3 H_2}\right)}$$

$$\frac{C(S)}{RS} = \frac{G_1 G_2 G_3}{1 + G_1 G_2 H_1 + G_2 G_3 H_2 + G_1 G_2 G_3}$$

Reduced block diagram is,

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Q. No.	Sub Q. N.	Answers	Marking Scheme
2		**Attempt any TWO of the following:**	**16- Total Marks**
	(a)	**For given transfer function** **T.F.=** $\frac{10(S+8)}{S(S+4)(S^2+6S+25)}$ **Find:** **(i) Poles** **(ii) Zeros** **(iii) Characteristic equation** **(iv) Order of system** **(v) Type of control system and** **Plot the S-plane with poles, zeroes for the system.**	**8M**

Ans:

$$\frac{C(s)}{R(s)} = \frac{10(s+8)}{s(s+4)(s^2+6s+25)}$$

i) Poles :- Poles are the roots of the Equ^n obtained by equating denominator to zero i.e (1M)

$s(s+4)(s^2+6s+25)$

$\therefore s = 0, \; s+4 = 0, \; s^2+6s+25 = 0$

$s = -4, \quad s = \frac{-6 \pm \sqrt{6^2-4(1)(25)}}{2(1)}$

$= \frac{-6 \pm \sqrt{36-100}}{2}$

$= \frac{-6 \pm 8i}{2} = -3 \pm 4j$

$\therefore s = 0, -4, -3 \pm 4j$

ii) Zeros :- Zeros are the roots of the equation obtained by equating numerator to zero (1M)

i.e, $s+8 = 0$

$s = -8$.

iii) Characteristic Equ^n :- (1M)

It is given by

$s(s+4)(s^2+6s+25) = 0$

$(s^2+4s)(s^2+6s+25) = 0$

$s^2(s^2+6s+25) + 4s(s^2+6s+25) = 0$

$s^4+6s^3+25s^2+4s^3+24s^2+100s = 0$

$\therefore s^4+10s^3+49s^2+100s = 0$.

iv) Order of system :- (1M)

It is the highest power of 's' in the denominator of closed loop T.f i.e chkts Equ^n

$\therefore$ Order $= 4$.

2M for Poles

1M for Zeros

1M for Chkt Equ

1M for Order

v) Type of control system :- (1M)

$$T.f = \frac{10(s+8)}{s(s+4)(s^2+6s+25)}$$

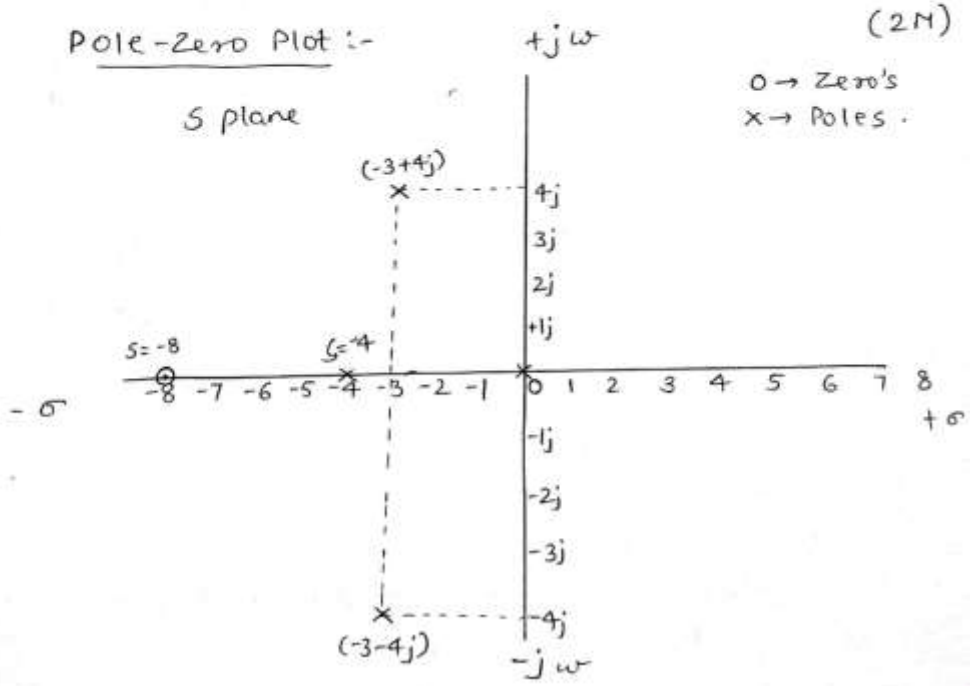
$$= \frac{10(s+8)}{s(s+4)(s+3+4i)(s+3-4i)}$$

$$= \frac{10(s+8)}{4s(1+0.25s)\cdot 25\left[1+\frac{s}{3+4j}\right]\left[1+\frac{s}{3-4j}\right]}$$

∴ Type of system is 1.

1M for Type

Pole-Zero Plot :- (2M)



2M for Pole-Zero plot

b) **A Unity Feedback system has** **8M**

G(S) = $\frac{40(S+2)}{S(S+1)(S+4)}$

Determine:

(i) The error co-efficients &

(ii) Error for ramp input with magnitude 4.

	Ans:	$G(s) = \frac{40(s+2)}{s(s+1)(s+4)}$ (i) Error coefficients :- (4M for Error coefficients) $K_p = \lim_{s\to 0} G(s)H(s) = \lim_{s\to 0} \frac{40(s+2)}{s(s+1)(s+4)} = \infty$ $K_v = \lim_{s\to 0} sG(s)H(s) = \lim_{s\to 0} s.\frac{40(s+2)}{s(s+1)(s+4)} = 20$ $K_a = \lim_{s\to 0} s^2G(s)H(s) = \lim_{s\to 0} s^2.\frac{40(s+2)}{s(s+1)(s+4)} = 0$ (ii) Error for ramp input with magnitude 4 (4 M) Steady state error for unit Ramp input $e_{ss} = \frac{A}{K_v}$ Where, $K_v = \lim_{s\to 0} s.G(s)H(s) = 20$ & $A = 4$ $\therefore e_{ss} = \frac{04}{20}$ $\therefore \boxed{e_{ss} = 0.2}$	**4M for Error Coefficients** **4M for steady state Error**
	c)	**Draw ladder diagram for 2 motor operation for following condition :** **(i) Start push button start motor M_1 & M_2.** **(ii) Stop push button stop motor M_1 first & after 10 seconds motor M_2.**	**8M**
	Ans:	Input/output address description - List of inputs and their addresses Start Button – I: 0/0	**1M for address**

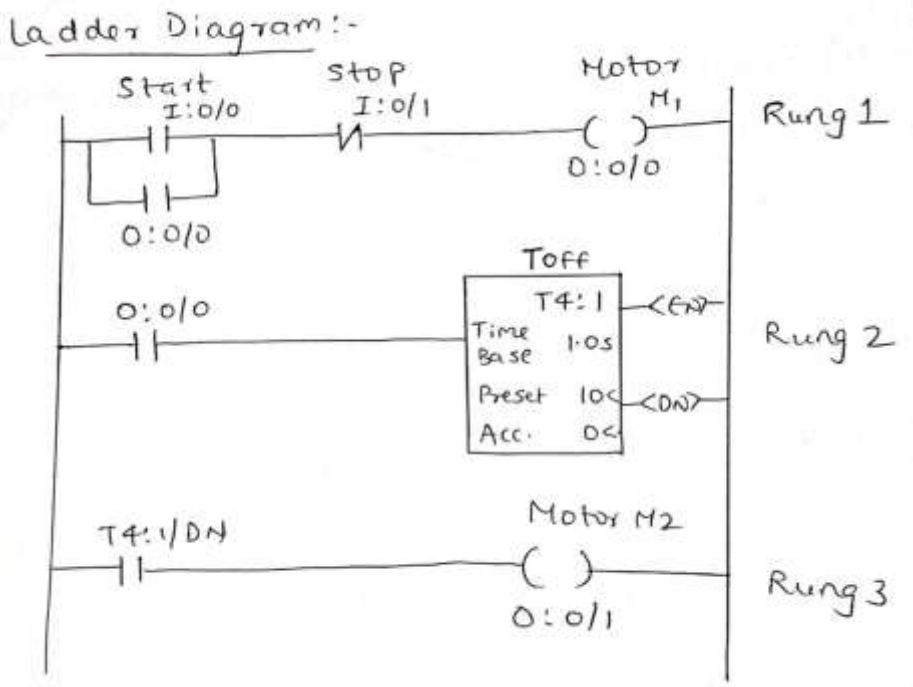
Stop Button – I: 0/1

List of outputs and their addresses

Motor M1 – O: 0/0

Motor M2 – O : 0/1

TOFF timer- T4 :1



4M for Ladder Diagram

Explanation –

Rung 1:

When start button is pressed motor M1 is ON.

Rung 2:

When motor M1 is ON, its auxiliary contact with same address gets closed which turn ON the OFF delay timer T4:1.

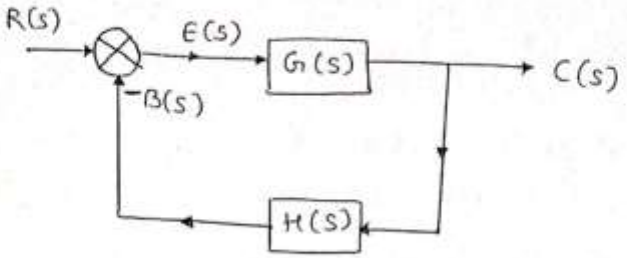
Rung 3:

When OFF delay timer gets supply DN bit is set which turn ON the output O:0/1 i.e motor

3M for Explanation

		M2. When stop button is pressed then main motor M1 shutdown immediately &its contact get open. Therefore supply of OFF delay timer goes OFF but its DN bit gets open after 10 sec so motor M2 remains ON for 10 sec even though motor M1 is OFF.	

Q. No.	Sub Q. N.	Answers	Marking Scheme
3		**Attempt any FOUR of the following:**	**16- Total Marks**
	a)	**Find the transfer function of closed loop control system with negative feedback.**	**4M**

	Ans:	Derivation of T.f of closed loop control System:-  R(S) → laplace of reference input r(t) C(S) → laplace of controlled output c(t) E(S) → laplace of error signal e(t) B(S) → laplace of feedback signal b(t) G(S) → Equivalent forward path T.F H(S) → Equivalent feedback path T.f Referring to fig. above we can write Equ^s as $E(S) = R(S) - B(S) \rightarrow (1)$ $B(S) = C(S)\,H(S) \rightarrow (2)$ $C(S) = E(S)\,G(S) \rightarrow (3)$ $B(S) = C(S)\,H(S)$ and substituting in Equ^ (1) $E(S) = R(S) - C(S)\,H(S)$ $E(S) = \frac{C(S)}{G(S)}$ $\frac{C(S)}{G(S)} = R(S) - C(S)\,H(S)$ $C(S) = R(S)\,G(S) - C(S)\,G(S)\,H(S)$ $\therefore C(S)\,[1 + G(S)\,H(S)] = R(S)\,G(S)$ $\therefore \boxed{\frac{C(S)}{R(S)} = \frac{G(S)}{1 + G(S)\,H(S)}}$ for negative feedback	**4M for Correct Derivation**
	b)	**Explain the benefits of PLC. (any four)**	**4M**

	Ans:	**Benefits of PLC:-** 1. Reduce human efforts 2. Maximum efficiency through machine and logic is controlled by human 3. Higher productivity 4. Superior quality of end products 5. Efficient uses of energy and raw material 6. Eliminate the high costs associated with inflexible, relay-controlled systems 7. Improved safety in working conditions. 8. Easily programmed and have an easily understood programming language.	**1M for correct point**
	c)	**Determine the stability of the closed loop unity feedback system using Routh criteria:** **G(S) =** $\frac{2}{S(S+1)(S+2)}$	**4M**

	Ans:	Characteristic Equation is, $1 + G(s)H(s) = 0$ $\therefore 1 + \frac{2}{s(s+1)(s+2)} = 0$ $\therefore s(s^2+3s+2) + 2 = 0$ $s^3+3s^2+2s+2 = 0$ Routh's array is :- s^3 | 1 2 s^2 | 3 2 s^1 | 1·33 0 s^0 | 2 As there is no sign change, system is stable.	**2M For Routh's Array** **2M For condition**
	d)	**Define control system. Compare open loop & closed loop control system. (any six)**	**4M**

Ans:

Control System : Control system is an arrangement of different physical elements connected in such a manner so as to regulate, direct, command itself or some other system.

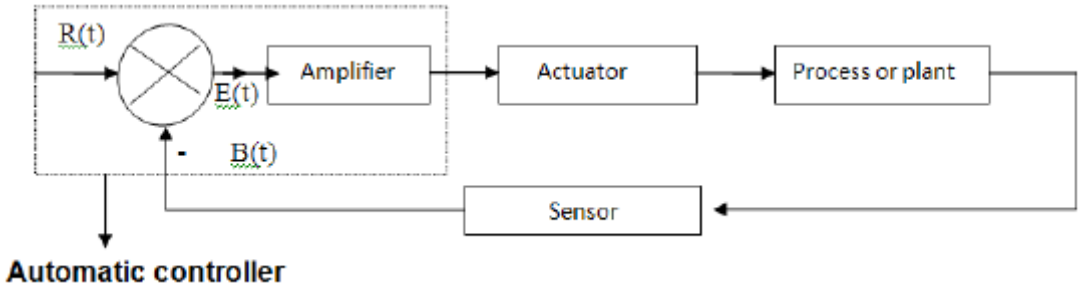
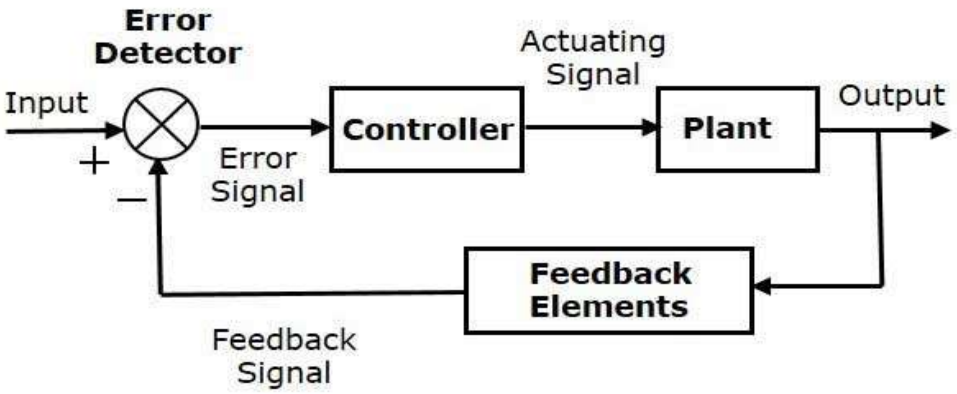
1Marks for definition

3 Marks for comparison (1/2 M for each point)

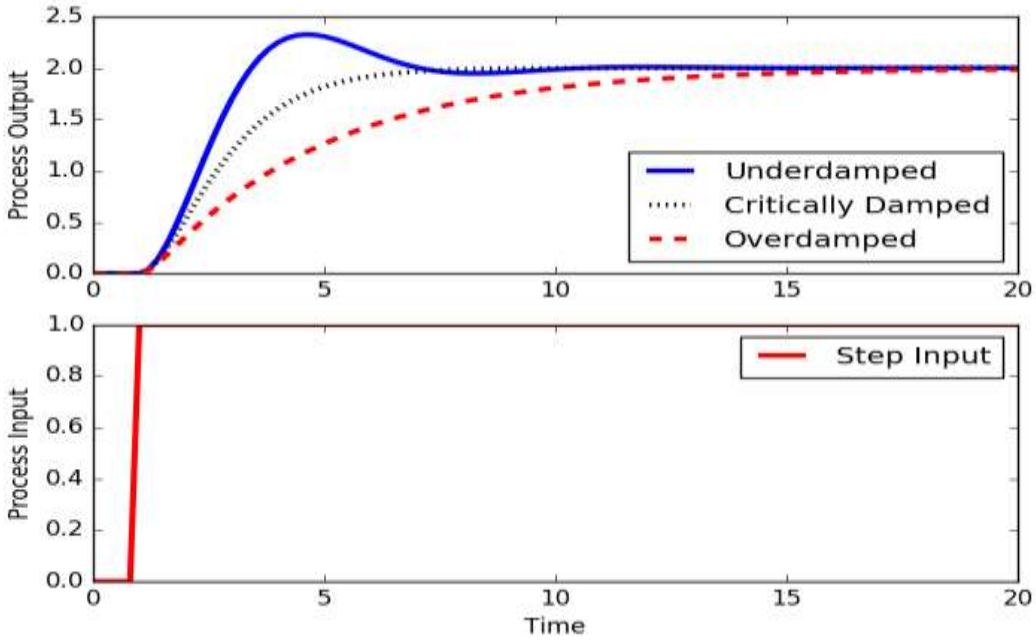
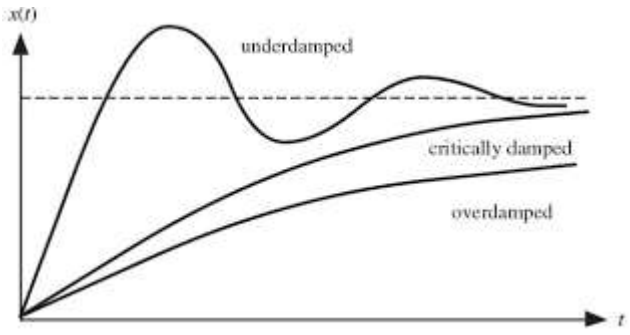
Sr. No.	Open Loop Control System	Close Loop Control System
1	It is simple and economical	It is complex and costlier.
2	It is easier to construct, as it requires less number of components	It is not easy to construct, as it requires more number of components
3	It consumes less power	It consumes more power
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

	e)	**Explain :** **(i) Scanning cycle** **(ii) Speed of execution**	**4M**
	Ans:	**(i) Scanning Cycle** :- 1. It is number of states/steps which the controller follows when it is put in RUN mode. 2. It is also called as operating cycle and is defined as "the number of states through which the controller scan the program before execution" 3. The loaded program is kept in memory of PLC and every time the program will be scan by the PLC. 4. The significance of scan cycle in PLC is to test the program and make it error free by going through above four states i.e. self test, input scan, program scan and output scan. **(ii) Speed of execution:** The speed at which PLC scans memory and executes the program is referred as a speed of execution. Higher CPU speeds provide faster performance that shortens task time.	**2M for each explanation**

Q. No.	Sub Q. N.	Answers	Marking Scheme
4	**(A)**	**Attempt any THREE of the following:**	**12- Total Marks**
	(a)	**Draw block diagram of process control system &describe the need of controller.**	**4M**

	Ans:	 **Automatic controller** **OR**  **NOTE: Any relevant diagram must be considered** **Need of controller** 1.To reduce human efforts. 2. To get maximum efficiency from machine and control them with human logic 3.To reduce complex circuitry of entire system 4. To eliminate the high costs associated with inflexible, relay-controlled systems. 5. Replacing Human Operators (Dangerous Environments & Beyond Human Capabilities)	**Block Diagram -2M** **Need of Controller-2M**
	(b)	**List any four specification of discrete DC input module.**	**4M**

	Ans:	**Specification of discrete DC input module.** Inputs per module: 8 (sink/source) Commons per module: 8 (isolated) Input voltage range: 20–52.8VDC Peak voltage: 52.8VDC ON voltage level: >18 V OFF voltage level: < 7V Input impedance: 4.8 K Ω Input current @ 24 / 48 VDC: 5 mA / 10 mA Minimum ON current: 3.5 mA Maximum OFF current: 1.5 mA Base power required 5V: 100 mA max OFF to ON response: 3–10 ms ON to OFF response: 3–12 ms Terminal type: Removable Status indicators: Logic Side Weight: 8.8 oz. (250 g)	**Any Four Specifications**
	(c)	**List different input devices & output devices used in PLC.**	**4M**
	Ans:	**Input device:** 1. Push button. 2. Temperature switches. 3. Limit switches. 4. Pressure switches. 5. Level Switches. 6. Proximity Switches. **Output devices:** 1. Motor. 2. Display. 3. Heater coil. 4. Relay. 5. Solenoid valve 6. Timer	**02 marks for input devices (Any four)** **02 marks for output devices (Any four)**

	(d)	**Draw the time response of second order control system for underdamp and overdamp conditions.**	**4M**
	Ans:	 **OR:**  **NOTE: Any relevant response must be considered.**	**2M for underdamp and 2M for overdamp conditions.**

	(B)	**Attempt any ONE of the following:**	**06- Total Marks**
	(a)	**List the timer instruction of PLC. Explain any one of them in details.**	**6M**
	Ans	Depending on the time delay and operation, there are two types of timers **PLC timer**- (i) ON delay timer (ii) OFF delay timer **Description** **(i)** ON delay timer 1) This instruction counts time interval when conditions preceding it in the rung are true. Produces an output when accumulated reaches the preset value. 2) Use T_{on} instruction to turn an output on or off after the timer has been on for a preset time interval. The T_{on} instruction begins to count time base intervals when the rung conditions become true. 3) 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. **Description** **(ii)** OFF delay timer 1)This instruction counts time interval when conditions preceding it in the rung are produces low	**Timer instruction list- 2M** **Explanation-4m** **(Any one)**

output when accumulated value reaches the preset value.
2) 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.
3) As long as rung conditions remain false the timer increments its accumulated value each scans 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.

	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	Accumulat or value		16 bit

Status bit explanation-

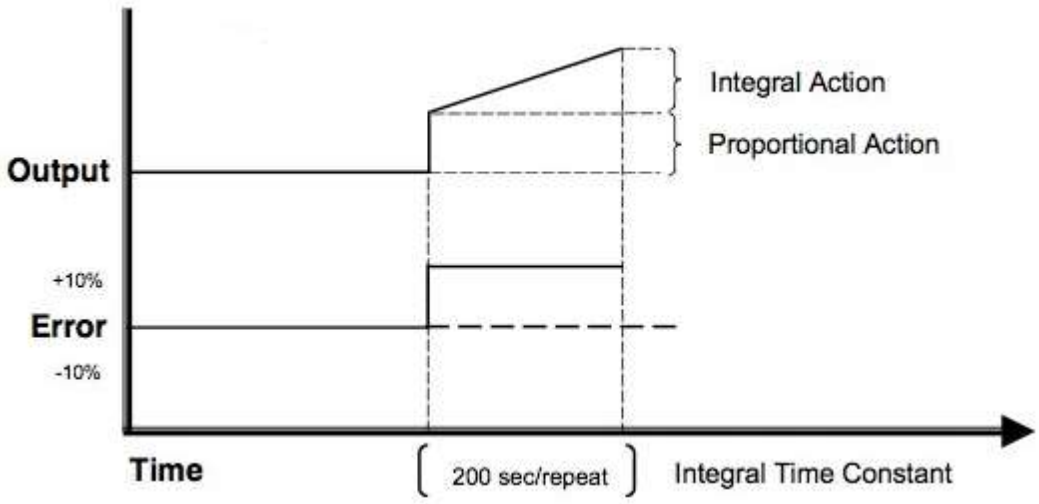
i) Timer done bit(bit13)-DN is reset when the accumulated value is equal to or greater than the preset value.It is set when rung condition are true.
ii) Timer enable bit(bit 14)-EN is set when rung condition are true. It is reset when rung condition become false.
iii) Timer timing bit(bit15)-TT is set 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.

(b)	**Explain PI control action. State its equation. State advantages of PI control. (any two)**	**6M**
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 $P(t) = k_p e(t) + k_p k_i \int_0^t e(t)\,dt + p(0)$	**Explanation-2M** **Equation-2M**

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.



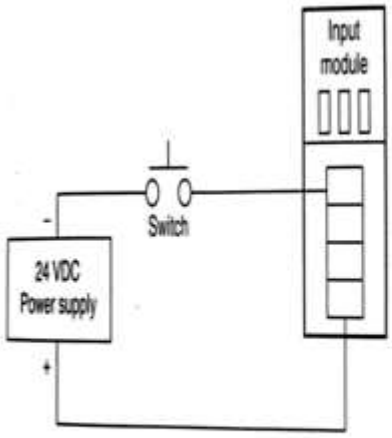
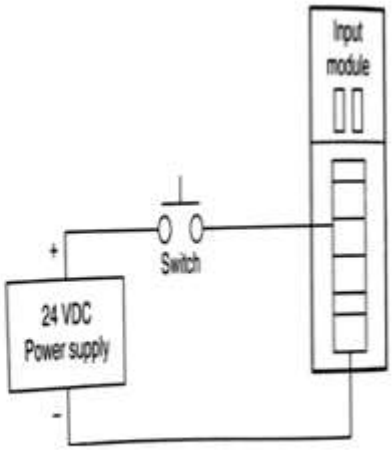
Advantages-2M

(Any Two)

Advantages of PI mode

1. It eliminates offset error i.e improves the steady state accuracy.
2. It decreases bandwidth of the system.
3. It increases the rise time so response becomes slow.
4. It filters out the high frequency noise.

Q. No.	Sub Q. N.	Answers	Marking Scheme
5.		**Attempt any TWO of the following:**	**16- Total**

			Marks
	(a)	**Describe sourcing & sinking concept in DC input module in PLC.**	**8M**
	Ans:	 **fig 1-Sourcing D.C input module with a sinking switch**  **Fig 2 - Sinking D.C input module with a sourcing switch** **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	**Diagram : 4M** **Explanation : 4M**

		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.	
	b)	**A unity feedback control system has** **G(S)=$\frac{26}{S(S+5)}$ if step input is given to the system.** **Calculate:** **(i) Rise time** **(ii) Damping ratio** **(iii) Peak overshoot** **(iv) Settling time**	**8M**
	Ans:	The open loop transfer function for unity feedback system is given by, $\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)}$ $= \frac{\frac{26}{s(s+5)}}{1+\frac{26}{s(s+5)}}$ $= \frac{26}{s^2+5s+26}$ Comparing with standard equation, $\frac{Wn^2}{s^2 + 2\xi Wn.\, s + Wn^2}$ We get, $Wn^2 = 26$ Therefore Wn = 5.099 rad/sec $2\,\xi\, Wn = 5$ $\xi = 0.49$ **i) Rise time**	**Each point : 2M**

$$t_r = \frac{\pi - \beta}{Wd}$$

Where

$\beta = \tan^{-1}\frac{\sqrt{(1-\xi 2)}}{\xi}$

$\beta = \tan^{-1}(0.8712/0.49) = \tan^{-1}(1.777) = 60.53° = 1.055$ radians

$Wd = Wn\sqrt{1-\xi 2}$

$= 5.099 * 0.8712 = 4.434$ rad/sec

Thus tr= (π – 1.055)/4.434

Therefore, **tr = 0.47 sec**

ii) Damping ratio

$2 \xi Wn = 5$

ξ= 0.49

iii) Peak overshoot

$$Mp\% = 100 \times e^{-\frac{\pi\xi}{\sqrt{1-\zeta^2}}}$$

$= 100 \times e^{-1.766} = 10 \times 0.171$

%Mp= 17.10

iv) Settling time

$$ts = \frac{4}{\zeta Wn}$$

$$= \frac{4}{0.49*5.099}$$

Therefore **ts = 1.601 sec**

	c)	**A system has G(S)=$\frac{K(s+13)}{S(S+3)(S+7)}$** **Where K is positive.** **Determine the range of K value for system stability.**	**8M**
	Ans:	The characteristic equation is given by,	**Charact eristic**

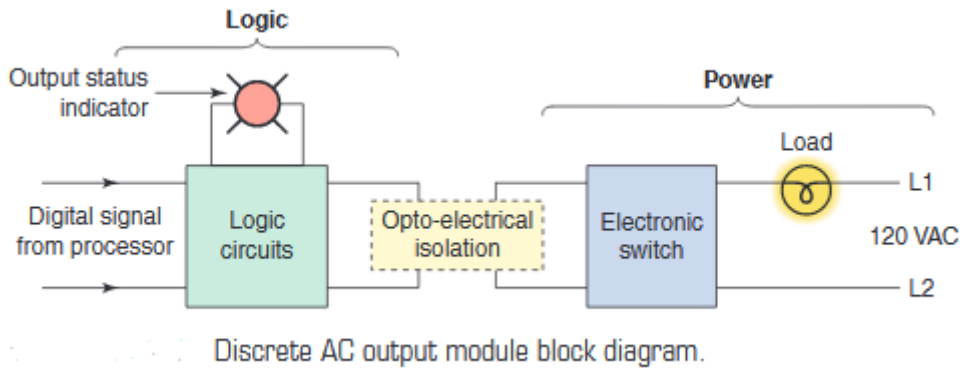
		1+ G(s) H(s) = 0 $1 + \frac{K(S+13)}{S(S+3)(S+7)} = 0$ s (s+3) (s+7) + k(s+13) = 0 $s^3 + 10s^2 + 21s + ks + 13k = 0$ $s^3 + 10s^2 + (21+k)s + 13k = 0$ from this equation, $a_0 = 1$, $a_1 = 10$, $a_3 = (21+k)$ and $a_4 = 13k$ s^3 | 1 21+k 0 s^2 | 10 13k s^1 | (210-3k)/10 0 s^0 | 13k for stability all elements in the first column of routh array must be positive therefore from row of s^0 row , 13k > 0 Therefore k > 0 therefore from row of s^1 row, (210-3k)/10 = 0 210 > 3k K < 70 Since k must be positive , the range of values of k for stability is 0 < k < 70.	**equation :3M** **Routh array : 2M** **2M** **Range : 1M**

Q. No.	Sub Q. N.	Answers	Marking Scheme
6.		**Attempt any FOUR of the following:**	**16- Total**

			Marks
	(a)	**Compare P control action with PID control action. (any four)**	4M
	Ans:	**NOTE : Any Relevant Comparison must be considered**	Any Four Points 1M for each Point

PARAMETER	P CONTROL	PID CONTROL
RISE TIME	Decrease	Minor Decrease
OVERSHOOT	Increase	Minor Decrease
SETTLING TIME	Small change	Minor Decrease
STEADY STATE ERROR	Decrease	No Change
STABILITY	Worse	If Kd small Better
OFFSET	Creates	eliminates

	b)	**State advantages & disadvantages of Routh's Stability criteria.**	4M
	Ans:	**Advantages:** It is a simple algebraic method to determine the stability of closed loop without salving for roots of characteristics equation. It is very useful for single variable, multivariable and loop systems. It progresses systematically. It can determine the range of k for stable operator. It can judge very easily the relative stability of a system. It is not tedious or time consuming method. It helps to determine the conditions of absolute and relative stability of a system. It can give the number of roots of the characteristics equation having positive real part in the unstable systems. **Disadvantages** It becomes complex for system of order more than 6 or 7. It can't be applied if coefficients of characteristics equation are complex It is useful to find out only the absolute stability of a system.	02 Marks each(Any two valid point)

		It is very complex to obtain relative stability of the system It cannot tell whether roots are real or complex It cannot give the exact location of the roots. It is valid only if the characteristics equation is algebraic and all coefficients are real.	
	c)	**Draw & explain AC discrete output module.**	**4M**
	Ans:	 Discrete AC output module block diagram. Discrete input modules perform four tasks in the PLC control system. They: • Sense when a signal is received from a field device. • Convert the input signal to the correct voltage level for the particular PLC. • Isolate the PLC from fluctuations in the input signal's voltage or current. • Send a signal to the processor indicating which sensor originated the signal. Figure. Shows the block diagram for one output of a typical discrete output module. Like the input module, it is composed of two basic sections: the power section and the logic section, coupled by an isolation circuit. The output interface can be thought of as an electronic switch that turns the output load device on and off. Logic circuits determine the output status. An output LED indicates the status of the output signal.	**Diagram -2M** **Explanation-2M**
	d)	**Explain PD control action. State advantages of PD control.(any two)**	**4M**

Ans:

- 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.

Explanation-2M

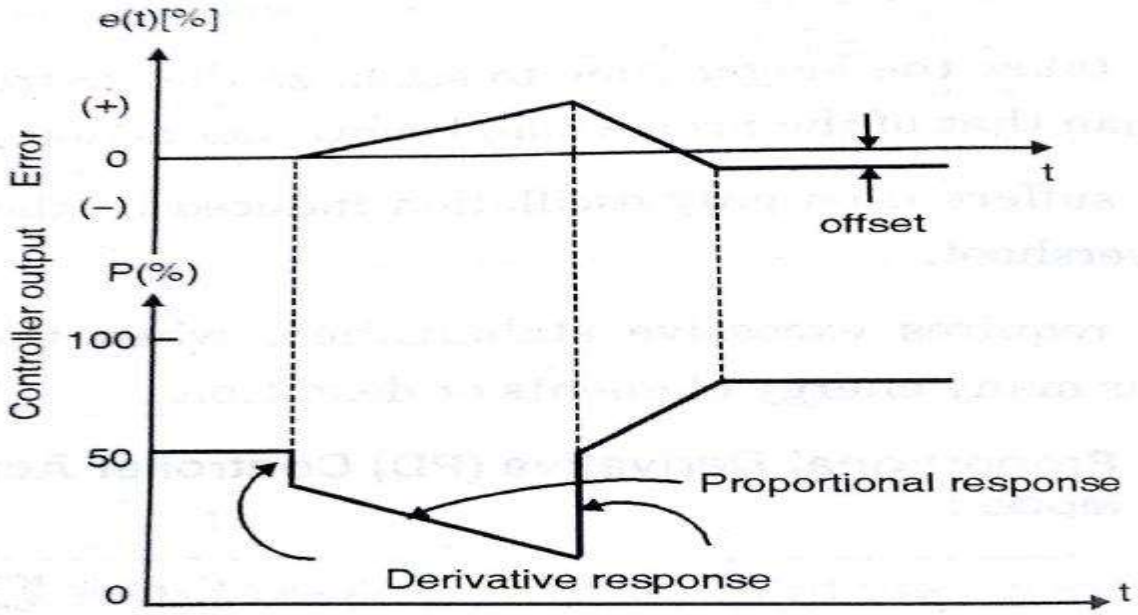
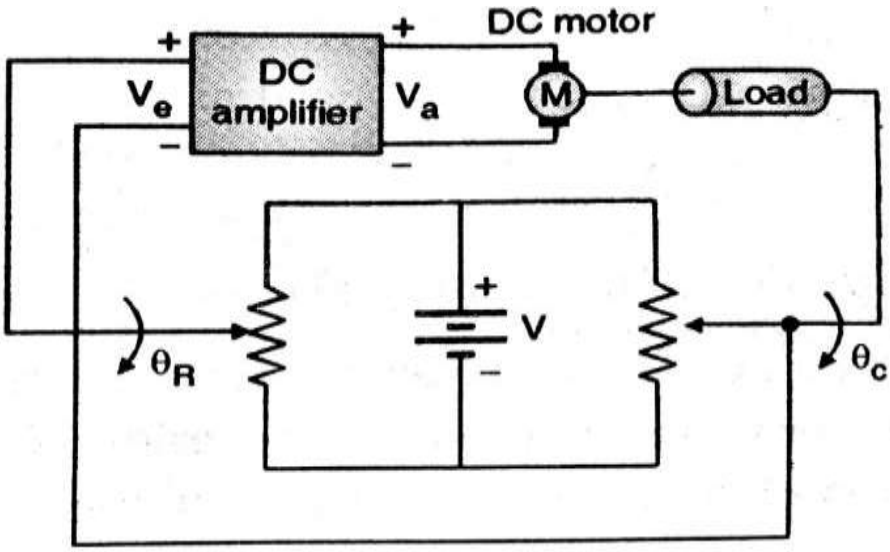


Fig- Proportional-Derivative action.

Advantage of PD mode

1. It improves the damping &reduces overshoot.
2. It reduces the rise time.
3. It allows the rise of narrower proportional band with its lesser offset.
4. Increases the controller gain during the error changes.
5. Can compensate the rapidly changing error.
6. Can handle the fast processes.
7. Can compensate some of the lag in a process.

Advantages-2M (Any Four)

	e)	**Define servo system. Draw & label the functional block diagram of DC servo motor.**	**4M**
	Ans:	Definition: Servo system is defined as automatic feedback control system working on error signals giving the output as mechanical position, velocity or acceleration.  1) The servo system consists of error detector, amplifier, motor as controller, load whose position is to be changed. 2) 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. **(NOTE :Explanation is optional)**	**Definati on-1M** **Diagram with labeling-3M**