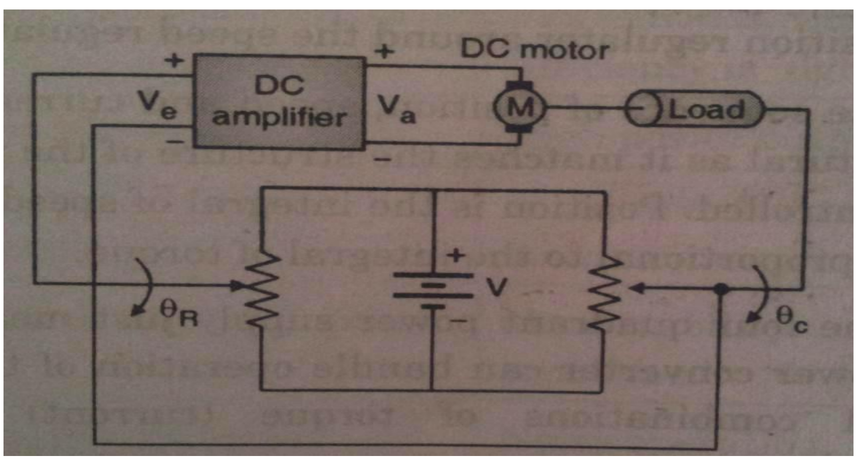
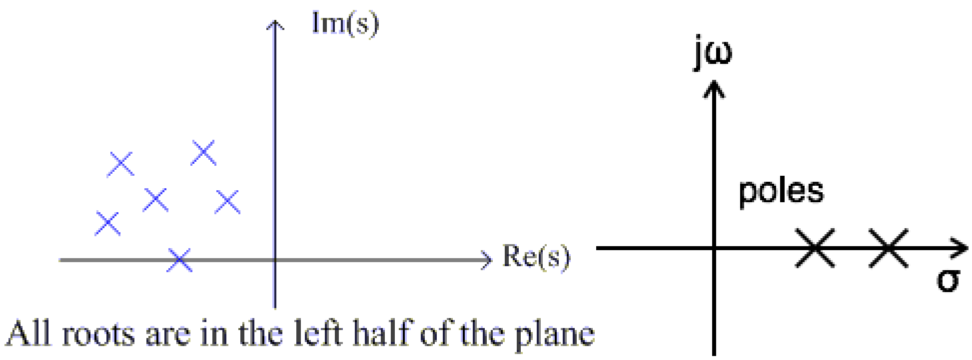
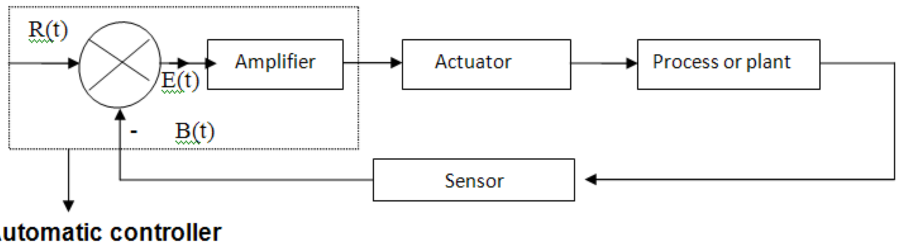
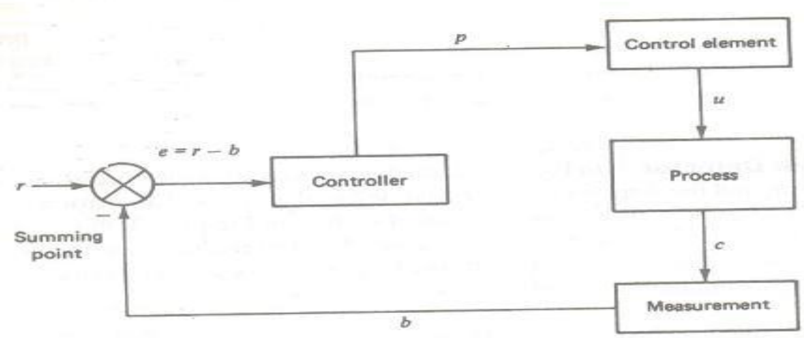
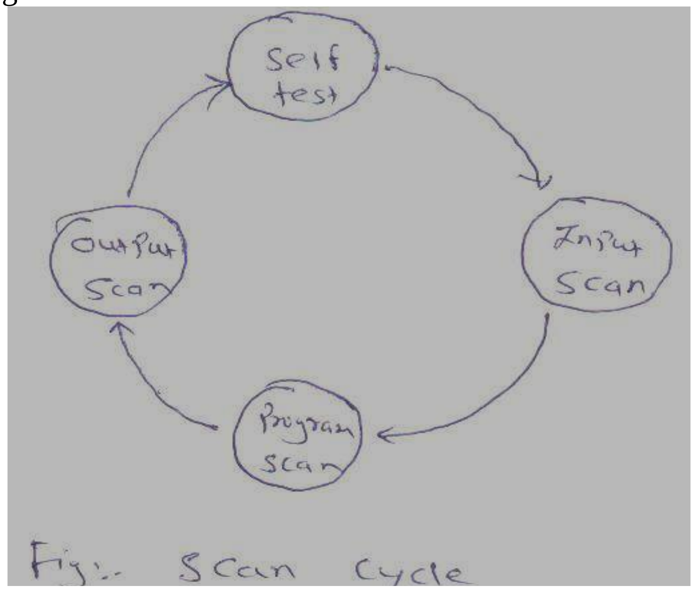
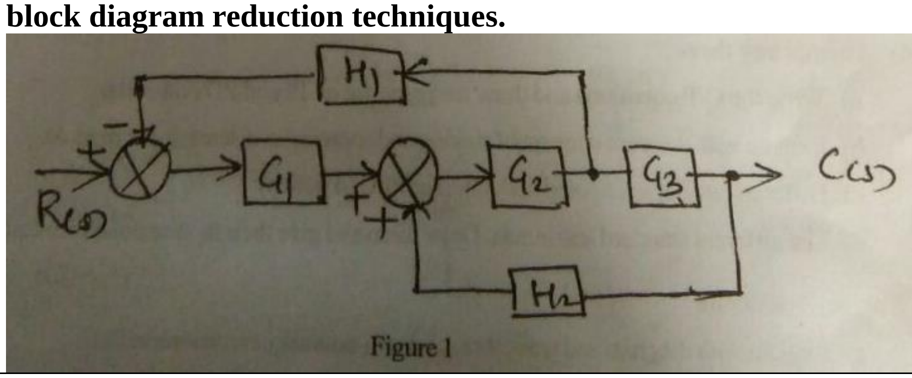
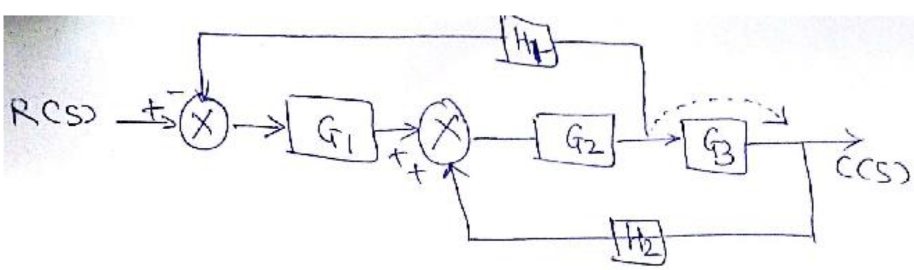
Important Instructions to examiners:

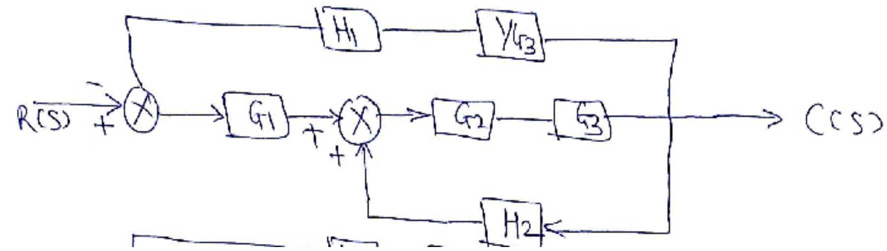
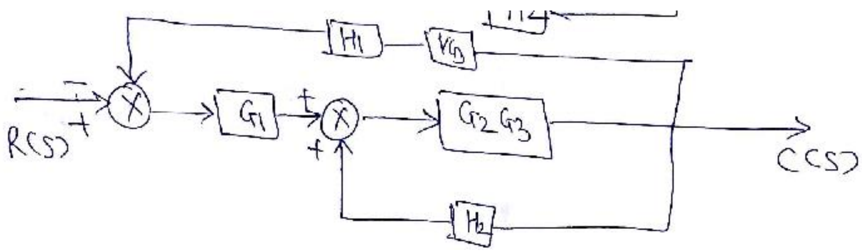
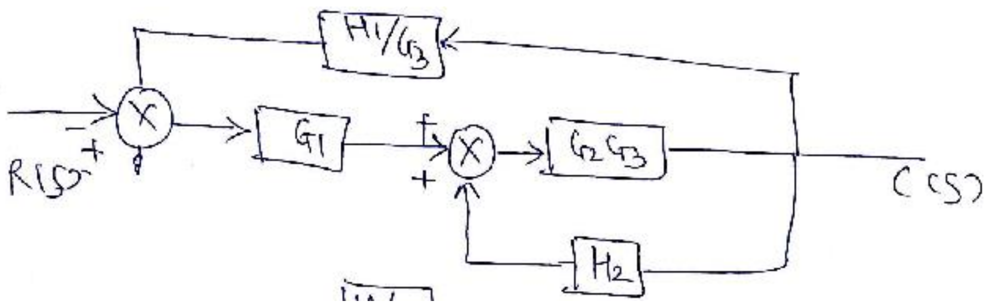
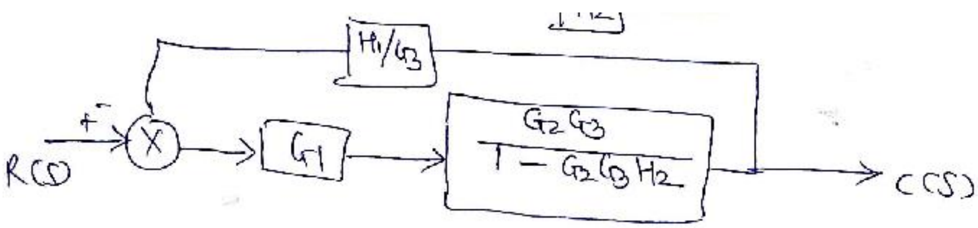
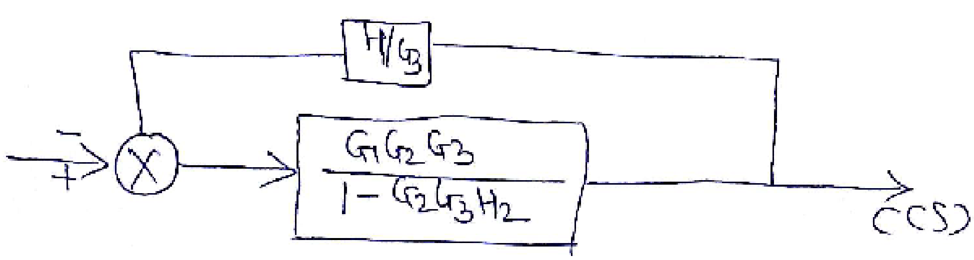
1) The answers should be examined by keywords and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling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

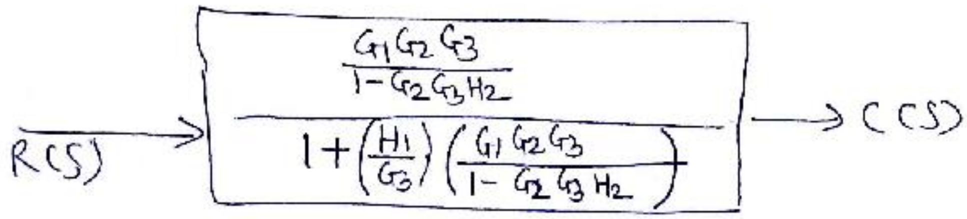
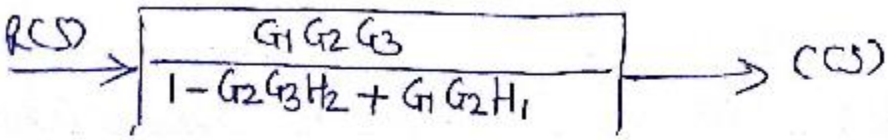
Q. No.	Question & its Answer	Remark	Total Marks
1 A)	**Attempt any three:**		12
a)	**Draw the block diagram of DC Servo System.**		04
Ans.	 **Fig: DC Servo Motor** 1) The servo system consists of error detector, amplifier, motor as controller and load whose position is to be changed. 2) DC servo system 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 not compulsory**	**03 Marks Diagram** **01 Mark for neat Labeling**	

b)	**State the need of PLC in automation.**		**04**
Ans.	**Need of PLC in automation** • To reduce human efforts. • To get maximum efficiency from machine and control them with human logic • To reduce complex circuitry of entire system • To eliminate the high costs associated with inflexible, relay-controlled systems. • Replacing Human Operators (Dangerous Environments & Beyond Human Capabilities)	**01 mark each (Any relevant four points)**	
c)	**Define stability and with the diagram of root location in s-plane define stable and unstable systems.**		**04**
Ans.	**Stability:** The system is said to be stable if it produces bounded output for a bounded input. It is used to define usefulness of the system. The stability implies that the system performance should not change even if there are small changes in system input. Any control system must be stable.  **Stable System** **Unstable System** • The system is said to be stable if poles of closed loop the system lies on left half of s-plane • The system is said to be unstable if poles of closed loop system lies on right half of s-plane **OR** • **STABILITY**: A linear time invariant system is said to be stable if the system is excited by a bounded input, output is also bounded and controllable. 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 for a bonded input it produces unbounded output. In absence of the input, output may not return to zero it shows certain output without input.	**01 mark Stability** **01 Mark Diagram of root location** **01 Mark Stable System** **01 Mark Unstable System**	

d)	**Draw block diagram of Process Control System.**		**04**
Ans.	 Process control system consists of process or plant , sensor, error detector, automatic Controller, actuator or control element. **OR**  The block diagram of process control system consists of **Measuring element, Error detector, Controller, Final control element and Process.**	**03 Marks Diagram** **01Mark for neat Labeling only**	
B)	**Attempt any ONE :**		**06**
a)	**Explain:** **i) Benefits of PLC in automation(3 points)** **ii) Scanning Cycle**		**06**
Ans.	**i) Benefits of PLC in automation** • Higher productivity. • Superior quality of end product. • Efficient usage of energy and raw materials • Improved safety in working conditions. • Fast • Easily programmed and have an easily understood programming language. **ii) Scanning Cycle** • It is number of states/steps which the controller follows when it is put in RUN mode. • It is also called as operating cycle and is defined as "the number of states through which the controller scan the program before execution" • The loaded program is kept in memory of PLC and every time the	**03 Mark (Any three points)** **01 Mark Definition**	

	program will be scan by the PLC. It has four states which are shown in fig. below.  Fig:- Scan Cycle • 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.	**01 Mark Diagram** **01 Mark (Significati on or need)**	
b)	**Derive the transfer function of the system as shown in figure 1, using block diagram reduction techniques.**  Figure 1		**06**
Ans.	Shift Take Off point after G3 block, we get 	**01 Mark**	

		01 Mark	
	Multiplying G2 & G3, We get 	01 Mark	
	Multiplying H1 & 1 / G3, we get 	01 Mark	
	Eliminating Feedback loop of H2, we get 	01 Mark	
	Multiplying G1 and other transfer function, we get 		

	Eliminating feedback loop H1 / G3 we get,  Final Transfer function can be obtained from following diagram 	**01 Mark**	
2	**Attempt any TWO:**		**16**
a)	**A) A second order system is given** $$\frac{C(s)}{R(s)}=\frac{6}{s^2+5s+6}$$ **Determine :** **a) Rise Time b) Peak Time c) Settling Time d) Peak overshoot**		**08**
Ans.	Comparing equation 1 with standard equation, $$\frac{C(s)}{R(s)}=\frac{Wn^2}{s^2+2.\xi.Wn.s+Wn^2}$$ We get, $Wn^2=6$, So, Wn = 2.45 rad /s $2.\xi.Wn=5$ So, ξ= 1.02 rad / s (approx.. 1 rad/s) Wd = Wn$\sqrt{1-\xi}$ So, Wd = 0 rad /s **Assume ξ= 0.8(or less than 1) and find wd, Tr, Tp, Ts & %Mp.** **So that system is underdamped we find all parameters.**	**01 Mark** **01 Mark** **01 Mark** **01 Mark**	

	OR Ideally the above 4 listed parameters can be given as, i) Rise time is given by tr $=\frac{\pi-\beta}{Wd}$, Where $\beta = \frac{\sqrt{1-\zeta^2}}{\zeta}$ ii) Peak Time is given by $t_p = \frac{\pi}{Wd}$ iii) Max overshoot is given by $Mp\% = 100 \times e^{-\frac{\pi\xi}{\sqrt{1-\zeta^2}}}$ iv) Settling time is given by $t_s = \frac{4}{\zeta.Wn}$ System is critically damped & hence no oscillations and no damped Therefore all 4 specifications do not exist on the response of the above system. **NOTE: Any appropriate answer with formula and suitable assumption may also considered. If the problem is solved by assuming any arbitrary value of zeta approximately near to 1 then also 02 marks may be given**	**02 Mark Formulae** **02 Mark (Conclusion or calculations with assumed value of zeta)**	
b)	**For a given transfer function** $\frac{C(s)}{R(s)} = \frac{s(s+2)}{(s^2+2s+2)(s^2+7s+12)}$ **Find:** **i)Poles ii) Zeros iii) Pole-Zero Plot iv) Characteristic Equation**		**08**
Ans.	**i) Poles: We can get poles from equations in the denominator** 1) $(s^2+7s+12) = 0.$ So root of the equation can be determined as (s+3).(s+7)=0i.e. either s = – 3 OR s = – 4	**01 Mark**	

2) $(s^2 + 2s + 2)$ — **02 Mark**

For the quadratic equation $ax^2+bx+c=0$,

the poles are $= \frac{-b \pm \sqrt{b^2-4ac}}{2a} = \frac{-2 \pm \sqrt{2^2-4.1.2}}{2.1} =$

i.e. - $\frac{-2 \pm \sqrt{-4}}{2} = \frac{-2 \pm 2j}{2} = -1 \pm j$

Therefore poles are $-1+j$ & $-1-j$

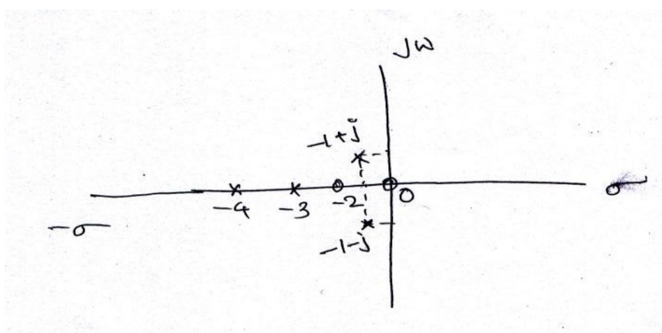
ii)Zeros: We can get zeros from equation in the numerator — **02 Mark**

So for s (s+2) equation we can get roots by comparing it with zero

s (s + 2) = 0

So zeros i.e. roots of the equation are 0 & –2

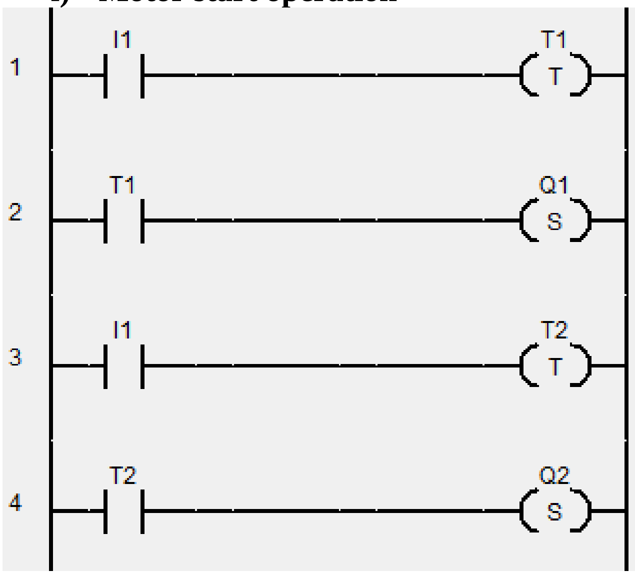
iii)Pole-Zero Plot: — **02 Mark**



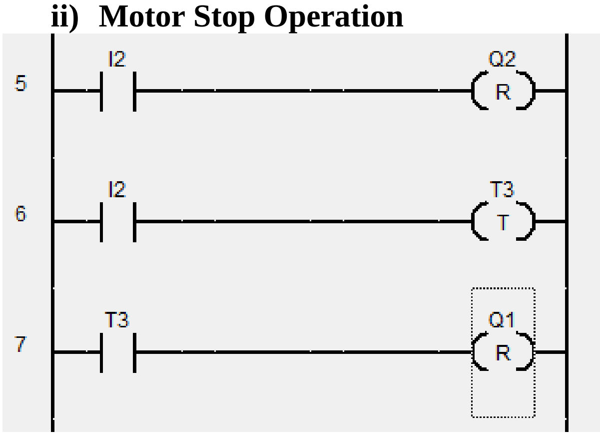
iv)**Characteristic equation**= $(s^2 + 2s + 2)(s^2 + 7s + 12)$ — **01 Mark**

c)	**Draw ladder diagram for 2 motor operation for following condition** **i) Start push button starts motor M_1 after 10 seconds and motor M_2 after 20 seconds.** **ii) When stop push button is pressed it stops M_2 and after 15 seconds M_1.**		**08**
Ans.	I1 & I2 are start & stop push buttons. T1 is On Delay Timer which turns on after 10 seconds after getting I1 T2 is On Delay Timer which turns on after 20 seconds after getting I1 T3 is On Delay Timer which turns on after 10 seconds after getting I2		

i) Motor start operation — **04 Mark**

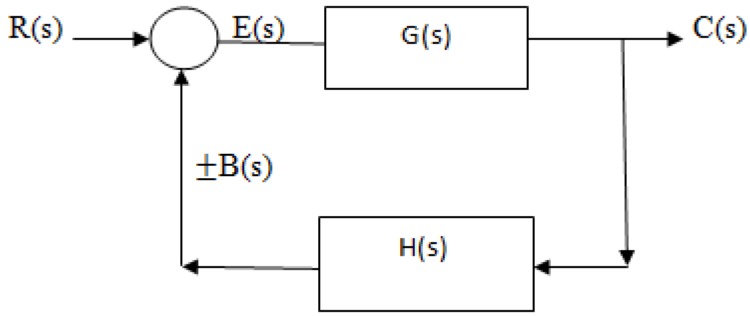


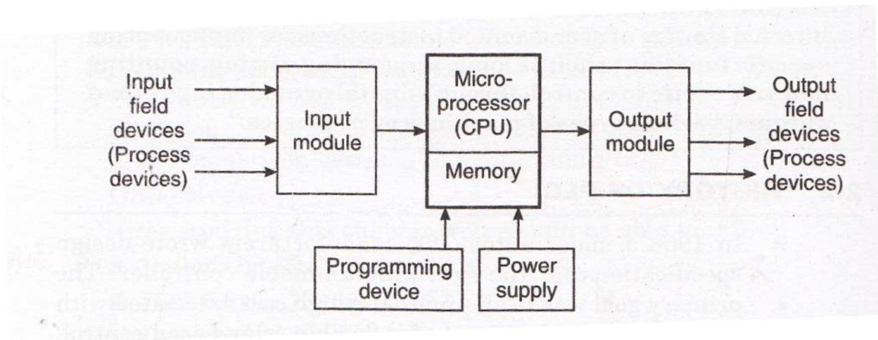
ii) Motor Stop Operation — **04 Mark**



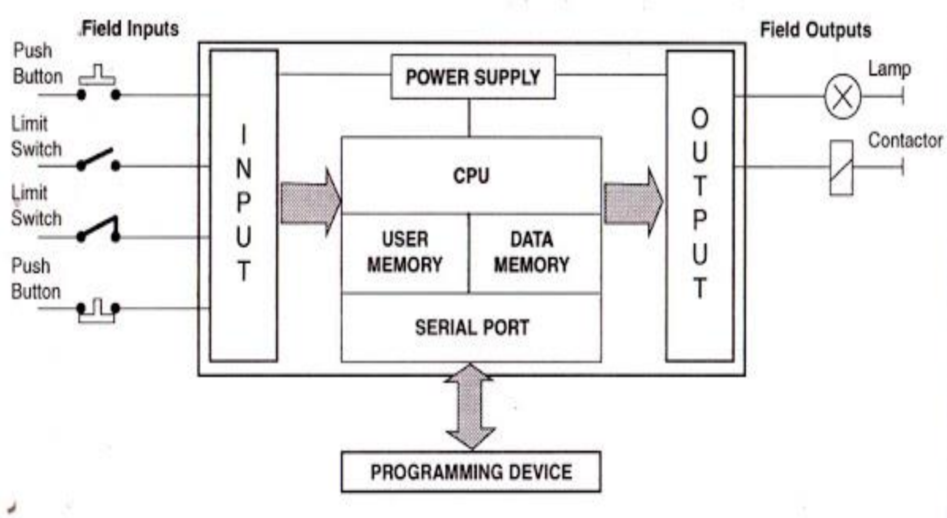
NOTE: Any relevant ladder logic may considered.

3	**Attempt any FOUR :**		**16**
a)	**Define transfer function. Derive an expression for transfer function of closed loop system.**		**04**
Ans.	**Definition**-Transfer function is the ratio of Laplace transform of output of system to Laplace transform of input of system ,when all initial conditions are assumed to be zero. Expression for Transfer function of closed loop system Consider a simple form of closed loop system	**01 Mark Definition**	

	 Where R(s) -Reference input G(s)-Forward path T.F C(s) - Controlled output H(s) –Feedback path T.F E(s)-Error signal B(s)-Feedback signal According to T.F Definition Transfer Function = $\frac{Laplace\ of\ output}{Laplace\ of\ input} = \frac{C(s)}{R(s)}$ Here Error signal is given by E(s)= R(s) $\pm$ B(s)……………………………………………(1) Feedback signal is given below B(s)= C(s).H(s)…………………………………………….(2) Output of system is given as C(s) =G(s).E(s)………………………………………………..(3) Put the value of E(s) and B(s) in equation (3) C(s) = G(s).[R(s) $\pm$ C(s).H(s)] C(s) =G(s).R(s) $\pm$ G(s)C(s).H(s) C(s)$\mp$ G(s)C(s).H(s) = G(s).R(s) C(s)[1$\mp$G(s)H(s)] = G(s)R(s)	**03 Mark Expression**	

<table>
<tr><td></td><td>By rearranging the equation ,we get Transfer Function of closed loop system as
$$\frac{c(s)}{R(s)} = \frac{G(s)}{[1 \mp G(s)H(s)]}$$</td><td></td><td></td></tr>
<tr><td>b)</td><td>Draw the block diagram of PLC and explain its C.P.U. block.</td><td></td><td>04</td></tr>
<tr><td>Ans.</td><td>


OR



A simplified block diagram of a PLC shown in above Fig. It has three major units/sections.

- I/O (Input/Output) Modules.
- CPU (Central Processing Units).
- Programmer/Monitor.

CPU Section:-
The Central Processing Unit, the brain of the system is the control portion of the PLC. It has three Subparts.
</td><td>02 Marks Block Diagram

02 Marks for relevant Explanation</td><td></td></tr>
</table>

- Memory System
- Processor
- Power Supply

Memory System:-

The memory is the area of the CPU in which data and information is stored and retrieved. The total memory area can be subdivided into the following four Sections.

- I/O Image Memory

The input image memory consists of memory locations used to hold the ON or OFF states of each input field devices, in the input status file.
The output status file consists of memory locations that stores the ON or OFF states of hardware output devices in the field. Data is stored in the output status file as a result of solving user program and is waiting to be transferred to the output module's switching device.

- Data Memory

It is used to store numerical data required in math calculation, bar code data etc.

- User Memory

It contains user's application program.

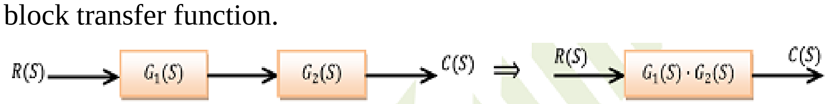
- Executive Memory

It is used to store an executive program or system software. An operating system of the PLC is a special program that controls the action of CPU and consequently the execution of the user's program. A PLC operating system s designed to scan image memory, interprets the instruction of user's program stored in main memory, and executes the user's application program the operating system is supplied by the PLC manufacturer and is permanently held in memory.

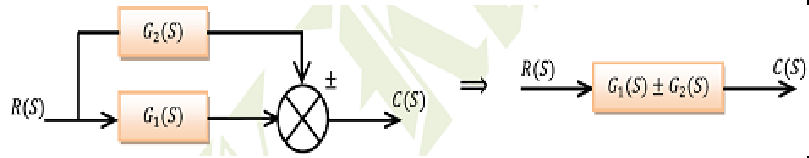
c) **State with diagram any four block diagram reduction rules.** **04**

Ans. i) Combining a block in cascade: When two or more blocks are connected in series, their overall transfer function is the product of individual block transfer function.

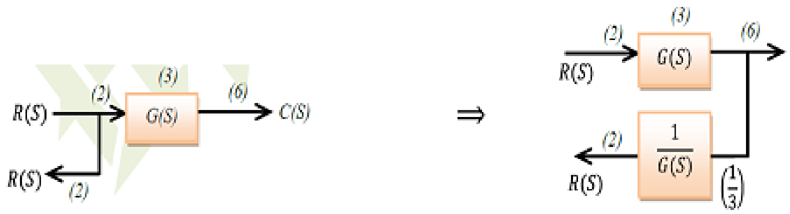
04 Marks (Any four rules)



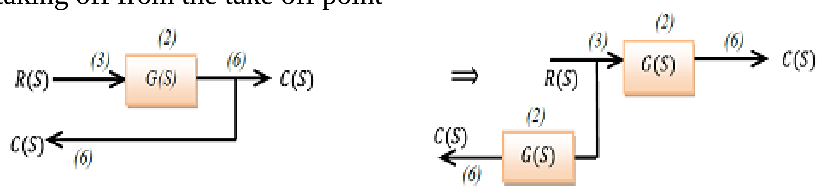
ii) Combining two blocks in parallel: When two or more blocks are connected in parallel, their overall transfer function is the addition or difference of individual transfer function.



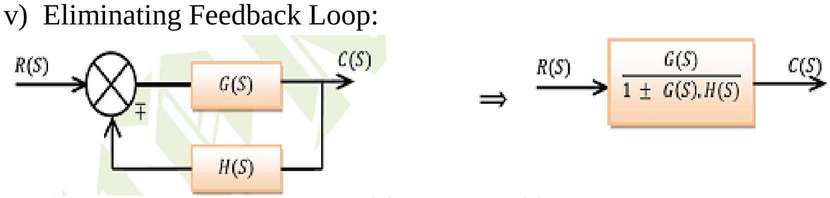
iii) Shifting a take off point after a block: To shift take off point after a block, we shall add a block with transfer function 1/G in series with signal having taking off from that point.



iv) Shifting a take off point before a block: To shift take off point before a block, we shall add a block with transfer function G in series with signal having taking off from the take off point

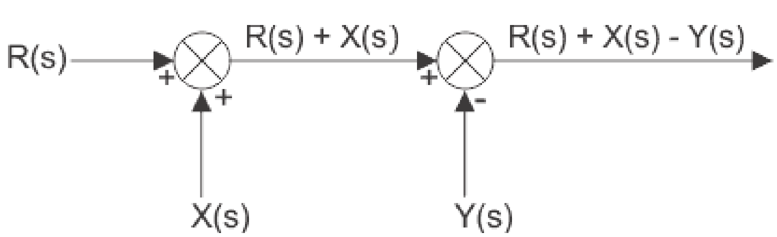


v) Eliminating Feedback Loop:

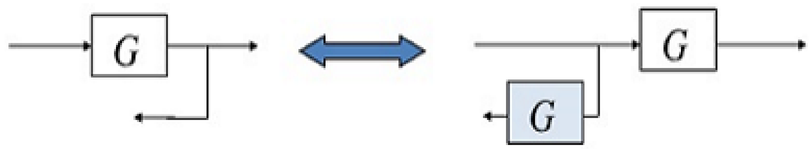


$$\frac{C(s)}{R(s)} = \frac{G(s)}{1 \pm G(s).H(s)}$$

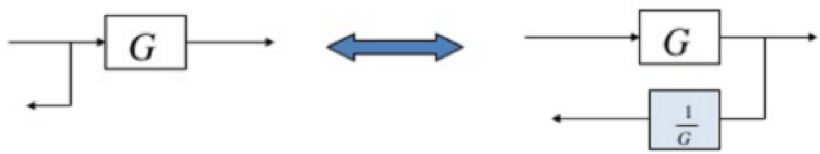
vi) Interchanging Summing Points: The order of summing points can be interchanged, if two or more summing points are in series and output remains the same.



vii) Moving Take off point before a summing point: To shift a take off point before summing point, add a summing point in series with take off point.



viii) Moving Take off point after a summing point: To shift a take off point after summing point, one more summing point is added in series with take off point.



ix) Moving summing point after a block: To shift summing point after a block, another block having transfer function G is added before the summing point.

x) Moving summing point before a block: To shift summing point before a block, another block having transfer function 1/G is added before the summing point.

d) **By means of Routh's criteria determine the stability of the system $s^4 + 2s^3 + 8s^2 + 4s + 3 = 0$.** **04**

Ans. Find even & odd coefficient from characteristics equation

F (s) = $s^4 + 2s^3 + 8s^2 + 4s + 3 = 0$

(2) Makes Routh's array — **03 Marks Routh array**

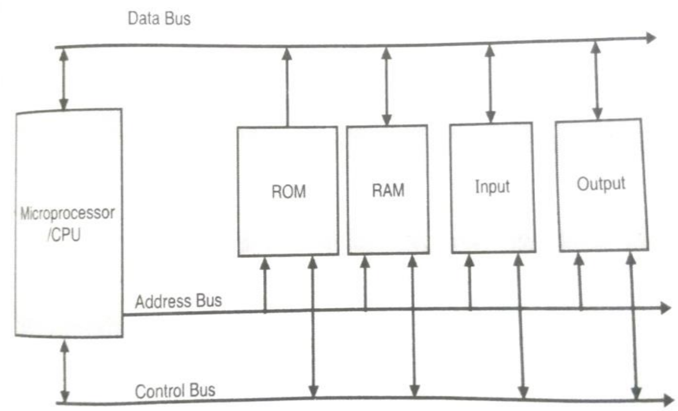
S4	1	8	3
S3	2	4	0
S2	6	3	0
S1	3	0	
S0	3	0	

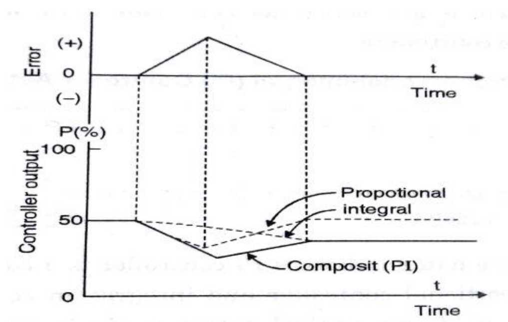
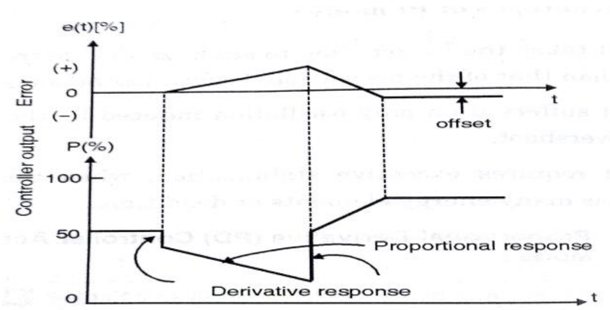
3) **Conclusion** – As in the first column of Routh's array there is no sign ange in the first column therefore system is stable — **01 Mark conclusion**

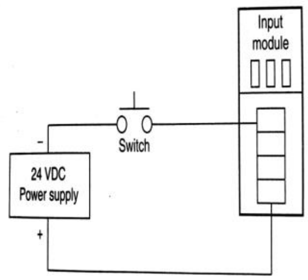
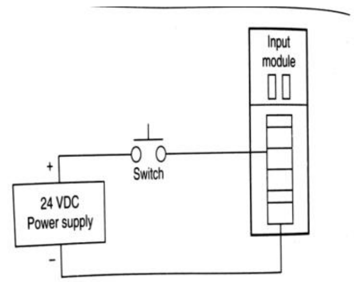
e) **Explain the function and Organization of memory in PLC.** **04**

Ans.

Organization of memory in PLC

		**02 Marks Diagram**	
	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 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. **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	**02 Marks explanation**	

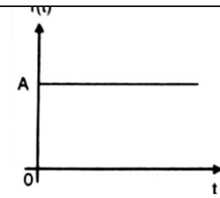
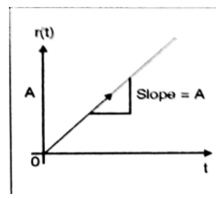
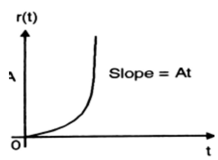
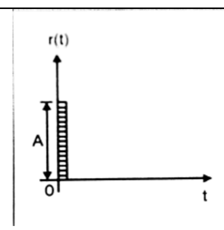
	programmable read only memory is similar to the EPROM .Instead of UV light exposure for erasure, an electrical signal is applied to the chip. The speed of erasing of EEPROM is greater than EPROM.		
4 (A)	**Attempt any THREE:**		**12**
(a)	**Write the O/P equations and draw the response of PI and PD controller.**		**04**
Ans.	**1)PI controller-** **Output equation-** $P = K_p \, . \, e_p + K_p K_i \int_{\rho}^{t} e_p(t). \, dt + P_I(0)$ **Response-**  **2)PD controller-** **Output equation-** $P = K_p \, . \, e_p + K_p K_D \frac{d}{dx}(e\,p) + P_{(0)}$ **Response-**  	**02 Marks O/P equations** **02 Marks for Responses**	
(b)	**Explain with diagram concept of sinking and sourcing in discrete input**		**04**

	module.		
Ans.	Fig 1-Sourcing D.C input module with sinking switch Fig 2 - Sinking D.C input a 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 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.	**02 Marks for concept of sinking with diagram** **02 Marks for concept of sourcing with diagram**	

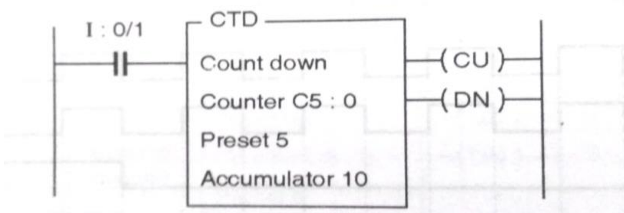
(c)	**Differentiate between fixed and modular PLC. (4 points)**		**04**
Ans.	(see table below)	**04 Marks (Any four points)**	

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.

(d)	**List different standard test inputs. Draw them and give their Laplace equations.**		**04**
Ans.	**Different standard Test input** **1.** Step input **2.** Ramp input **3.** Parabolic input **4.** Impulse input	**01 Mark list**	

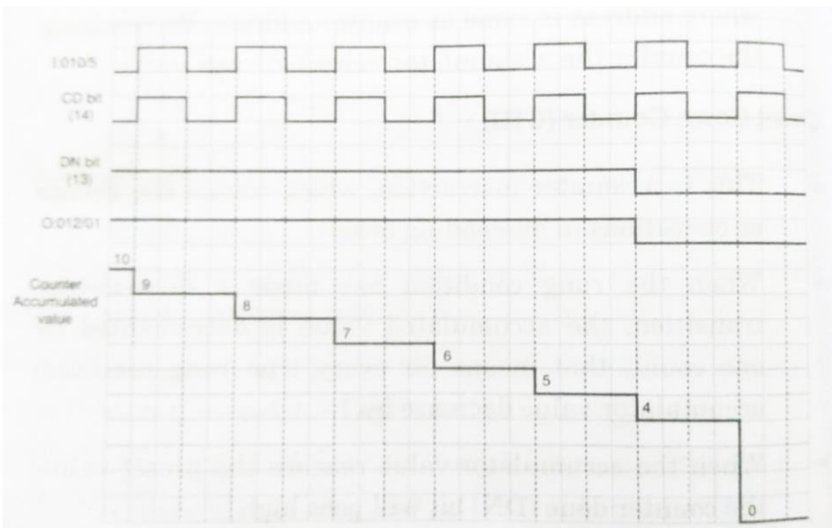
Standard test input	Laplace Representation	Waveforms	Marks
Step input(position function) r(t)	L.T of r(t) =R(s)=A/s		**03 Marks Laplace equation(Any three inputs)**
Ramp input(Velocity function) r(t)	L.T of r(t) = R(s)=A/s^2		
Parabolic input(Acceleration r(t) function)	L.T of r(t) = R(s)=A/s^3		
Impulse input r(t)	L.T of r(t) = R(s)= 1 if A=1		

B)	**Attempt any ONE:**		**06**
(a)	**Explain with diagram and waveform of down-counter instructions in PLC.**		**06**
Ans.	**Functional diagram of Down counter**	**02 Marks Functional diagram**	



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

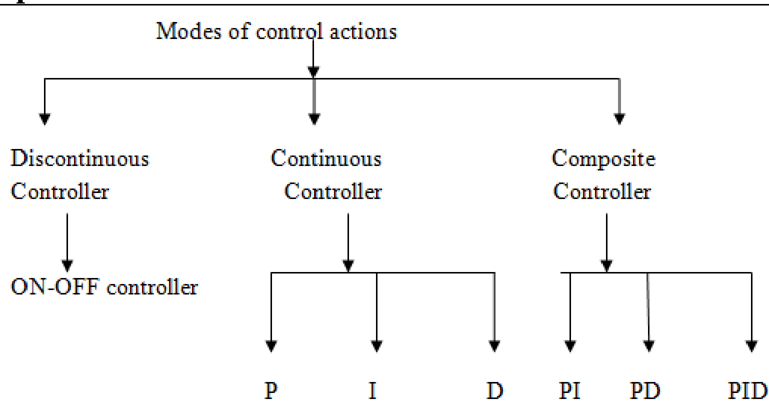
- This is a counter instruction, which counts the events or operations in descending order.
- When the rung condition has made a false to true transition, the accumulated value is decremented by one count , that means for every true rung condition accumulator value decrease by 1.
- When accumulator value reaches the preset value, the counter done (DN) bit will goes high
- This DN bit can be use to turn on any output field device. The counter can be reset by using separate input. This input reset the accumulated value to zero



Waveform of down counter</td><td>

02 Marks explanation

02 Marks waveform</td><td></td></tr>
<tr><td>**(b)**</td><td>**List types of control actions. Give its output equation and corresponding laplace transforms.**</td><td></td><td>**06**</td></tr>
<tr><td>**Ans.**</td><td>


</td><td>**02 Marks List**</td><td></td></tr>
</table>

1)O /P equation of ON-OFF controller

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

2) O/P equation of PI controller

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

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

3) O/P equation of PD controller

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

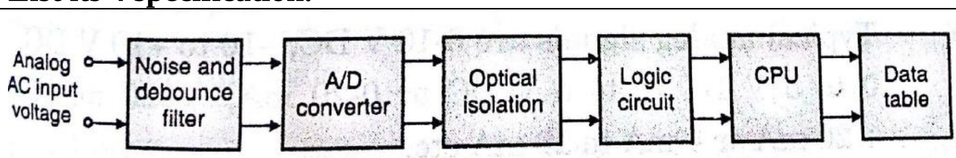
4) O/P equation of PID controller

$$P(t) = k_p e(t) + k_p k_i \int_0^t e(t)\,dt + k_p k_d \frac{de(t)}{dt} + p(0)$$

04 Marks o/p equation

5	**Attempt any TWO:**		**16**
a)	**Draw the block diagram of analog input module. Explain each block. List its 4 specification.**		**08**

Ans.



03 Marks Block Diagram

- Analog input module is a module which connects the PLC to a analog input signal such as signals from thermocouple, flow meter etc. Analog input module give ability to the PLC to monitor continuously time varying signals such as temperature, level, pressure etc.
- This module converts the analog signals from analog to digital signal which can be handled by processor.
- Typical signal levels are usually 0-10V DC, –10 to +10V DC, 0 to 5V DC, 1 to 5V DC or 0-20mA, -20mA to +20mA or 4mA to 20mA etc.

03 Marks for Explanation of each block

<table>
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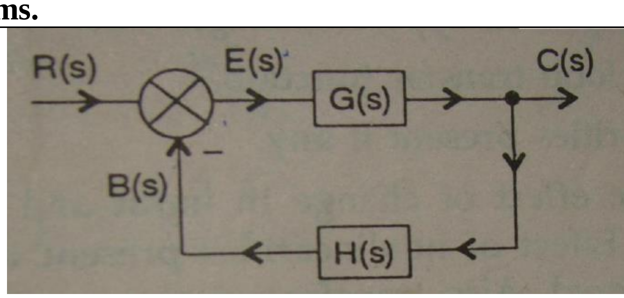
The block diagram of analog input module consists of filter, ADC, optical isolation, logic circuit. Analog input modules are selected to accept either voltage or current signals.
When analog input is provided to PLC through analog input module, it reaches different noise and debounce filters. Using these filters the noise is filtered out from the signal
The signal is converted to digital signal using ADC. This digital signal is passed through optical isolation to logic circuit.
The logic selection allows digital signal to CPU and on the data table for storage.

<table>
<tr><th>Specifications</th><th>Typical Value</th></tr>
<tr><td>Output Voltage</td><td>±10</td></tr>
<tr><td>Output Current</td><td>0-20mA</td></tr>
<tr><td>Accuracy (0-55^oC)</td><td></td></tr>
<tr><td>Voltage Output</td><td>±2% of Full Scale</td></tr>
<tr><td>Current Output</td><td>±2% of Full Scale</td></tr>
<tr><td>Settling Time</td><td></td></tr>
<tr><td>Voltage Output</td><td>100 us</td></tr>
<tr><td>Current Output</td><td>2 ms</td></tr>
<tr><td>Maximum Drive</td><td></td></tr>
<tr><td>Voltage Output</td><td>5000Ω</td></tr>
<tr><td>Current Output</td><td>500Ω</td></tr>
<tr><td>Resolution full scale</td><td></td></tr>
<tr><td>Voltage Output</td><td>12 bit</td></tr>
<tr><td>Current Output</td><td>11 bit</td></tr>
</table>
</td><td>02 Marks Specifications(Any four)</td><td></td></tr>
<tr><td>b)</td><td>Derive steady state error and error constants equations for Type-0 and Type-1 systems.</td><td></td><td>08</td></tr>
<tr><td>Ans.</td><td>


Steady state error can be derived as,

E(s) = R(s) – B(s)
</td><td>04 Marks Derivation of steady state error</td><td></td></tr>
</table>

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

But, B(s) = C(s).H(s)
E(s) = R(s) – C(s).H(s)
But, C(s) = E(s).G(s)
So, E(s) = R(s) – E(s).G(s).H(s)
i.e. E(s) [1 + G(s).H(s)] = R(s)
i.e. $E(s) = \frac{R(s)}{1+G(s).H(s)}$
Steady state error is given by,
$e_{ss} = \lim_{t\to\infty} e(t)$
By using final value theorem we get,
$e_{ss} = \lim_{s\to 0} s.E(s)$
i.e. $e_{ss} = \lim_{s\to 0} \frac{s.R(s)}{1+G(s).H(s)}$
Kp, Kv& Ka are obtained by following mathematical equation,
$Kp = \lim_{s\to 0} G(s).H(s)$
$Kv = \lim_{s\to 0} s.G(s).H(s)$
$Ka = \lim_{s\to 0} s^2 G(s).H(s)$
<table>
<tr><td>Type of system</td><td>Step Input
R(s) = 1/s</td><td>Ramp Input
$R(s) = 1/s^2$</td><td>Parabolic Input
$R(s) = 1/s^3$</td></tr>
<tr><td>0</td><td>$\frac{A}{1+Kp}$</td><td>∞</td><td>∞</td></tr>
<tr><td>1</td><td>0</td><td>$\frac{A}{Kv}$</td><td>∞</td></tr>
</table>

</td><td>**04 Mark Error Constants**</td><td></td></tr>
<tr><td>**c)**</td><td>**Using Routh's criteria, determine the range of K values for system to be stable.**</td><td></td><td>**08**</td></tr>
</table>

$$G(s).H(s) = \frac{K}{s(s+2)(s+4)(s+5)}$$

Ans. The characteristics equation of transfer function is given by
1 + G(s).H(s) = 0

$$So,\quad 1 + \frac{K}{s(s+2)(s+4)(s+5)} = 0$$

i.e. $s(s+2)(s+4)(s+5) + K = 0$

i.e. $s^4 + 9.s^3 + 20.s^2 + 2.s^3 + 18.s^2 + 40.s + K = 0$

i.e. $s^4 + 11.s^3 + 38.s^2 + 40.s + K = 0$

thus a0 = 1, a1 = 11, a2=38, a3 = 40 and a4= K

The Routh's array can be written as under:

S^4	1	38	K
S^3	11	40	0
S^2	$\frac{11x38 - 1x40}{11} = 34.36$	K	0
S^1	$\frac{1374.4 - 11.K}{34.36}$	0	
S^0	K		

02 Marks for characteristics equation

04 Marks for Solving Array

For stability of a system there should be no change in sign.

i) i.e. $\frac{1374.4-11K}{34.36}$>0 and hence K = 0

OR

ii) $\frac{1374.4-11K}{34.36}$>0 i.e. 1374.4–11K > 0

So, 1374.4 > 11 K

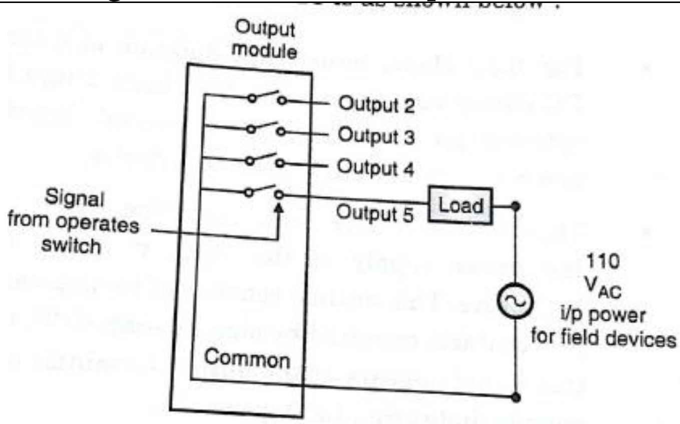
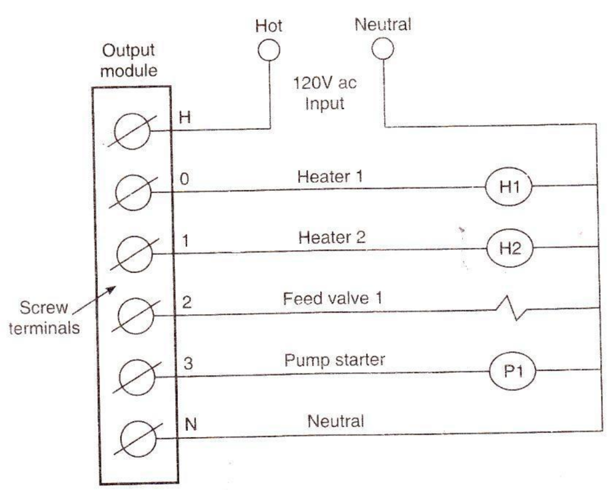
K_{max}< 124.94

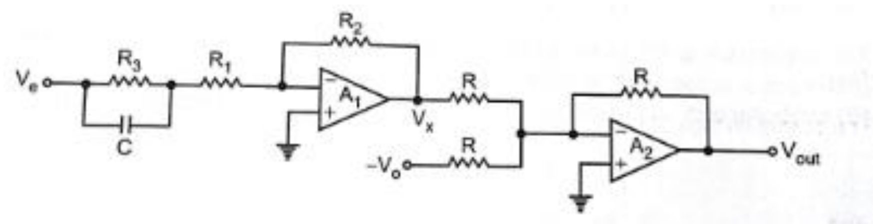
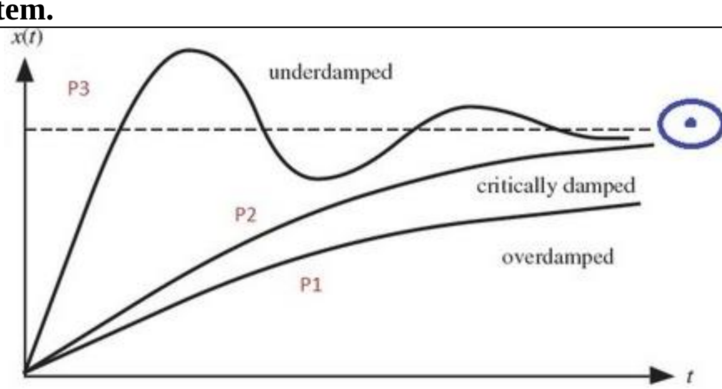
Combining both conditions for stability, we get 0 < K < 124.94

02 Marks Stability Conditions and range of K

6	**Attempt any FOUR of the following**		**16**
a)	**Explain w.r.t proportional action**		**04**

	i) offset **ii) proportional band**		
Ans.	**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. • A common characteristic of proportional control is an error between the set point and control point, which is referred to as offset or droop. • Offset is an undesirable characteristic of proportional only control loops in proportional controller and is easily eliminated by adding Integral Action. **Proportional Band:** • It is a range of deviation, in percent scale; that corresponds to the full range of deviations. It is independent on gain. • It is defined as percentage of error which results in 100% change in controller output. • 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. • Proportional band is defined as the amount of change in the controlled variable required to drive the loop output from 0 to 100%. In a controller the manipulating variable is proportional to the control deviation within the proportional band. • The gain of the controller can be matched to the process by altering the proportional band. If the proportional band is set to zero, the controller action is ineffective. • A very narrow proportional band is tending towards two step control action, since a large change in the controller output will result from a small change in controlled action • A very wide proportional band may result into sluggish or slow control	**02 Marks** **02 Marks**	
b)	**State any two advantages and disadvantages of Routh Array.**		**04**
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	**02 Marks each(Any two valid point)**	

	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 cant be applied if coefficients of characteristics equation are complex • It is useful to find out only the absolute stability of a system. • It is very complex to obtain relative stability of the system • It can not 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)	**Describe the wiring details of Discrete output module**		**04**
Ans.	 **Typical wiring for 120 V AC discrete output module**  Typical discrete output module wiring diagram • The above figure 1 & fig 2 show the basic field wiring for digital	**02 Marks for Diagram**	

	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.	**02 Mark for relevant Explanation**	
d)	**Draw electronic PD controller. State its equation and give its two disadvantage.**		**04**
Ans.	**Electronic PD Controller**  **Equation of PD controller can be given as,** $P(t) = P(0) + Kp. E(t) + Kp.Kd.\frac{de(t)}{dt}$ Where Kp is proportional controller gain, Kd is derivative controller gain, e(t) is error signal **Disadvantages:** • It cannot eliminate the offset of proportional controller. • The derivation is assumed to change at constant rate. But if not then it may give unpredictable result.	**02 Marks for Diagram** **01 Mark For equation** **½ Mark for Each Disadvantages**	
e)	**State with diagram the effect of damping on the response of second order system.**		**04**
Ans.	 		

	Effect of damping in response of 2nd order control system:	**01 Mark each for all 4 cases with diagram**	

No.	Range of ζ	Type of close loop poles	Nature of response	System Classification
1	**$\zeta = 0$**	Purely imaginary	Oscillations with constant amplitude & frequency	Undamped
2	**$0 < \zeta < 1$**	Complex Conjugates with negative real parts	Damped Oscillations	Underdamped
3	**$\zeta = 1$**	Real, Equal and Negative	Critical & Pure exponential	Critically damped
4	**$1 < \zeta < \infty$**	Real, equal & Negative	Purely exponential slow and sluggish	Overdamped