WINTER – 19EXAMINATION

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

Important Instructions to examiners:

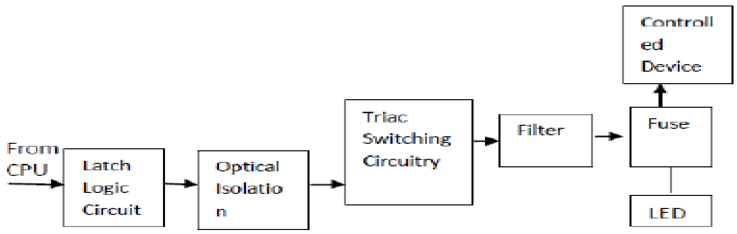
1) The answers should be examined by key words and not as word-to-word as given in themodel answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may tryto assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling 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.	Answer	Marking Scheme
Q.1	**(A)**	**Attempt any THREE:**	**12-Total Marks**
	i)	**State need of PLC in automation. List any four benefits of PLC in automation.**	**4M**
	Ans:	**Need of automation in Industries :** 1. To Increase productivity 2. To Increase product quality 3. To Increase flexibility and convertibility 4. Reduces manpower 5. Reduction of personal accident 6. Reduces cost of product 7. Better inventory control 8. Increases profit **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.	**2M** **2M**
	ii)	**Draw the Block diagram of DC output module and explain threshold detector block in**	**4M**

it.

Ans: **2M**

Block diagram of DC output module:



OR

Any other relevant diagram shall be considered

Threshold detection: **2M**

Threshold detection circuitry detects if the incoming signal has reached or exceeded a predetermined value for a predetermine time, and whether it should be classified as valid ON or OFF signal.

iii) **List the timer instruction of PLC. Explain any of them in detail.** **4M**

Ans: Depending on the time delay and operation there are two types of timers **1M**

PLC timer-

- ON delay timer
- OFF delay timer

ON delay timer : **3M**

1) This instruction counts time interval when conditions preceding it in the rung are true. Produces an output when accumulated value reaches the preset value.
2) 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.
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.	

OR

OFF delay timer

1) This instruction counts time interval when conditions preceding it in the rung are false. Produces low 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 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.

	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)	**Write the expression of proportional controller and define :** **(1) Proportional Band** **(2) Offset**	**4M**
	Ans:	**(1) Proportional Band**	**2M**

The proportional band is the band of controller output over which the final control element will move from one extreme to another. Mathematically, it can be expressed as:

$$PB = \frac{100}{K_p}$$

So if the proportional gain, is very high, the proportional band is very small.

OR

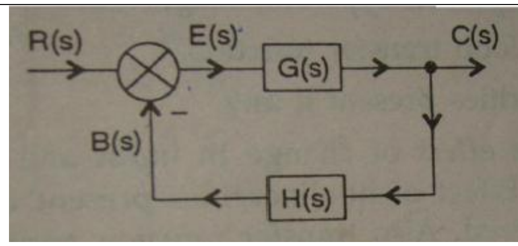
Proportional Band: It is defined as percentage of error which results in 100% change in controller output

Offset in proportional controller: **2M**

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

B)		**Attempt any <u>ONE</u>:**	**6-Total Marks**
	i)	**Derive the exprssion for steady state error (ess). State two factors on which it depends.**	**6M**

Ans:



1M(Diagram)

$E(s) = R(s) - B(s)$

But $B(s) = C(s) * H(s)$

$E(s) = R(s) - C(s)\,H(s)$

And $C(s) = E(s) * G(s)$

$E(s) = R(s) - E(s)\,G(s)\,H(s)$

$E(s) + E(s)\,G(s)\,H(s) = R(s)$

$E(s) = R(s)/1+G(s)\,H(s)$ for non unity feedback

$E(s) = R(s)/1+ G(s)$ for unity feedback

Steady State error, $ess = \lim_{t \to \infty} e(t)$

By using final value theorem of Laplace transform, $ess = \lim_{S \to 0} S*E(s)$

Substituting E(S) from the expression derived,

$ess = \lim_{S \to 0} SR(s)/1+G(s)H(s)$ where G(s)H(s) is the open loop transfer function.

3M (Derivation)

ess for step input: - 02marks

for step input , R(s) = 1/S ,therefore $ess = \lim_{S \to 0} S*1 / S(1+G(s)*H(s))$

$ess = 1/ \lim_{S \to 0} (1+G(s)*H(s)) = 1/ 1+ \lim_{S \to 0} G(s)*H(s)$

where $\lim_{S \to 0} G(s)*H(s)$ is the position error constant Kp

Therefore ess = 1/1+Kp

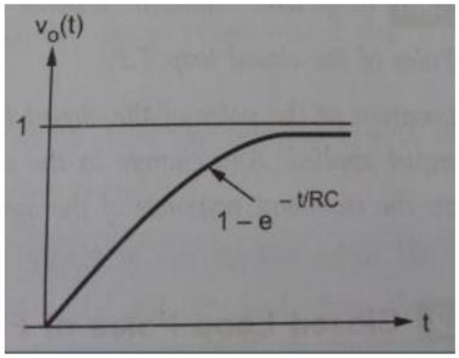
The **steady-state error** will **depend** on the type of input (step, ramp, etc.) as well as the system type (0, I, or II).

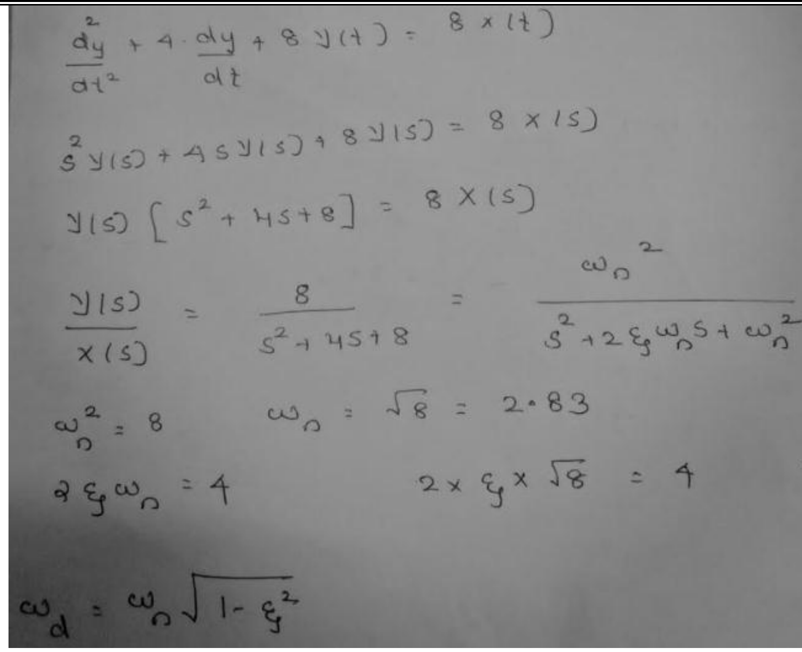
2M (Factors)

ii)	**Compare fixed and modular PLC. (any six points)**		**6M**
Ans:	(table below)		**1M Each (Any 6 points)**

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
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.2		**Attempt any TWO:**	**16-Total Marks**
	a)	**Derive an expression for unit step response of fist order system. Draw its response curve.**	**8M**
	Ans:	Consider a simple first order system be excited by a unit step input. The T.F. of first order system is given by , $\frac{Vo(s)}{Vi(s)} = \frac{1}{1+sRC}$ For unit step input, $v_i(t) = 1$, for $t \geq 0$ $= 0$, for $t < 0$. The Laplace equivalent is $Vi(s) = \frac{1}{s}$ $\therefore Vo(s) = \frac{1}{s(1+sRC)} = \frac{A^1}{s} + \frac{B^1}{1+sRC}$ Using Partial fraction method we get: $A^1 = 1$ & $B^1 = -RC$ Substituting the values of A^1 and B^1, we get $\therefore Vo(s) = \frac{1}{s} - \frac{RC}{1+sRC}$ Taking Laplace inverse, we get $v_o(t) = 1 - e^{-\frac{t}{RC}} \Rightarrow C_{ss} + c_t(t)$ The steady state response $C_{ss} = 1$ and transient term $c_t(t) = -e^{-\frac{t}{RC}}$	**5M** **(Derivation)**

		The output waveform is as shown.  	**3M** **(Response)**
	b)	**Four given differential equation.** $$\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 8y(t) = 8x(t)$$ **Where y = output and x = Input** **Find :** **(i) Settling time (ii) Rise time** **(iii) Peak time (iv) Peak overshoot**	**8M**
	Ans:	Ideally the above 4 listed parameters can be given as, i) Rise time is given by $t_r = \frac{\pi - \beta}{W_d}$, Where $\beta = \frac{\sqrt{1-\zeta^2}}{\zeta}$ ii) Peak Time is given by $t_p = \frac{\pi}{W_d}$ iii) Max overshoot is given by $Mp\% = 100 \times e^{-\frac{\pi\zeta}{\sqrt{1-\zeta^2}}}$ iv) Settling time is given by $t_s = \frac{4}{\zeta . W_n}$	**2M Each**



$$\frac{d^2y}{dt^2} + 4\frac{dy}{dt} + 8y(t) = 8x(t)$$

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

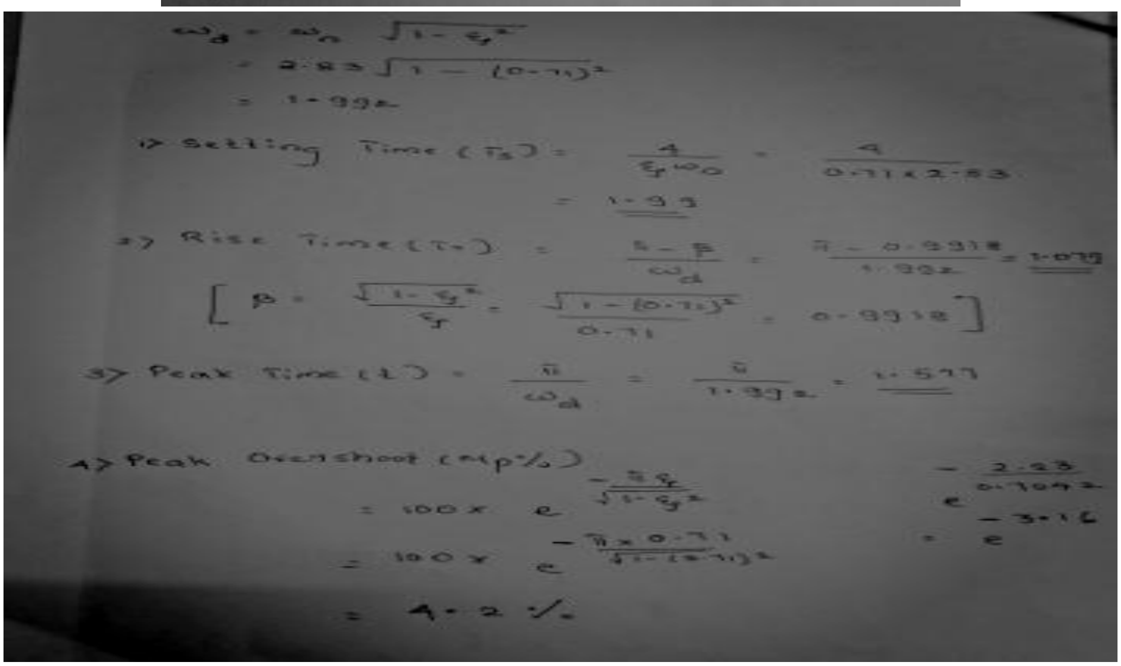
$$Y(s)\left[s^2 + 4s + 8\right] = 8X(s)$$

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

$$\omega_n^2 = 8 \qquad \omega_n = \sqrt{8} = 2.83$$

$$2\xi\omega_n = 4 \qquad 2 \times \xi \times \sqrt{8} = 4$$

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



$$\omega_d = \omega_n\sqrt{1-\xi^2} = 2.83\sqrt{1-(0.71)^2} = 1.992$$

1> Settling Time $(T_s) = \frac{4}{\xi\omega_n} = \frac{4}{0.71 \times 2.83} = 1.99$

2> Rise Time $(T_r) = \frac{\pi - \beta}{\omega_d} = \frac{\pi - 0.9918}{1.992} = 1.079$

$\left[\beta = \frac{\sqrt{1-\xi^2}}{\xi} = \frac{\sqrt{1-(0.71)^2}}{0.71} = 0.9918\right]$

3> Peak Time $(t_p) = \frac{\pi}{\omega_d} = \frac{\pi}{1.992} = 1.577$

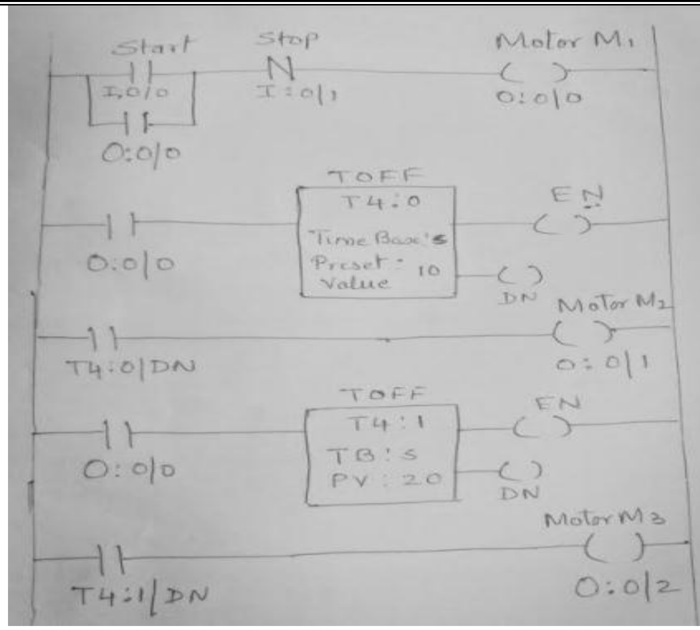
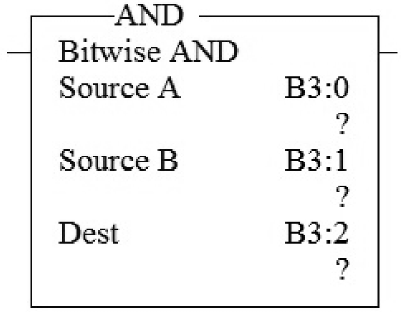
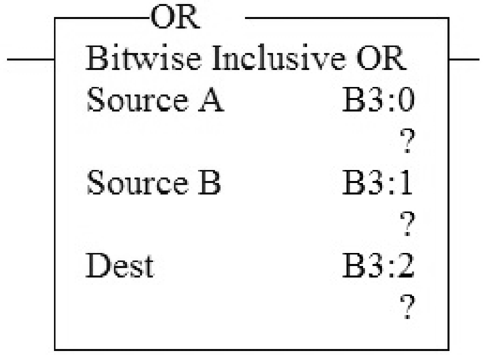
4> Peak Overshoot $(M_p\%)$

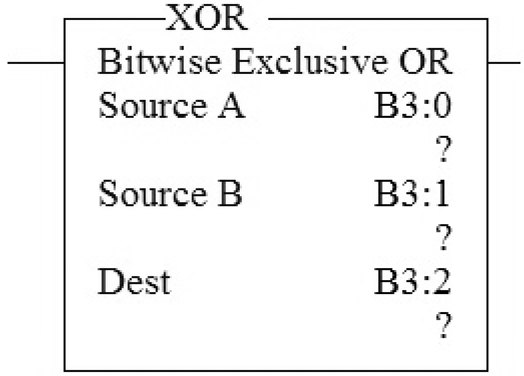
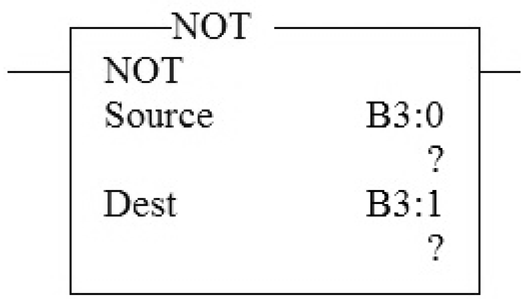
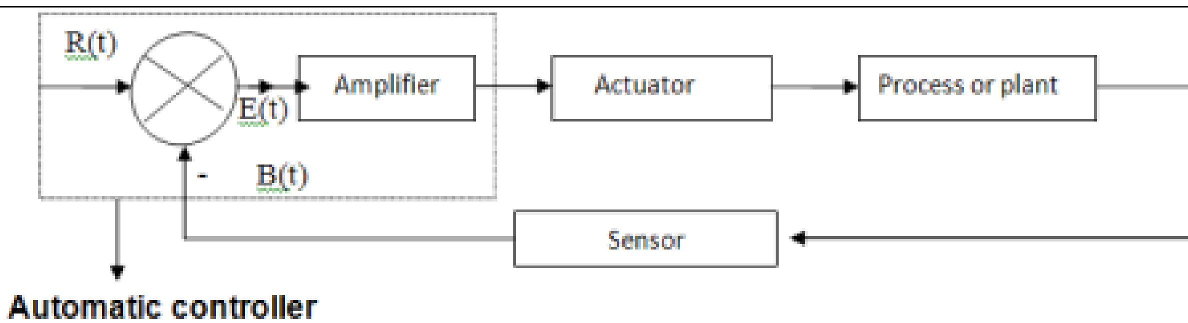
$$= 100 \times e^{-\frac{\pi\xi}{\sqrt{1-\xi^2}}} \qquad e^{-\frac{2.23}{0.7042}}$$

$$= 100 \times e^{-\frac{\pi \times 0.71}{\sqrt{1-(0.71)^2}}} \qquad = e^{-3.16}$$

$$= 4.2\%$$

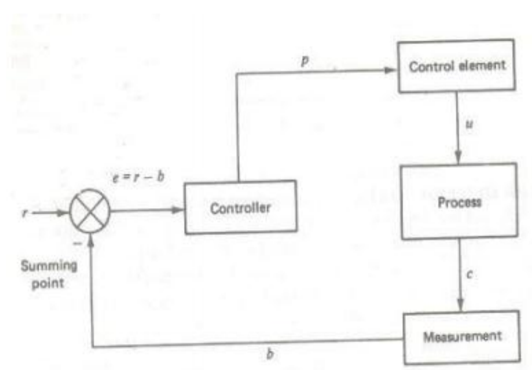
c)	**Draw ladder diagram for 3 motor for following conditions:** **(i) State push button motor M_1,M_2 and M_3.** **(ii) Stop push button, M_1 first, after 10 seconds motor M_2 and after 20 seconds motor M_3.**	**8M**
Ans:	**List of inputs and their addresses** **Start button – I : 0/0** **Stop button – I : 0/1** **List of outputs and their addresses** **Motor M1 – O : 0/0** **Motor M2 – O : 0/1** **Motor M3- O: 0/2** **OFF delay timer –T4.0** **OFF delay timer –T4.1**	**2M List**

			**6M Ladder Program**
Q.3		**Attempt any FOUR :**	**16Marks**
	a)	**Explain any two logical instruction in PLC.**	**4M**
	Ans:	**1) AND instruction**  In the above picture, there are totally three parameters, SOURCE A – Address of First Binary Value SOURCE B – Address of Second Binary Value DESTINATION –AND operation result of Source A & B stored in this address. **2) OR instruction**  In the above picture, there are totally three parameters, SOURCE A –Address of First Binary Value SOURCE B –Address of Second Binary Value	**Any two instructions : 2M each**

		DESTINATION –OR operation result of Source A & B stored in this address **3) XOR instruction**  In the above picture, there are totally three parameters, SOURCE A –Address of First Binary Value SOURCE B –Address of Second Binary Value DESTINATION –XOR operation result of Source A & B stored in this address. **4) NOT instruction**  In the above picture, there are totally two parameters, SOURCE -Address of Binary Value DESTINATION –NOT operation result of Source stored in this address.	
	b)	**Draw block diagram of process system. Explain the function of each block.**	**4M**
	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.	**Diagram :** **2M** **Explanation:** **2M**

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



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".

c) **The control system having unity feedback has** **4M**

$$G(S) = \frac{20}{S(1+4S)(1+S)}$$

Find:

(i) Type of system
(ii) Static error coefficients

Ans:

(i) Type of system

$$G(S) = \frac{20}{S(1+4S)(1+S)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Type of the system : 1M

Each error

$$G(s)H(s) = \frac{K(1+T1s)+(1+T2s)}{S^{j}\ (1+Ta\ s)(1+Tb\ s)}$$

Where j is type of system ....(2)

coefficients : 1M

Comparing equation (1) with equation (2) we get j = 1.Here H (s) = 1
This indicates that the given system is type 1 system.

(ii) **Static error coefficients**

a)

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

$$= \lim_{s \to 0} \frac{20}{s(1+4s)(1+s)}$$

Here H (s) = 1
Therefore, Kp = ∞

b)

$$K_v = \lim_{s \to 0} s.G(s).H(s)$$

$$= \lim_{s \to 0} \frac{20.s}{s.(1+4s)(1+s)}$$

Therefore, Kv = 20

c)

$$K_a = \lim_{s \to 0} S^2.G(s).H(s)$$

$$= \lim_{s \to 0} \frac{20.s.s}{s.(1+4s)(1+s)}$$

Therefore, Ka = 0

d) **For close loop system with positive feedback**

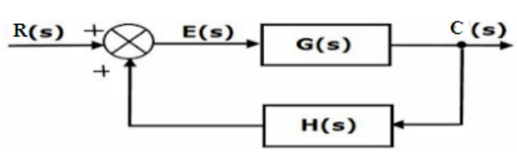
$$\frac{C(S)}{R(S)} = \frac{G(S)}{1 - G(S)\,H(S)}$$

4M

Ans:

Block diagram of closed loop system with positive feedback,

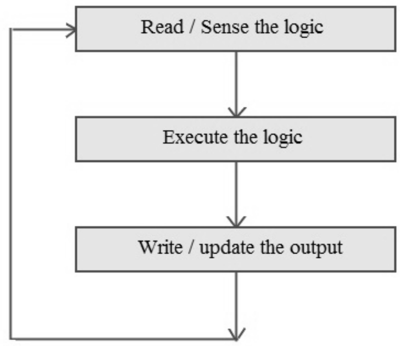
Block diagram : 1M



E(s) = Actuating or Error Signal
R(s) = Reference Input Signal.
G(s) = Forward Path Transfer Function.
C(s) = Output Signal.
H(s) = Feedback Transfer Function.
B(s) = Feedback Signal

Derivation : 3M

		So, the transfer function of the closed loop system is Y(s)/X(s). From the block diagram, C(s) = G(s).E(s) ....1 B(s) = H(s).C(s) ....2 E(s) = R(s) + B(s) ....3 (For positive feedback) Put the value of E(s) from eq.3 in eq.1 C(s) = G(s).[R(s) + B(s)] C(s) = G(s).R(s) + G(s).B(s) ....4 Put the value of B(s) from eq.2 in eq.4 C(s) = G(s).R(s) + G(s).H(s).C(s) C(s) - G(s).H(s).C(s) = G(s).R(s) C(s){1 - G(s).H(s)} = G(s).R(s) $\frac{C(s)}{R(s)} = \frac{G(s)}{1-G(s).H(s)}$	
	e)	**Identify given devices as input and output devices of PLC. State their Use:** **(i) Solenoid valve (ii) Proximity switch** **(ii) Leven sensors (iv) Heater coil**	**4M**
	Ans:	1) Solenoid valve : Output device Use: Solenoid valve is used to control i.e. ON/OFF the instrument air supply to the valve actuator. 2) Proximity switch: Input device Use: Proximity switches are used to detect the presence of an item without making contact with it. 3) Level sensors : Input device Use: Used to monitor the depth of a liquid in a tank. It gives a signal when the level in some container reaches a particular level. 4) Heater coil: Output device Use: It is used to detect the temperature.	**Each device : ½ M** **Each use : ½ M**
Q.4	**(A)**	**Attempt any THREE:**	**12 Total Marks**
	(i)	**Explain scan cycle of PLC with neat diagram.**	**4M**

	Ans:	 **Scan Cycle of PLC** **Step 1: Read / Sense the input** Firstly, PLC reads the on/off status of the external input signals. After scanning the input, it gets stored in the input memory. This input included switches, pushbuttons, proximity sensors, limit switches, pressure switches, etc. **Step 2: Execute the logic by the processor** This scanned input gets transferred to the CPU for processing from input memory. The processor executes the programming instructions based on the input. After the execution, the result (on/off) will be stored in the device memory. **Step 3: Update / write the output:** When the program executes the last instruction, it will send the on/off status to the output device memory. The outputs include solenoids, valves, motors, actuators, and pumps.	**Diagram : 2M** **Explanation : 2M**
	(ii)	**Give the principle of derivative action. Write its standard equation.**	**4M**
	Ans	**Principle of derivative control action:** The controlled output is proportional to the rate of change of error signal OR The output of the controller is proportional to derivative of the input signal. **Mathematical expression:** $P = K_D * [de_p / dt]$ **OR** $P(t) = K_D * [de(t) / dt]$ Where K_D = Derivative gain constant and $[de_p / dt]$ = rate of change of error signal	**Principle : 2M** **Expression : 2M**
	(iii)	**(i) Determine the stability of given system by Routh's array method having characteristic equation as** $S^6 + 2S^5 + 8S^4 + 12S^3 + 20S^2 + 16S + 16 = 0$	**4M**
	Ans	**Given,** $S^6 + 2S^5 + 8S^4 + 12S^3 + 20S^2 + 16S + 16 = 0$ **Step 1** : Routh's array	**Each step : 1M**

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				

Step 2 : Make auxiliary equation of the row which is just above row of zero.

$A(s) = 2s^4 + 12s^2 + 16$

Take $\frac{d\,A(s)}{ds} = 8s^3 + 24s$

Step 3 : 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			

Step 4 :

As there is no sign change system may be marginally stable or unstable

To examine this, solve A(s) = 0

$2s^4 + 12s^2 + 16 = 0$

Put $s^2 = t$

Therefore,

$2t^2 + 12\,t + 16 = 0$

$(2t + 4)\,(t + 4) = 0$

$t = -2$ and $t = -4$

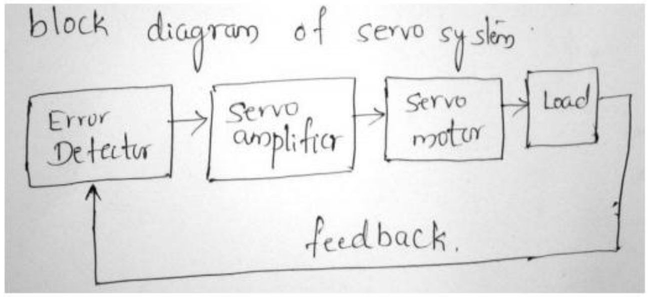
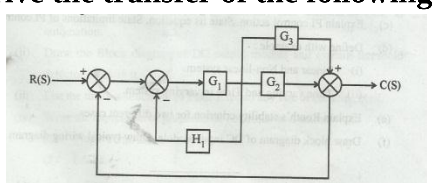
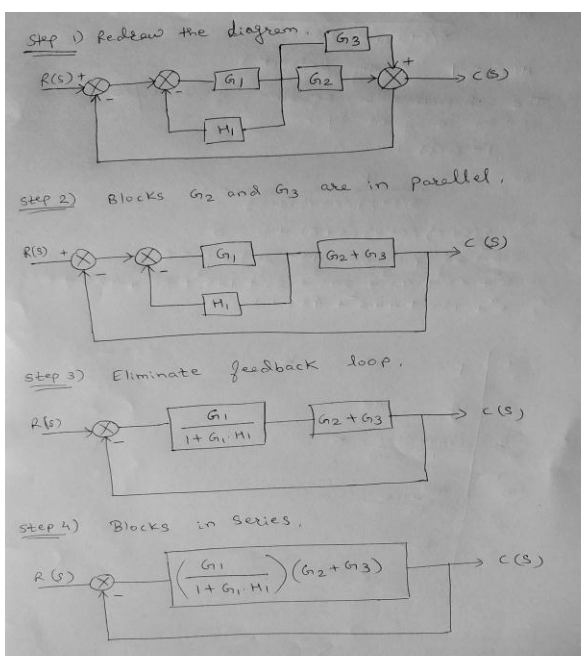
But $s^2 = t$

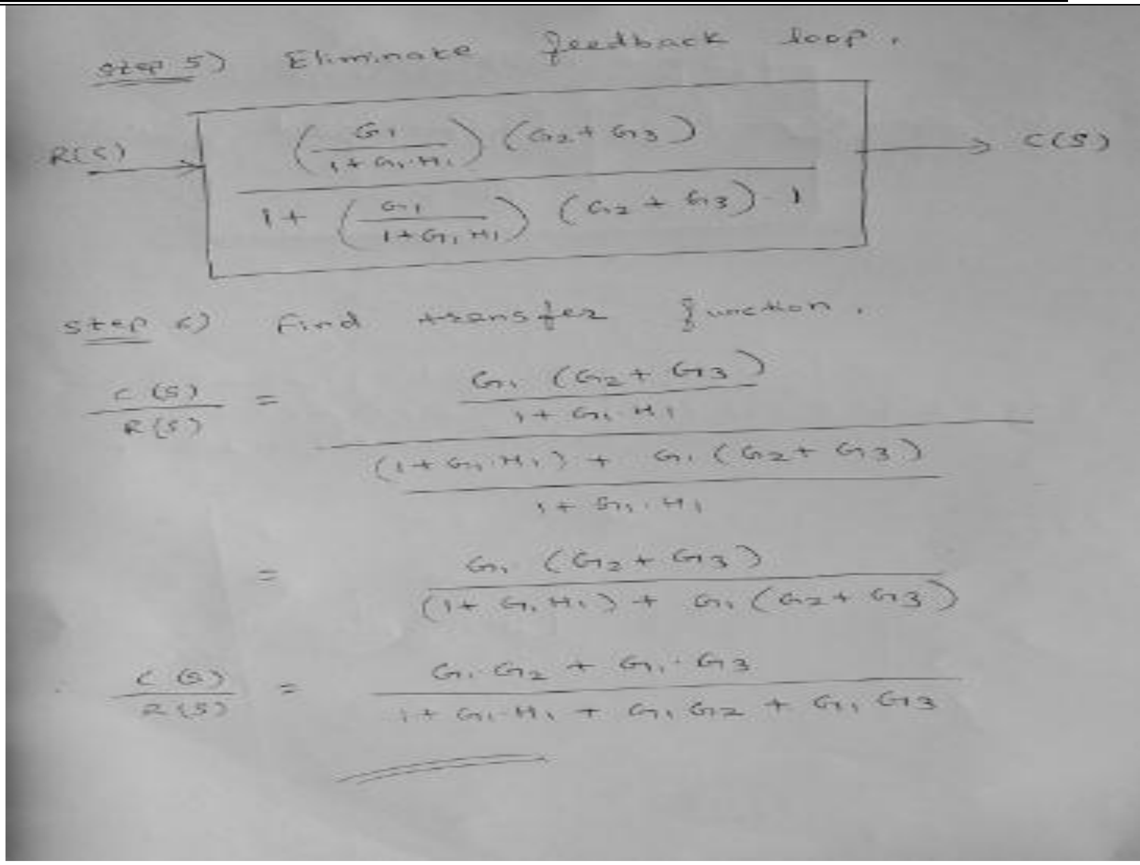
$s^2 = -2$ and $s^2 = -4$

therefore $s = \pm\, 1.41\, j$ and $s = \pm\, 2j$ (It shows that four poles are on imaginary axis.)

Hence system is marginally stable.

	(iv)	(i) **Define servo system. Draw explain block diagram of servo system.**	**4M**

	Ans	**Definition of Servo system:-** Servo systems are automatic feedback control systems which work on error signals with o/p in the form of mechanical position, velocity or acceleration.  **Error detector**: It may potentiometer (in DC servo system) or synchro (in AC servo system). One of the i/p of error detector is reference i/p and other is connected to load. The difference between these two i/ps is error signal. **Servo amplifier**: The error is amplified by amplifier. **Servo motor**: it may be AC, DC or stepper. Servo motor is connected to load mechanically. Thus motor can adjust the load position according to error. Thus this system automatically tries to connect any deviation to the error detector changes according to the error.	**Definition: 1M** **Block diagram : 1M** **Explanation : 2M**
	(B)	**Attempt any ONE:**	**6M**
	(i)	**Define transfer function. Derive the transfer of the following block diagram.**  	**6M**
	Ans	**Transfer function:** It is defined as the ratio of Laplace transform of output of the system to Laplace transform of input of the system.  	**Definition : 1M** **1M each step**



step 5) Eliminate feedback loop.

$$R(S) \rightarrow \frac{\left(\frac{G_1}{1+G_1H_1}\right)(G_2+G_3)}{1+\left(\frac{G_1}{1+G_1H_1}\right)(G_2+G_3)\cdot 1} \rightarrow C(S)$$

step 6) Find transfer function.

$$\frac{C(S)}{R(S)} = \frac{\frac{G_1(G_2+G_3)}{1+G_1H_1}}{\frac{(1+G_1H_1)+G_1(G_2+G_3)}{1+G_1H_1}}$$

$$= \frac{G_1(G_2+G_3)}{(1+G_1H_1)+G_1(G_2+G_3)}$$

$$\frac{C(S)}{R(S)} = \frac{G_1G_2+G_1G_3}{1+G_1H_1+G_1G_2+G_1G_3}$$

(ii) **Find the range of K stability of a unity feedback system with characteristic equation.** **6M**

$$G(S) = \frac{K}{S(S+2)(S+4)(S+6)}$$

Ans

Characteristic equation: $1 + G(S)H(S) = S(S+2)(S+4)(S+6) + K = 0$

$$= (S^2 + 2S)(S^2 + 10S + 24) + K = 0$$

$$= S^4 + 12S^3 + 44S^2 + 48S + K = 0$$

Routh's array:

S^4	1	44	K
S^3	12	48	0
S^2	40	K	0
S	(1920-12K)/40	0	0
S^0	K	0	0

For the system to be stable, $K > 0$

$$K > 0$$

$$\frac{1920 - 12K}{40} > 0$$

$$1920 - 12K > 0$$

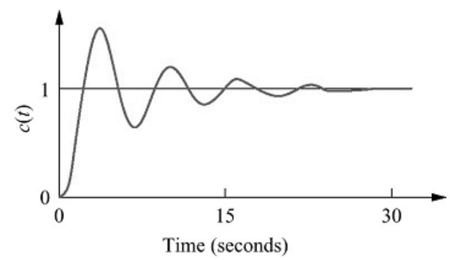
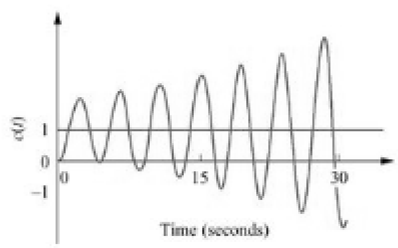
OR

$$160 > K$$

Characteristic equation : 1M

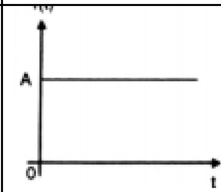
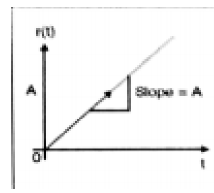
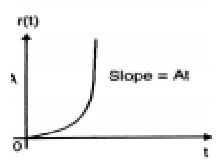
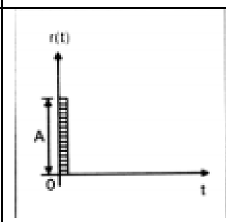
Routh's array : 4M

Range : 1M

		Therefore, the range of K for the system to be stable is $$160 > K > 0$$	
Q.5		**Attempt any FOUR:**	**16Total Marks**
	(a)	**Define stable and unstable with its response and locations of roots in S – plane.**	**4M**
	Ans:	**Stable systems** are those which give bounded output for bounded input. Response of the system is as shown below **(note: optional)**  For stable systems root location should be on left side of S-plane. **Unstable systems** are those which give unbounded output for bounded input. Response of the system is as shown below**(note: optional)**  For unstable systems root location should be on right side of S-plane.	**2M** **2M**

(b) **List different standard test signals. Draw them and give their Laplace representation.** **4M**

Ans: **1M Each**

Standard test input	Laplace Representation	Waveforms
Step input(position function) r(t)	L.T of r(t) =R(s)=A/s	
Ramp input(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^3	
Impulse input r(t)	L.T of r(t) = R(s)= 1 if A=1	

(c) **Explain in brief ON – OFF control action.** **4M**

Ans: **4M**

It has only two fixed positions such as on (1) and off (0). The output signal P remains either 0% or
100% depending upon whether the error is negative or positive.

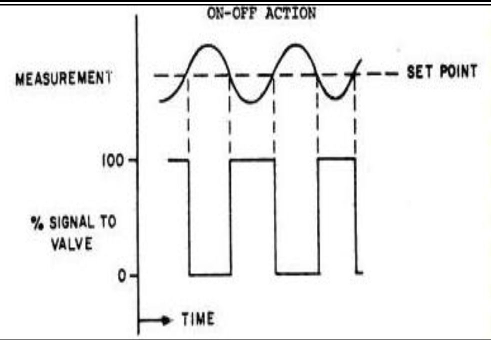
P = 100% (on) for positive error

P = 0% (off) for negative error .

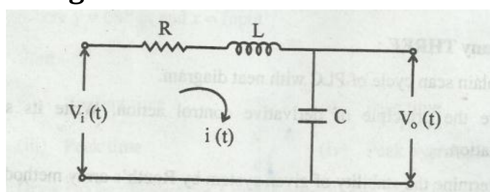
Consider a practical example of temperature control system with Set Point "x".

When the temperature is more than "x" the on - off controller will be and when it is less than "x" ,on - off controller will be on.

Example:- Relays, Thermostat

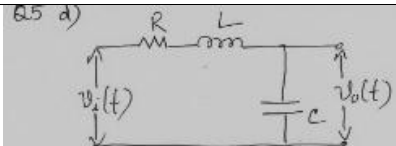


(d) **Derive the transfer function of given electrical circuit.** **4M**



Ans: **4M**

Q5 d)



Applying KVL to the input loop,

$$V_i(t) = R\cdot i(t) + L\cdot\frac{di(t)}{dt} + \frac{1}{C}\int i(t)\,dt$$

Laplace Transform is

$$V_i(s) = R\,I(s) + L\cdot s\cdot I(s) + \frac{1}{Cs}I(s)$$

$$V_i(s) = \left(R + Ls + \frac{1}{Cs}\right)I(s)$$

$$V_i(s) = \left(\frac{RCs + LsCs + 1}{Cs}\right)I(s)$$

$$= \left(\frac{s^2LC + RCs + 1}{Cs}\right)I(s) \quad \text{——} \ (1)$$

Applying KVL to the output loop,

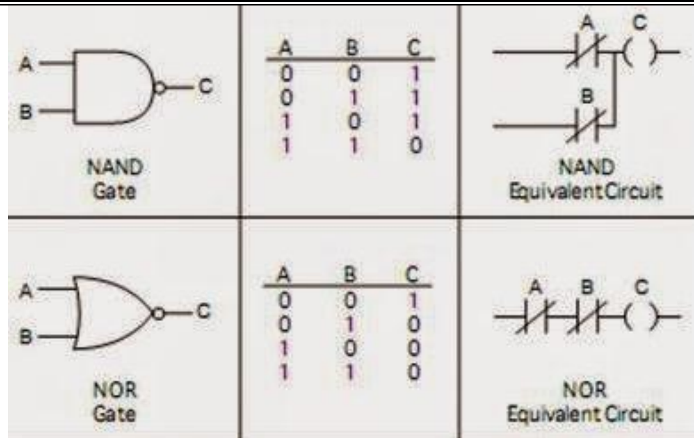
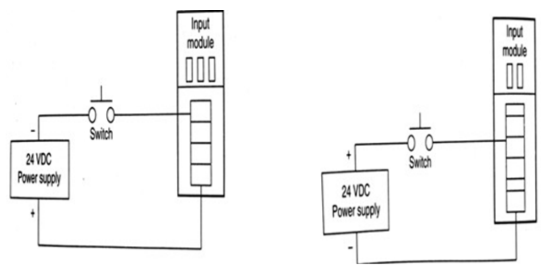
$$V_o(t) = \frac{1}{C}\int i\,dt$$

Laplace Transform is $V_o(s) = \frac{1}{Cs}I(s)$ —— (2)

Transfer function = $\dfrac{\text{Laplace Transform of o/p}}{\text{Laplace Transform of i/p}}$

$$\frac{(2)}{(1)} = \frac{\frac{1}{Cs}I(s)}{\left(\frac{s^2LC + RLC + 1}{Cs}\right)I(s)} = \boxed{\frac{1}{s^2LC + RCs + 1}}$$

(e) **Draw the ladder diagram (i) NAND gate, (ii) NOR gate.** **4M**

	Ans:		**2M Each**
Q6.		**Attempt any FOUR:**	**16M**
	(a)	**Describe sinking and sourcing concept in DC input module with neat diagram.**	**4M**
	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. 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. 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	**2M- Diagram** **2M- Explanation**
	(b)	**Draw the block diagram of PLC and explain each block in it.**	**4M**
	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.	**2M- Diagram** **2M- Description**

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.

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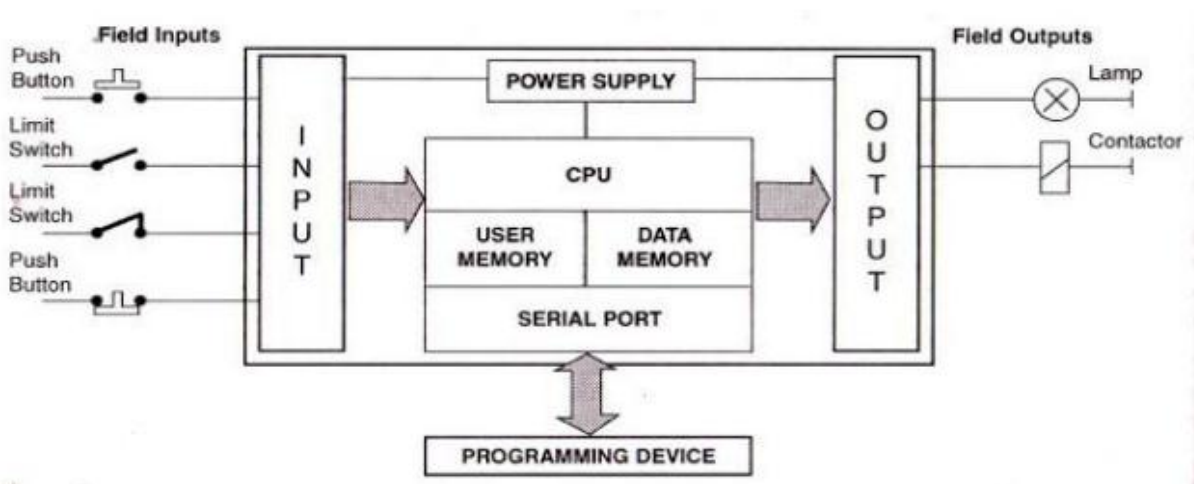


Block diagram of PLC

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

		• 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.	
	(c)	**Explain PI control action. State its equation. State limitations of PI controller.**	**4M**
	Ans:	It is the combination of Proportional and Integral controller. The output equation is $P_{out} = K_p E_p + K_p K_1 \int_0^t E_p dt + P_0$ where Po is the controller output when time t=0 If the error is not zero, the proportional controller gives correction and integral begins to change the accumulated value of the error which is initially.Integral controller is rarely used alone because of its slow response to disturbances. When it is combined with proportional controller, its slow response can be eliminated. Here, one to one correspondence of the proportional controller is available and integral controller eliminates offset. PI mode ensures that when a deviation takes place, prop mode reacts immediately to change the controller output since there is not a time integral of deviation. Offset error occurs with a load change but mode provides a new controller output which in turn changes the error to be zero after a load change. **Characteristics:** i) When error=0, controller output is Po (output when t=0) When error is not zero, the proportional controller gives correction and integral begins to change the accumulated value of the error which is initially **Limitations of PI controller**: It is slow.	**2M-Explanation 1M-Expression 1M-Limitation**
	(d)	**Define with example:** **(i) Linear and Non – linear system.** **(ii) Time varying and Time in varying system.**	**4M**
	Ans:	Linear and systems: Systems which obey superposition theorem. example: Potentiometer	**2M Each**

Non – linear system: Systems which do not obey superposition theorem.
example: Logarithmic amplifier
Time varying system: Systems in which parameters vary with time.
Example: Rocket launching in which as the spacecraft moves, fuel burns and mass of the spacecraft decreases with time.
Time in varying system: Systems in which parameters do not vary with time.
Example: Electrical circuits.

(e) **Explain Routh's stability criterion for two different cases.** **4M**

Ans: The necessary & sufficient condition for system to be stable is all the terms in the first column of routh's array must have same sign. There should not be any sign change in the first column of Routh's array. **2M Each**

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.

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	∞		

As third row element is zero the next row element becomes (infinity) and Routh's array fails.The procedure is to replace 0 with a small positive number € and continuing with Routh's array.

Case 2:

If all the element of a row are zero then due to this the elements of the next row cannot be determined and Routh's test fails.
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	0	← 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

$A(S) = S^4 + 3S^2 + 3.$

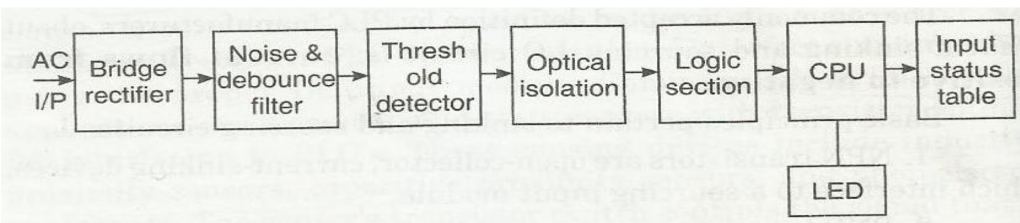
Differentiate this equation w.r.t S

$$\frac{dA(s)}{ds} = 4s^3 + 6s + 0 = 4s^3 + 6s$$

Zeros in S^3 row are now replaced by the co-efficient 4 & 6.

	(f)	**Draw block diagram of DC input module. Draw typical wiring diagram of it.**	**4M**

Ans: **Block Diagram:** **2M**



Wiring: **2M**