WINTER – 14 EXAMINATION

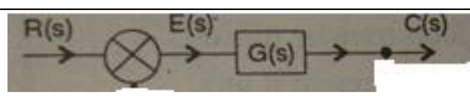
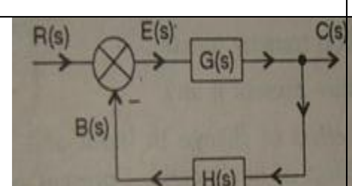
Subject Code: 17536 **Model Answer**

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 judgments 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.

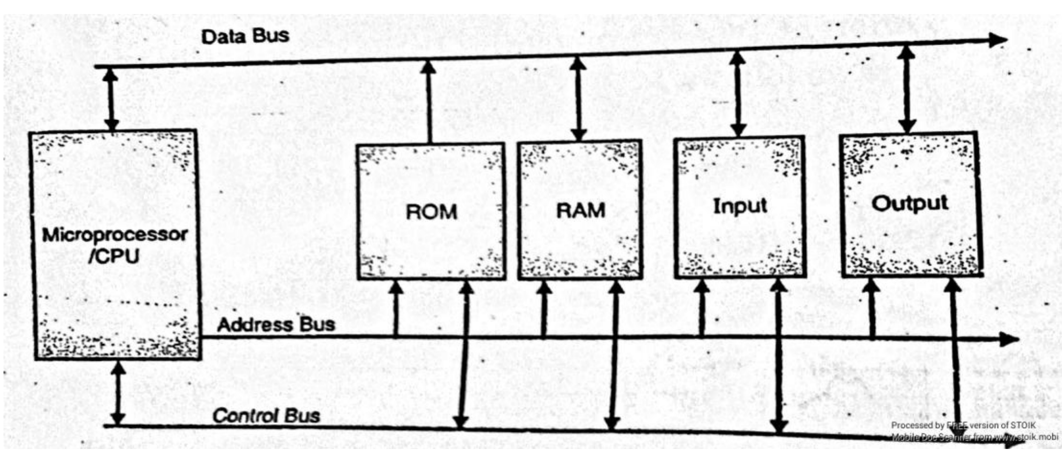
Q. No.	Question & Model Answer	Remark	Total Marks
1.A	**Attempt any Three:**		**12**
i)	**Define stable and unstable system ; critically stable and conditionally stable system**		**04**
Ans:	STABLE : A linear time invariant system is said to be stable if following conditions are satisfied: 1.) When the 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 for each definition**	

	OR In this type of system for some bounded input output is bounded for certain conditions of a particular parameter. If the conditions of the parameter changed then for the same bounded input, the output becomes unbounded.		
ii)	**Name any 4 input and output devices each used with PLC**		**04**
Ans:	<u>Input device:</u> Push button : Temperature switches: Limit switches. Pressure switches: <u>Output devices</u>: Motor: display: Heater coil: Relay: • **Note: ant other relevant I/O device can be considered.**	**1 mark for each I/O device**	
iii)	**Compare open loop and closed loop system based on block diagram , transfer function , examples and stability**		**04**
Ans:			

parameter	Open loop	Closed loop	
Block diagram:			**1 marks each point**
Transfer function:	$\frac{C(s)}{R(s)} = G(s)$	$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s) * H(s)}$	

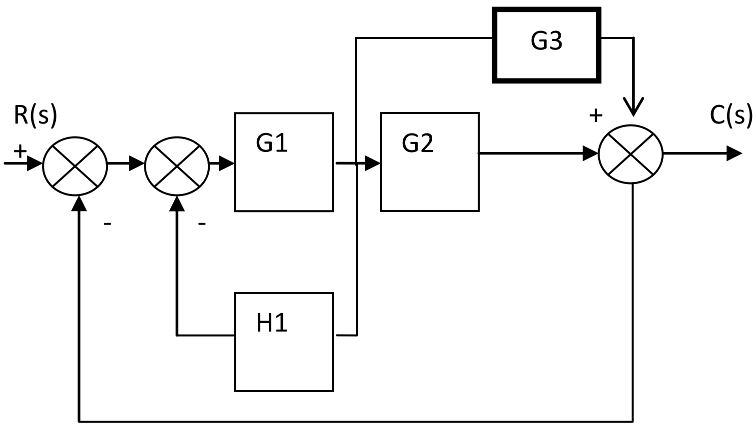
	Examples :	Automatic toaster, coffee maker, hand drier, traffic control etc	Air contioning, automatic iron, water level controller, automatic speed controller, voltage stabilizer etc	
	Stability	Generally Stable in nature	Generally unstable in nature due to feedback.	

iv)	**Classify different modes of process control**		**04**
Ans:	There are following three mode of control action: 1. Continuous control action mode.: a. Proportional control b. Integral control c. Derivative control 2. Dis Continuous control action mode. a. On-off control 3. Composite control action mode. a. Proportional Integral control b. Proportional Derivative control c. Proportional Integral Derivative control		
1.B	**Attempt any One:**		**06**
i)	**Describe in brief memory organization of PLC**		
Ans:	Different types of memory that are generally used in PLC s are as follows: 1. RAM: 2. ROM A.)EPROM B.)EEPROM In PLC program instructions are stored in the memory. An internal communication high way also known as a bus system, carries information to and fro from the CPU, Memory and I/O units under the control of CPU Memory unit for storage of program.	**6 marks for relevant explaination**	

	The user ladder logic program, is in the memory of PLC. The main program and other programs are necessary for operation of PLC. The organization of the data and information in the memory is called memory map There are two types of memory used in PLC: Volatile and non volatile memory , in non volatile memories are generally used for storing user program so that the programs can return during power failure. OR Memory is classified into two types: 1. Storage memory: in storage memory store information on the status of i/o devices, pre assigned value of internal relay status and values for mathematical functions, this is called a data table or register table and stores information in two types: status and numbers,. Status is stored in the form of ON or OFF and nos are stored in the form of 1's and 0's is unique bit of memory. 2. User memory: in this memory, ladder logic programming is carried out and stored. User memory consists of program files or register table and holds the complete operation.  • **Diagram is optional**		

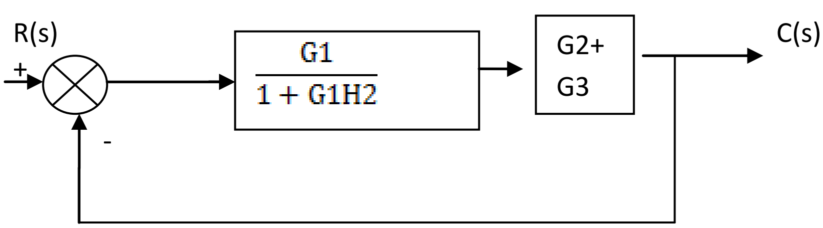
ii)	**Derive the transfer function of the following block diagram:**		**06**

Ans:



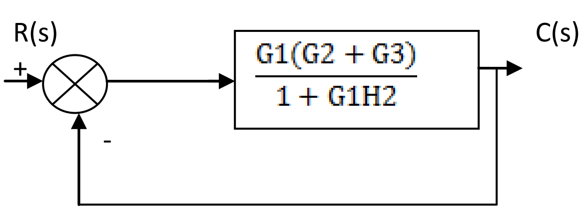
Step 1: Apply simple minor loop and parallel rule:
Now system becomes

2 marks



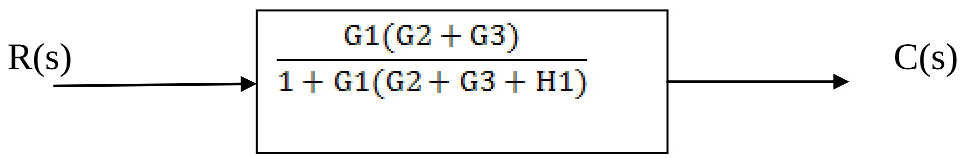
Step 2: Apply series rule:

2 marks



Step 3:
Unity feedback path A(s)=1

2mark

	$$\frac{\frac{G1(G2+G3)}{1+G1H1}}{1+\frac{G1(G2+G3}{1+G1H1}}$$ 		
2.	**Attempt any Two:**		**16**
a)	**Transfer function of second order system is given by** **:$\frac{C(S)}{R(S)} = \frac{2s}{S^2+6S+2s}$ Find Tr, Tp, Ts and % Mp for unit step input.**		**08**
Ans:	**In above problem , assume "25" in place of "2s" in numerator and denominator;** **Then solve as follows**: Comparing the given equation with the standard form of second order equation, $\frac{C(s)}{R(s)} = \frac{{\omega_n}^2}{{\omega_n}^2+2\xi\omega_n s+s^2} = \frac{25}{s^2+6s+25}$ we get, ${\omega_n}^2$=25 Therefore, $\omega_n = 5rad/sec$ $2\xi\omega_n$=6 , ξ=0.6	**(1 Mark for each parameter Means for ω_n, ξ , θ ,ωd ,Tr,Tp, Ts,and %Mp)**	

	$\theta = \tan^{-1}(\frac{\sqrt{1-\xi^2}}{\xi}) = \tan^{-1}(\frac{\sqrt{1-0.6^2}}{0.6}) = 0.9272$rad $\omega d = \omega n\sqrt{(1-\xi^2)} = 5\sqrt{(1-0.6^2)} = 4$ rad/sec $T_r = \frac{\pi-\theta}{\omega d} = \frac{\pi - 0.9272}{4} = \underline{\underline{0.5535sec}}$ $T_p = \frac{\pi}{wd} = \frac{\pi}{4} = \underline{\underline{0.785sec}}$ $T_s = \frac{4}{\xi w_n} = \underline{\underline{1.33sec}}$ $\%M_p = e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}} * 100 = \underline{\underline{9.48\%}}$		
b)	**A unity feedback system has** **$G(s) = \frac{10(s+1)}{s^2(s+2)(s=10)}$ find out:** **1. type of system** **2. static error coefficient Kp,Kv, Ka** **3. steady state error for input $r(t)=1+4t+t^2/2$**		**08**
Ans:	Comparing the equation in stanadard form: $G(s)H(s) = \frac{K(1+T1s)+(1+T2s)}{S^j\ (1+Ta\ s)(1+Tb\ s)}$..... $G(s) = \frac{10(1+s)}{s^2\ (1+0.5s)(1+0.1s)}$ Where j = type of system ∴ j=2 <u>This is type 2 system.</u>	**1 mark for type of system** **3**	

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

$$Kp=\lim_{s\to 0} G(s)\,H(s) = \lim_{s\to 0} \frac{10(s+1)}{s^2\,(s+2)(s+10)}*1 = \infty$$

$$Kv=\lim_{s\to 0} s\,G(s)\,H(s) =\lim_{s\to 0} \frac{s\,10(s+1)}{s^2\,(s+2)(s+10)}*1 = \infty$$

$$Ka=\lim_{s\to 0} s^2\,G(s)\,H(s) =\lim_{s\to 0} \frac{s^2\,10(s+1)}{s^2\,(s+2)(s+10)} * 1$$

$$=\lim_{s\to 0} \frac{10(s+1)}{(s+2)(s+10)}=\frac{10(0+1)}{(0+2)(0+10)} =\frac{10}{20} = 0.5$$

Kp = ∞
Kv = ∞
Ka = 0.5

Steady state error where input r(t)=1+4t+t2/2

Hence steady state error $ess1=\frac{A}{1+K_p}=\frac{1}{1+\infty} = 0$

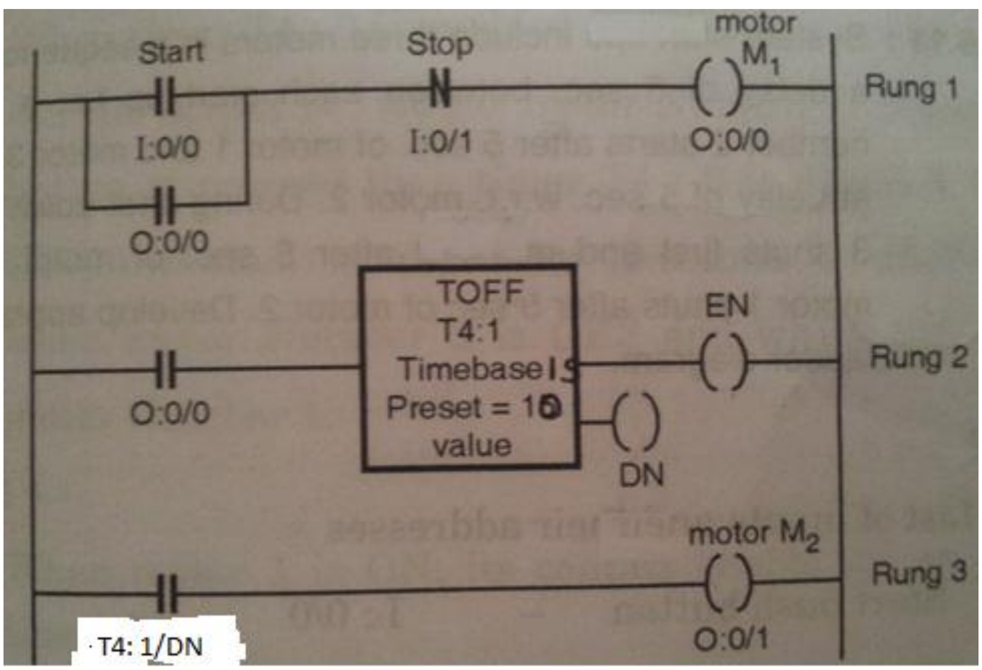
$ess2=\frac{A}{K_v}=\frac{4}{\infty} = 0$

$ess3 = \frac{A}{K_a} =\frac{1}{0.5} =2$

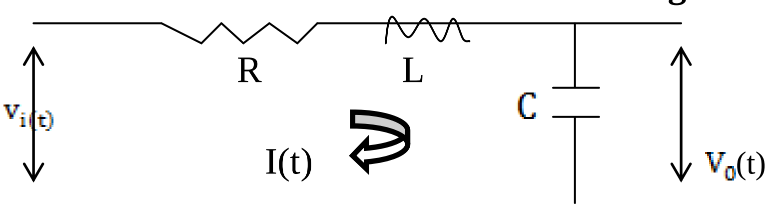
Hence total steady state error is Ess= ess1+ ess2+ ess3
= 0 + 0 + 2
= 2

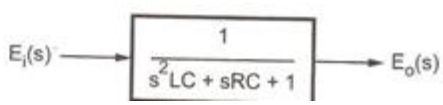
</td><td>marks for each param Kp, Kv, Ka

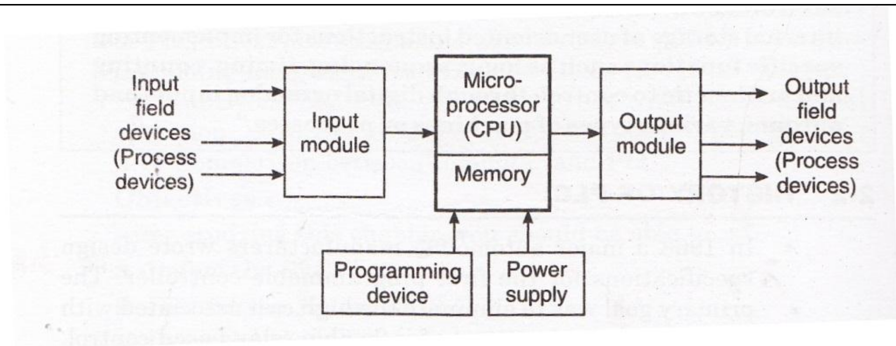
4 marks for steady state error</td><td></td></tr>
<tr><td>c)</td><td>Draw ladder diagram for 2 motor operations for following conditions
1. Start push button starts motors M1 and M2 and
2. Stop push button stop motors M1 first and after 10 seconds motor M2</td><td></td><td>08</td></tr>
</table>

Ans:	➢ Input/output address description- 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 T_{OFF} timer- T4 :1 ➢ Ladder Diagram –  Fig – Programming Ladder Diagram Explaination – rung 1: When start button is pressed motor M1 is ON. Rung 2: When motor M_1 is ON, its auxiliary contact with same	**Input /output address description-2 mark,** **Programming Ladder diagram-4 mark,** **Explanation of ladder diagram-2 mark)**	

	address gets closed which turn ON the OFF delay timer T_4:1. Rung 3: When OFF delay timer gets supply DN bit is set which turn ON the output O:0/1 i.e motor M_2. When stop button is pressed then main motor M_1 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 M_2 remains ON for 10 sec even though motor $M_1$is OFF.		
3.	**Attempt any four:**		**16**
a)	**Find the transfer function of the network given in figure:**		**04**

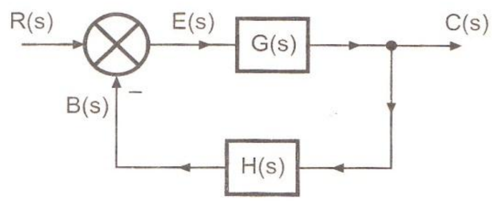
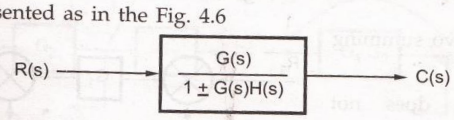


Ans:	$E_i = iR + L\frac{di}{dt} + \frac{1}{C}\int i\,dt$ ... (1) input $= E_i$; output $= E_o$ Laplace transform of $\int f(t)\,dt = \frac{F(s)}{s}$, ... Neglecting initial conditions and Laplace transform of $\frac{df(t)}{dt} = sF(s)$ ... Neglecting initial conditions Take Laplace transform, $\therefore \quad E_i(s) = I(s)\left[R + sL + \frac{1}{sC}\right]$ $\frac{I(s)}{E_i(s)} = \frac{1}{\left[R + sL + \frac{1}{sC}\right]}$ ... (2) Now $\quad E_o = \frac{1}{C}\int i\,dt$ ... (3) $\therefore \quad E_o(s) = \frac{1}{sC} I(s)$ $\therefore \quad I(s) = sCE_o(s)$ ... (4) Substituting value of I(s) in equation (2), $\therefore \quad \frac{sCE_o(s)}{E_i(s)} = \frac{1}{\left[R + sL + \frac{1}{sC}\right]}$ $\boxed{\frac{E_o(s)}{E_i(s)} = \frac{1}{sC\left[R + sL + \frac{1}{sC}\right]} = \frac{1}{RsC + s^2 LC + 1}}$ So we can represent the system as in the Fig. 3.6.  	**Applying KVL for input & output 01 M ,** **Laplace Transform both equation 01M Each ,** **Transfer function 01M)**	
b)	**Draw block diagram of PLC and explain each block in brief:**		**04**

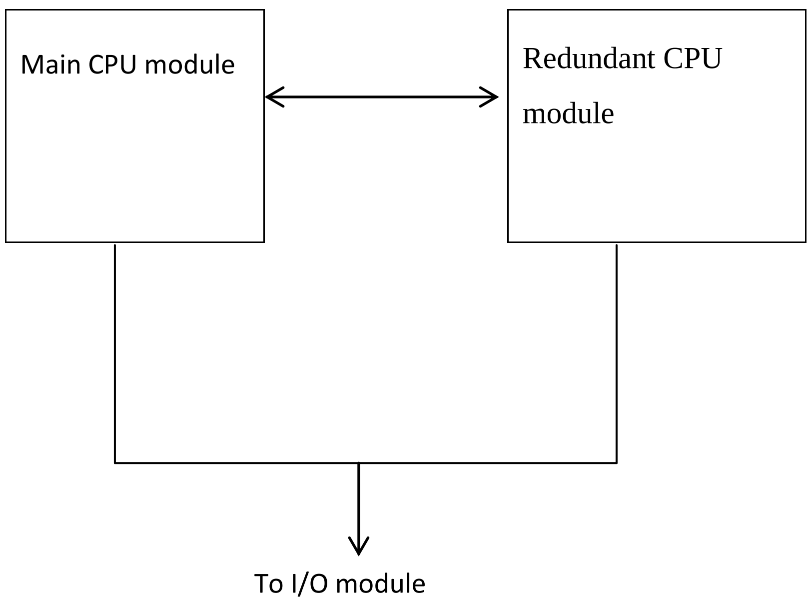
<table>
<tr><td></td><td>

<u>Processor:</u> - This is microprocessor that controls and supervises the entire process. It is the controller of a PLC.
<u>Memory:</u> - 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.
<u>Programming Device:</u> - 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
Personal Computer
<u>Input Module</u>: - It serves link between input field devices and PLC’s CPU.
<u>Out Module</u>: - It serves as the link between PLC‘s CPU and hardware output field devices
<u>Power supply</u>: - It converts AC line voltages to DC voltage
• Note: any relevant block diagram and explanation can be considered</td><td>Block diagram 02M

Explanation 02M</td><td></td></tr>
<tr><td>c)</td><td>Define transfer function. Derive the expression of T.F of closed loop system</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td><u>Transfer function:</u> It is defined as the ratio of Laplace transform of output of the system to the Laplace transform of input, under the assumptions that all initial conditions are to be zero.
$$T(s) = \frac{\text{Laplace transform of output}}{\text{Laplace transform of input}} = \frac{C(s)}{R(s)}$$</td><td>Definition 01M</td><td></td></tr>
</table>

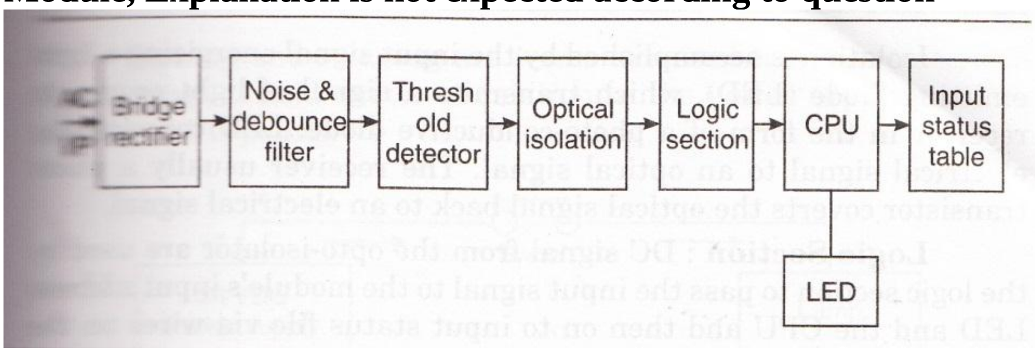
	Consider a simple closed loop system using negative feedback as shown  **Fig. 7.6** where E(s) = Error signal, and B(s) = Feedback signal Now, E(s) = R(s) − B(s) But B(s) = C(s)H(s) E(s) = R(s) m B(s) B(s) = C(s)H(s) ... (2) C(s) = E(s)G(s) ... (3) B(s) = C(s)H(s) and substituting in equation (1) E(s) = R(s) m C(s)H(s) $E(s) = \frac{C(s)}{G(s)}$ $\frac{C(s)}{G(s)} = R(s) \text{ m } C(s)H(s)$ C(s) = R(s) G(s) m C(s) G(s)H(s) C(s) [1 ± G(s)H(s)] = R(s) G(s) $\boxed{\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s)H(s)}}$ **Use + sign for negative feedback** and use – **sign for positive feedback.** This can be represented as in the Fig. 4.6  Closed Loop T.F.	Derivation of T.F 03M	
d)	**For system, characteristic equation is** **s^4+22s^3+10s^2+s+k=0, find k**		**04**

Ans:	Note:- Student should get marks for finding the range of "K" OR for finding marginal value of" K" Applying Routh's criterion **Solution :** s^4 | 1 10 K s^3 | 22 1 0 s^2 | 9.95 K 0 s^1 | $\frac{9.95-22K}{9.95}$ 0 s^0 | K Marginal value of `K' which makes row of s^1 as row of zeros. $9.95 - 22\,K_{mar} = 0$ $\therefore\ K_{mar} = \mathbf{0.4524}$ Range of K: $\frac{9.95-22K}{9.95} > 0$ $=9.95 - 22K > 0$ $= 9.95 > 22K$ $= \frac{9.95}{22} > K$ $= 0.45227 > K$ **So range of K is 0 < K < 0.45227**	**2 Marks For Routh array** **2 Marks For finding value of K**	
e)	**Describe the term redundancy in PLC.**		**04**
Ans:	During any critical application of PLC, it is very important that PLC should work reliably and continuous control of process even though there is failure of power supply or processor due to any reason. To achieve this, there must be stand by processor and power supply with the other PLC. This feature of PLC is called redundancy. Redundancy means extra system components added or kept stand by to avoid the change of total system failure. For critical	**03 Marks for explanation**	

	process, redundancy for power supply and / or CPU may be provided as shown in following figure. 	01 Marks For diagram	
4.A.	**Attempt any three:**		12
i)	**Compare proportional and integral controller on the basis of equation, advantages, response to error and application**		04
Ans:		Each point 01M	

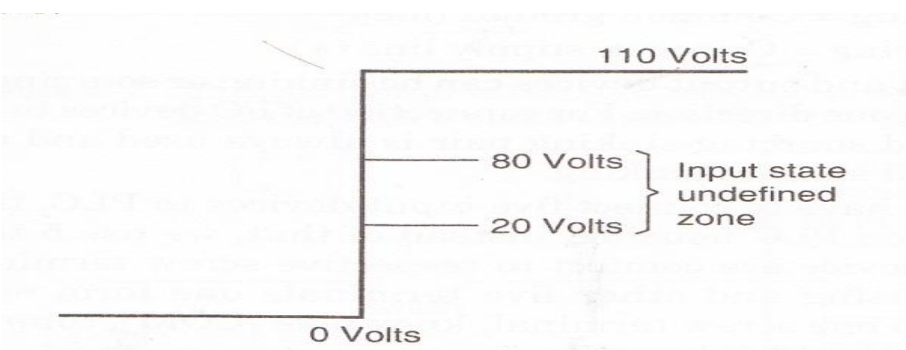
Parameters	Proportional controller	Integral Controller
Equation	$P_{out} = K_p E_p + P_0$ $P_{out} \rightarrow$ Controller output $E_p \rightarrow$ Error Percentage $K_p \rightarrow$ Propornality constant $P_0 \rightarrow$ Controller Output at SP	$P_{out} = K_i \int_0^t E_p dt + P_0$ $P_{out} \rightarrow$ Controller output $E_p \rightarrow$ Error Percentage $K_i \rightarrow$ Integral constant $P_0 \rightarrow$ Controller Output at SP
Advantage (any one)	1.looks into present error 2.moderate response speed 3.moderate stability	1.looks into Past history of error 2.eliminates noise 3.eliminates Offset
Response to error	Response to direction of error. Controller output α to error.	Response to magnitude of error i.e. size and time duration. Rate of change of output α error

<table>
<tr><td></td><td><table><tr><td>Application</td><td>Used in processes with moderate to small process time lags</td><td>Used in processes with small process lags and small capacitance such as flow,level, pressure control system</td></tr></table></td><td></td><td></td></tr>
<tr><td>ii)</td><td>Draw block diagram the AC input module of PLC</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>Note :-Print mistake in Question Draw block diagram of AC input Module, Explanation is not expected according to question

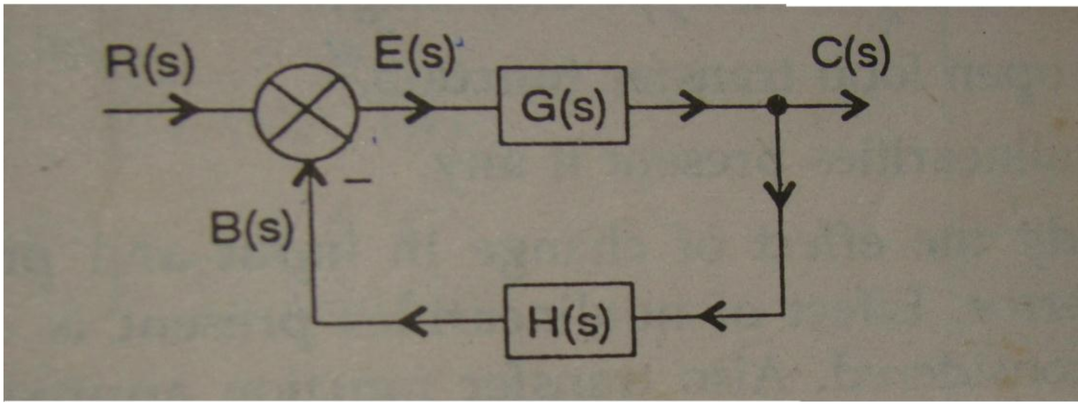


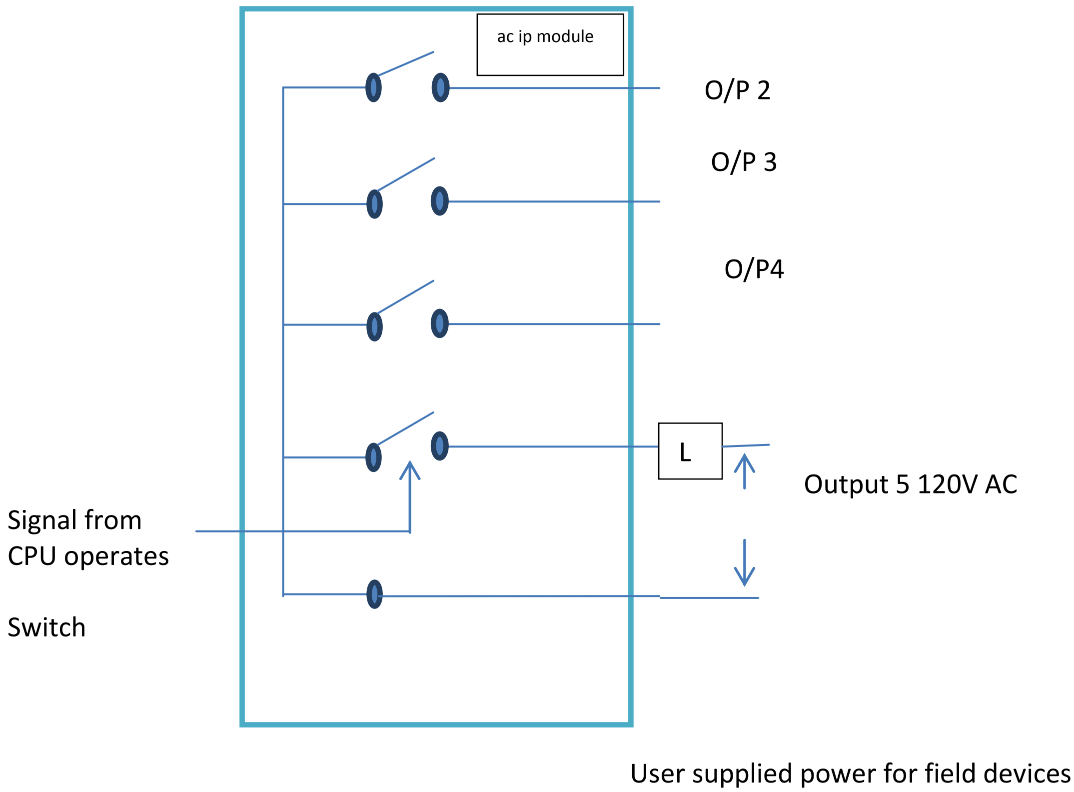
Power conversion: It consists of rectifier which converts the incoming AC signal to a pulsating dc level, which is passed through filter and other logic in order to deliver a clean and denounced dc signal.

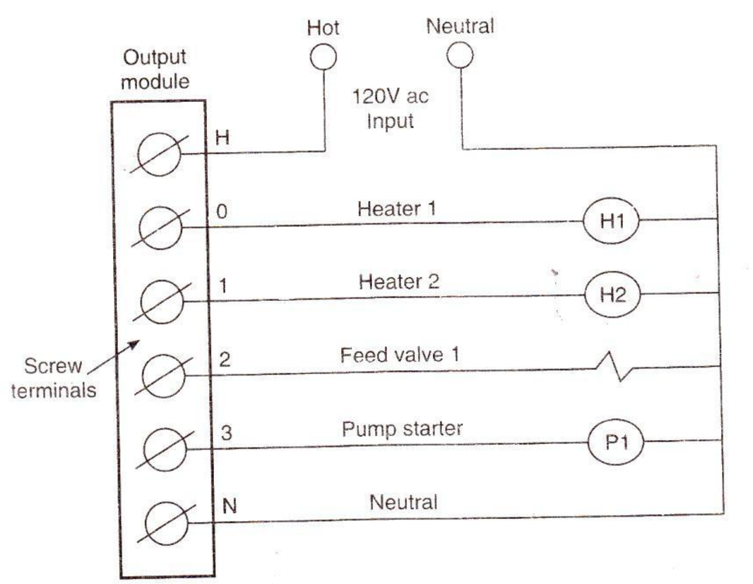
Threshold detector: It detects if monitoring signal has reached or exceeded a predetermine d value. A valid ON sate will be between 80-132V ac. The upper voltage limit for a valid OFF state is below 20V. The voltage between 20V and 80V is called undefined zone.


</td><td>4 marks for neat block diagram</td><td></td></tr>
</table>

	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 module's input address LED and the CPU.		
iii)	**Describe the role of PLC in automation.**		**04**
Ans:	1. In an automated system, PLC is commonly regarded as the heart of control system. 2. With a control application program stored within the memory of PLC in execution, PLC constantly monitors the state of the system. 3.PLC provides easy and economical solution for many automation tasks such as logic/sequence control, PID control & computing, co-ordination and communication, operator control and monitoring. 4.Any manufacturing application, which involves repetitive or discreet operation for that application PLC, can be used. 5.Intelligence of an automated system is greatly depending on the ability of a PLC to read in the signal from various types of automatic sensing and manual input devices. 6.An automatic system is also depending on the ability of the PLC to control various output field devices like motor, solenoid valve etc.	**4 Mark for any four relevant points**	
d)	**Derive the derivation of steady state error in terms of open loop transfer function G(s).H(s). Find e_{ss} for a step input**		**04**

Ans:	 $E(s) = R(s) - B(s)$ 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. 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	**02 Marks for derivation of steady state error.** **02 Marks for Ess for step input**	
4.B.	**Attempt any one:**		**06**
i)	**Describe the wiring details of AC output module of PLC.**		**06**
Ans:			



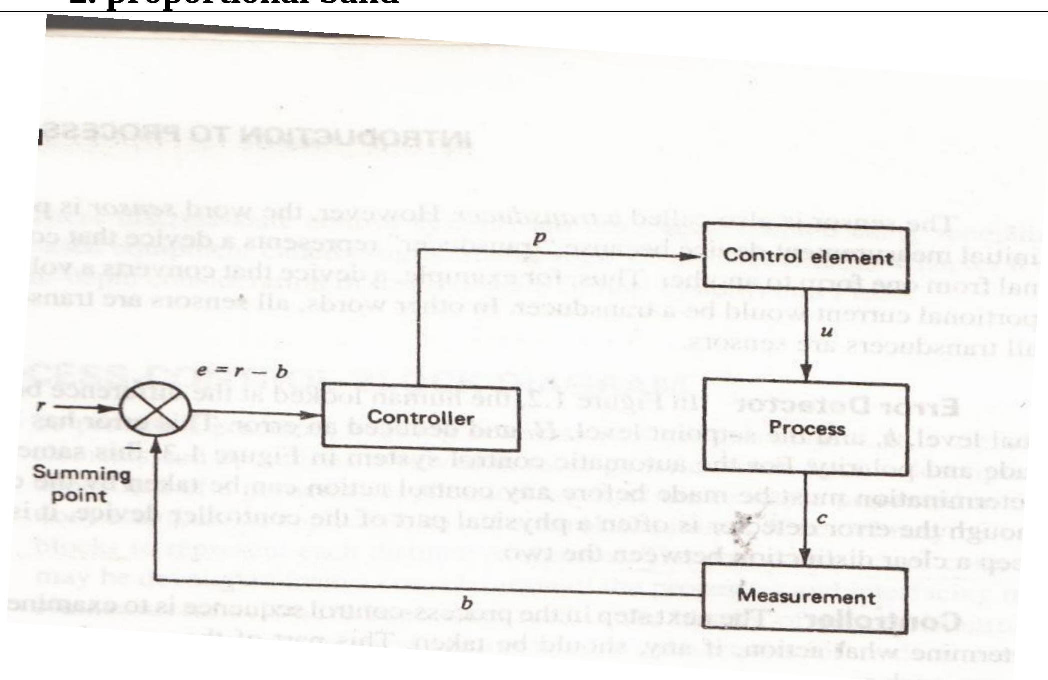


Typical discrete output module wiring diagram

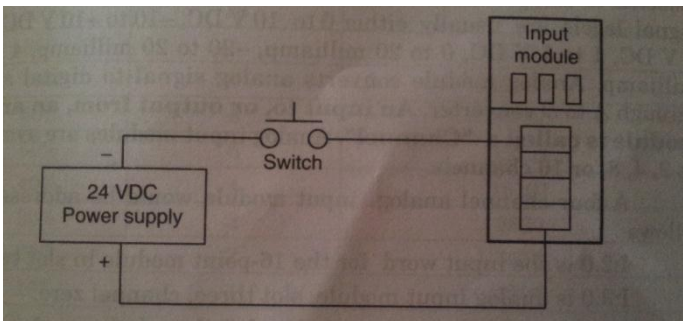
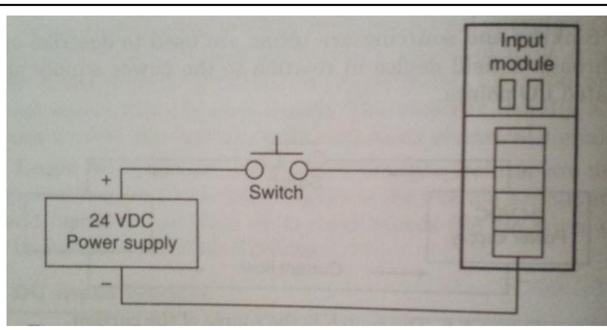
Fig.2

diagram 03M

<table>
<tr><td></td><td>The above figure 1 & fig 2 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.</td><td>Explanation 03M)</td><td></td></tr>
<tr><td>b)</td><td>Draw labeled block diagram process controlled system and explain. Define w.r.t controller
1.offset error
2. proportional band</td><td></td><td>06</td></tr>
<tr><td>Ans:</td><td>
</td><td>Block diagram 01M</td><td></td></tr>
</table>

	Process: It is often called as the plant. Process can consist of a complex assembly of phenomena that relate to some manufacturing sequence Measurement: It refers to the conversion of variable into some corresponding analog of the variable such as pneumatic pressure, to voltage or current. A sensor is device that performs the initial measurement and energy conversion variable into analogous digital. Error detector: It detects error before any control action can be taken by the controller Controller: This path of the control system controls the measured value w.r.t set point Control element: The final control element controls the measured value according to the output of controller.	**Explanation 03M,**	
	Definition of Offset Error: It is a permanent residual error in proportional controller which is inherent in nature; it is due to one to one correspondence existing between the controller output and error. Definition of Proportional Band: It is defined as percentage of error which results in 100% change in controller output. OR PB is percentage of full scale change in controller input required to change the controller output from 0% to 100%, corresponding to full operating range of final control element.	**Definition 02M each**	

5.	**Attempt any two:**		**16**
a)	**(i) Describe sinking and sourcing concept in D.C input modules of PLC.**		**04**
Ans:	 Fig 1 – Sourcing DC input Module with a sinking switch  Fig 2 – Sinking DC input module with a Sourcing switch 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	**Diagram- 2 mark,** **Explanation-2 mark)**	**04**

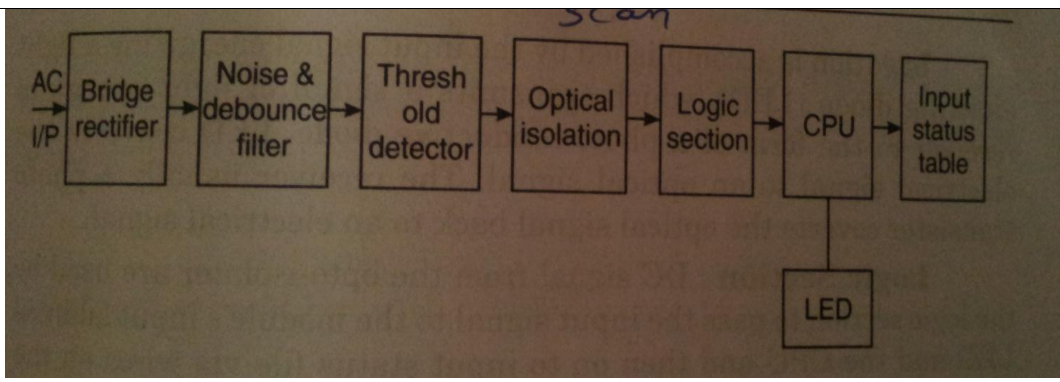
<table>
<tr><td></td><td>sinking & sourcing input & output circuit is current flows from positive to negative.
4. Basic principle retain to sinking & sourcing circuits.
➤ NPN transistors are open collector current sinking devices which interface to a sourcing input module.
➤ PNP transistors are open 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.</td><td></td><td></td></tr>
<tr><td>ii.)</td><td>Draw the block diagram of AC discrete input module of PLC.</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>

Fig – Block diagram of AC discrete input module of PLC</td><td>Neat Block Diagram-4mark</td><td></td></tr>
</table>

b.)	**(i) Draw the effect of damping on the response of second order system.**		
Ans:	(table below)	**1 mark for Each cases of ζ)**	

	Range of ζ	Type of close loop poles	Nature of response	System classification (Note: response diagram can also be considered)
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

b)	**(ii) Define the time response specification delay time Td, rise time Tr, settling time Ts & peak overshoot Mp.**		**04**
Ans:	(1) Delay Time Td = It is the Time required for the response to reach 50 % of the final value in the first attempt it is given by $T_d = \frac{1 + 0.7\zeta}{w_n}$	**(1 mark for each definiti**	

<table>
<tr><td></td><td>(2) Rise time Tr= It is the time required for the response to rise from 10% to 90% of the final value for overdamped systems & 0 to 100 % of the final value for under damped systems. It is given by
$$T_r = \frac{\pi - \theta}{w_d}$$
Where θ must be in radian
(3) Settling Time Ts = This is defined as the time required for the response to decrease & stay within specified % of its final value .
$$T_s = \frac{4}{\zeta w_n}$$
(4) Peak overshoot Mp = it is the largest error between reference input & output during the transient period.</td><td>on.

Note – Formulae are not compulsory</td><td></td></tr>
<tr><td>c)</td><td>By means of Routh's criteria, determine stability of system represented as $\boldsymbol{s^4 + 2s^3 + 8s^2 + 4s + 3 = 0}$</td><td></td><td>04</td></tr>
<tr><td>Ans:</td><td>(1) Find even & odd coefficient from characteristics equation
F (s) = $s^4 + 2s^3 + 8s^2 + 4s + 3 = 0$

(2) Makes Routh's array
$$\begin{array}{c|ccc} S4 & 1 & 8 & 3 \\ S3 & 2 & 4 & 0 \\ S2 & 6 & 3 & 0 \\ S1 & 3 & & \\ S0 & 3 & & \end{array}$$
Conclusion – As in the first column of Routh's array there isNO sign change means all the poles of characteristics equations are lie in LHS of S plane hence system is stable</td><td>Making Routh's array -6 marks,

conclusion -2 mark</td><td></td></tr>
</table>

6	**Attempt any FOUR of the following:**		**16**
a.)	**Describe ON- OFF control action. State its any one advantage & disadvantage of each**		
Ans:	(1) This is one of the most common & simplest mode of controller (2) It has to control two positions of control element, either on or off hence this mode is called as ON OFF controller, it is the cheapest controller & often used if its limitations are well within the tolerance. (3) This controller mode has two possible output states namely 0 % & 100%. Mathematically this can be expressed as P (t) = 0% (OFF) for $e_p < 0$ 100% (ON) for $e_p > 0$ Where p (t) – Controlled output e_p - Error based on % of span (4) Hence if the error rises above a certain critical value, the output changes from 0% to 100%. If the error decreases below certain critical value, the output falls from 100% to 0%. **Advantage of ON-OFF controller-** 1. It is most simple in construction. 2. It is most economical & cheapest. **Disadvantage of ON-OFF controller-** 1. It is not very suitable for complex systems. 2. It has a slow response.	**Explanation 2-mark,** **for each Adv - 1 mark & Disadv - 1 mark)**	**04**
b.)	**State Routh's stability criteria and discuss different cases to find stability of a system.**		
Ans:	Statement- The necessary & sufficient condition for system to be stable is " All the terms in the first column of array must have same sign. There should not be any sign change in the first column of Routh's array". If there are any sign changes existing then, (1) System is unstable (2) The no of sign changes equal the no of roots lying in the right half of the S- plane.	**statement -1 mark,**	

	Special case 1 1) Statement – First element of any of the rows of Routh's array is zero & the same remaining rows contains at least one non zero element. 2) Effect-The terms in the next row become infinite and Routh's test fails. 3) Solution for this said difficulty-Substitute a small positive number 'ϵ'in place of a zero occured as a first element in a row and complete the array with this number 'ϵ'.Then examine the sign change by taking $lim_{\epsilon\rightarrow 0}$. **Special case 2** 1) Statement-All the elements of a row in a Routh's array are zero. 2) Effect-The terms of the next row cannot be determined &Routh's test fails. 3) Solution for this said difficulty- (i) Form an equation by using the coefficients of a row which is just above the row of zeros. Such an equation is called as auxillary equation denoted as A(s) . (ii)Take the derivative of an auxiliary equation with respect to 's' (iii) Replace row of zeros by the coefficients of dA(s)/ds. (iv) Complete the array in terms of these new coefficients &by observing the first column of Routh's array state the stability of the system **Note: Marks can be given for relevant explanation too**	**case one - $1\frac{1}{2}$,** **case two - $1\frac{1}{2}$ mark**	
c)	**Explain the TON instruction of PLC.**		**04**
Ans:	Description 1) This instruction counts time interval when conditions preceding it in the rung are true. Produces an output when accumulator reaches the preset value. 2) Use TON instruction to turn an output on or off after the timer has	**Description-2,**	

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.

	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

Instruction parameter- Timer TON is 3 word element.

Status bit explanation-

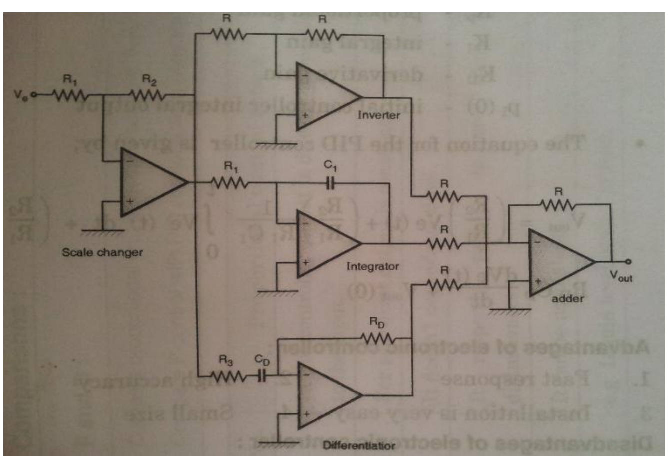
i) Timer done bit(bit13)-DN is set when the accumulated value is equal to or greater than the preset value.It is reset when rung condition become false.
ii) Timer enable bit (bit 14)-EN is set when rung condition are true.It is reset when rung condition become false.
iii) Timer timing bit(bit15)-TT is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

Instruction parameter-1,

status bit explanation -1

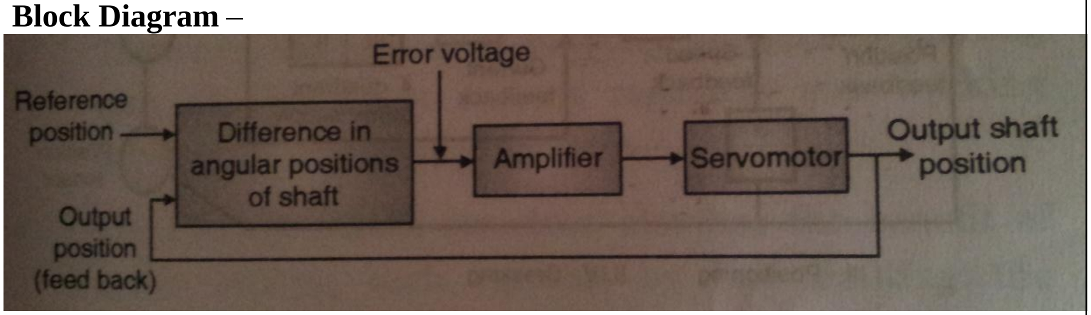
d) **Draw electronic PID controller. state its equation and give its two advantages**. **04**

Ans:



PID controller equation-

Diagram-2 mark,

	$P(t) = k_p e(t) + k_p k_i \int_0^t e(t)dt + k_p k_d \frac{de(t)}{dt} + p(0)$ **Advantages of PID controller** 1) It reduces the overshoot which often occurs when integral control action is added to proportional control action. 2) It counteracts the lag characteristics introduced by the integral control action. 3) It approaches the tendencies towards oscillations. 4) It eliminates the offset introduced by proportional control action.	**equation-1 ,** **advantages any two-1)**	
d)	**Define Servo System. Draw its standard block diagram and explain**.		**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. **Block Diagram** –  Fig – Standard Block Diagram of Servo System	**Definition- 1 mark,** **any one block diagram - 2 mark,**	

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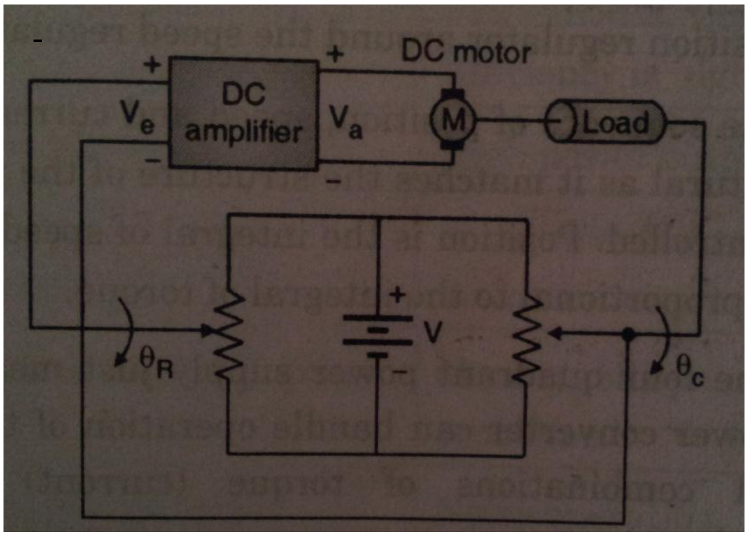

Fig- DC Servo System

Explanation

1) The standard block diagram of servo system consists of error detector, amplifier, motor as controller, load whose position is to be changed.

2) Servo systems is to be divided into two type a) Dc servo systems b) Ac servo system

3) 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.

4) 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 position .The error between two position 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.
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<td>Brief Explanation-1 mark)</td>
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