T.Y. Diploma : Sem. V
[ET/EN/EX/EJ/DE/ED/EI]

Control System & PLC

Time: 3 Hrs.] Prelim Question Paper Solution **[Marks : 100**

Q.1(a) Attempt any THREE of the following : [12]

Q.1(a) (i) Consider a system with characteristic equation [4]

$S^5 + 2S^4 + 2S^3 + 4S^2 + 11S + 10 = 0$

Determine stability using Routh's criteria.

Ans.: 1) Firstly Find even & odd coefficient from characteristics equation

S5 + 2.S4 + 2.S3 + 4.S2 + 11.S + 10 = 0.

2) The routh's array for above characteristics equation is formed as follows

S^5	1	2	11	
S^4	2	4	10	
S^3	0	6	0	Special case
S^2	∞	10		
S^1				
S^0				

Substitute a small positive number ε in place of 0 occurred as a first element in a row. Complete the array with this number ε. Then examine the sign

Change by taking $\lim\limits_{\varepsilon\to 0}$

S^5	1	2	11
S^4	2	4	10
S^3	ε	6	0
S^2	4ε-12/ε	10	0
S^1	$\dfrac{(24\varepsilon-72-10\varepsilon^2)}{4\varepsilon-12}$	0	0
S^0	10	0	0

To examine sign change

$\lim\limits_{\varepsilon\to 0} 4\varepsilon-12/\varepsilon = \infty$

$\lim\limits_{\varepsilon\to 0}(24\varepsilon-72-10\varepsilon\text{^}2)/4\varepsilon-12 = 6$

So, Final Array is

S^5	1	2	11
S^4	2	4	10
S^3	ε	6	0
S^2	∞	10	0
S^1	6	0	0
S^0	10	0	0

Routh"s stability criteria states that the elements of 1st column of Routh"s array should not have any sign change for the system to be stable. The number of sign changes in the 1st column indicates the number of Poles on RHS which makes the system unstable. Here, No sign changes in the 1st column indicate system is stable.

(Note:- Alternative method of Rouths Array by replacing S with 1/Z in the original equation also can be considered n.)

Q.1(a) (ii) Give the classification of PLC. Explain modular PLC in brief. [4]

Ans.: classification of PLC

(1) According to structure of PLC
  a. Integral type
  b. Modular Type

(2) Depending upon the no. of I/Os
   a. Small(<100)
   b. Medium(<10000)
   c. Large(>10000)

(3) Depending upon the I/Os supported
   a. Digital
   b. Analog

Modular PLC

- Modular PLC Modular PLC is a constituent part of the PLC, are made of several separate modules, such as CPU module, I / O modules, power modules (including some in the CPU module) and a variety of functional modules.
- Modular PLC by the frame or the substrate and the various modules.
- Module installed in the socket frame or substrate.
- Features The modular PLC is flexible configuration, the system can choose different sizes according to needs, and easy to assemble, easy expansion and maintenance.
- Large and medium-sized PLC generally use the modular structure.

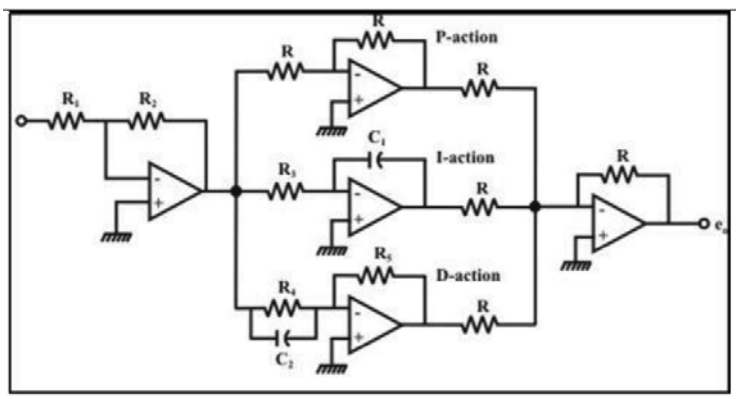
Q.1(a) (iii) Compare open loop and closed loop control system (four points). **[4]**

Ans.:

Sr. No.	Open Loop Control System	Close Loop Control System
1	It is simple and economical	It is complex and costlier
2	It is easier to construct, as it requires less number of components	It is not easy to construct, as it requires more number of components
3	It consumes less power	It consumes more power
4	It is more stable	Lit is less stable
5	It does not require feedback path element	It requires feedback path element
6	It has poor accuracy	It has better accuracy
7	It does not give automatic correction for external disturbances	It gives automatic correction for external disturbances
8	It is more sensitive to noise	It is less sensitive to noise
9	It is dependent on operating condition	It is not dependent on operating conditions
10	Its operation is degraded if non linearity are present	Its operation is not independent on conditions
11	It has slow response	It has fast response
12	It has high bandwidth	It has low bandwidth

Q.1(a) (iv) Draw electronic PID controller and state its equation. **[4]**

Ans.:



Equation

$$V = V_S + K_p * E + K * \int_0^t E * dt + K_D * \frac{dE}{dt}$$

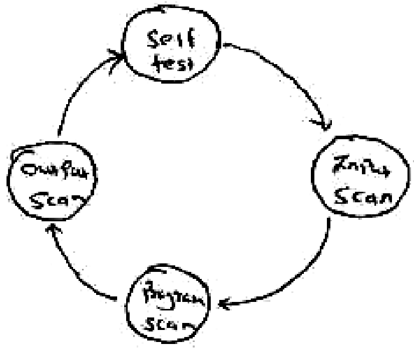
Where:
V = Control variable
V_S = Output Set point
K_P = Proportional gain
E = Error (SP-PV)
K_I = Integral gain
K_D = Derivative gain
t = Time

Q.1(b) Attempt any ONE of the following : [6]

Q.1(b) (i) State with respect to PLC : [6]
(1) Scanning Cycle & (2) Speed of execution

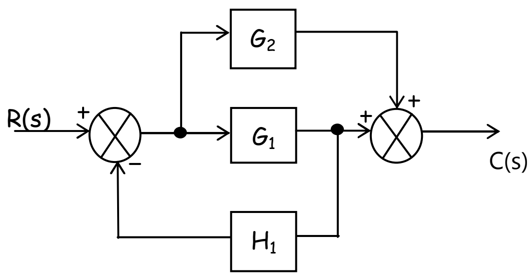
Ans.: Scanning Cycle

- 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 program will be scan by the PLC. It has four states which are shown in fig. below.
- 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.

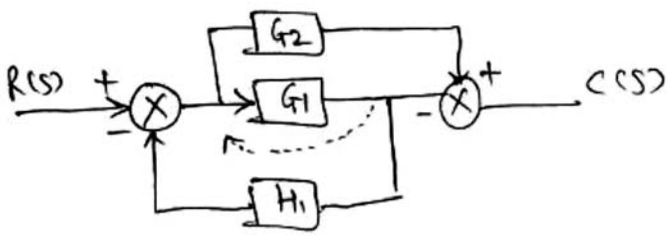


Speed of execution: The speed at which PLC scans memory and executes the program is referred as a speed of execution. Higher CPU speeds provide faster performance that shortens task time.

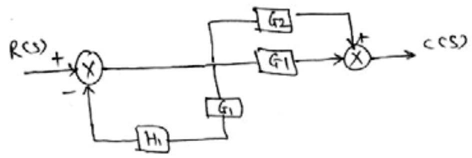
Q.1(b) (ii) Using block diagram reduction technique, obtain T.F. of the block diagram. [6]



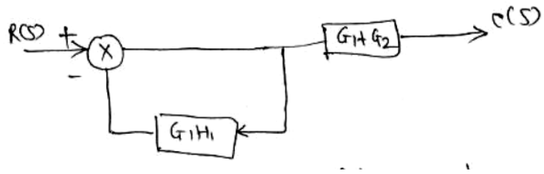
Ans.:



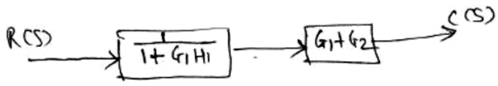
1) Shifting take-off point of H1 before G1, we get,



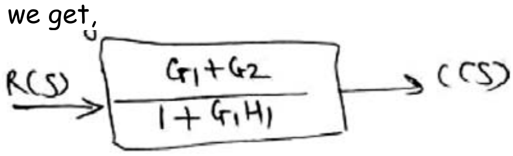
2)



3) Eliminating feedback loop G_1H_1 we get



4) Adding both block we get,



Q.2 Attempt any TWO of the following : [16]

Q.2 (a) Find K_p, K_v, K_a & steady state error for a system with open loop transfer function as [8]

$$G(S)\ H(S) = \frac{10(S+2)(S+3)}{S(S+1)(S+4)(S+5)}$$

Where input $r(t) = 3 + t + \frac{t^2}{2}$

Ans.: (i) Positional error coefficient (K_p) is given by,

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

Assuming unity feedback system i.e. H(s) = 1, we will get

$$K_p = \lim_{s\to 0} \frac{10(s+2)(s+3)}{s(s+1)(s+4)(s+5)}$$

$K_p = \infty$

(ii) Velocity error coefficient (K_v) is given by,

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

$$\text{So, } K_v = \lim_{s\to 0} s.\frac{10(s+2)(s+3)}{s(s+1)(s+4)(s+5)} = \lim_{s\to 0} \frac{10(s+2)(s+3)}{(s+1)(s+4)(s+5)}$$

$$K_v = \frac{60}{20} = 3$$

(iii) Acceleration error coefficient (K_a) is given by,

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

Assuming unity feedback system i.e. H(s) = 1, we will get

$$K_a = \lim_{s\to 0} S^2.\frac{10(s+2)(s+3)}{s(s+1)(s+4)(s+5)}$$

i.e. $K_a = 0$

(iv) Steady State Error is given as,

$$e_{ss} \lim_{s\to 0} \frac{s.R(s)}{1+G(s).H(s)}$$

Here R(s) = $L(3+t+\frac{t^2}{2})$ = $\frac{3}{s}+\frac{1}{s^2}+\frac{1}{s^3}$ for unit step input, we get

$$= \lim_{s\to 0} \frac{s(\frac{3}{s}+\frac{1}{s^2}+\frac{1}{s^3})}{1+\frac{10(s+2)(s+3)}{s(s+1)(s+4)(s+5)}} =$$

$$\lim_{s\to 0} \frac{(3s^2+s+1)(s+1)(s+4)(s+5)/s}{s(s+1)(s+4)(s+5)+10(s^2+5s+6)}$$

$e_{ss} = \infty$

Q.2 (b) A unity feedback system has **[8]**

$$G(S) = \frac{16}{S(S+5)}$$

If a step input is given, calculate (i) rise time, (ii) peak time, (iii) maximum overshoot, (iv) settling time.

Ans.: Comparing above equation with standard equation,

$$\frac{C(s)}{R(s)} = \frac{Wn^2}{s^2+2.\xi.Wn.s+Wn^2}$$

We get,

$Wn^2 = 16$, So, $W_n = 4$ rad/s

$2.\ \xi.Wn = 5$ So, $\xi = 0.625$

$W_d = W_n\sqrt{1-\xi^2}$ So, $W_d = 3.12$ rad/s

Ideally the above 4 listed parameters can be given as,

(i) Rise time is given by tr = $\frac{\pi-\beta}{Wd}$, where $\beta = \frac{\sqrt{1-\xi^2}}{\xi}$

$$\beta = \frac{\sqrt{1-\xi^2}}{\xi} = \frac{0.78}{0.625} = 1.24$$

$$tr = \frac{\pi-\beta}{Wd} = \frac{3.14-1.24}{3.12} = \frac{1.9}{3.12} = 0.608 \text{ sec}$$

(ii) Peak Time is given by tp = $\frac{\pi}{Wd} = \frac{3.14}{3.12}$ = 1 sec

(iii) Max overshoot is given by Mp% = $100\times e^{-\frac{\pi\xi}{\sqrt{1-\xi^2}}}$

$$Mp = 100\times e^{-\frac{\pi.\xi}{\sqrt{1-\xi^2}}} = 100\times e^{-\frac{3.14\times 0.625}{\sqrt{1-0.39}}}$$

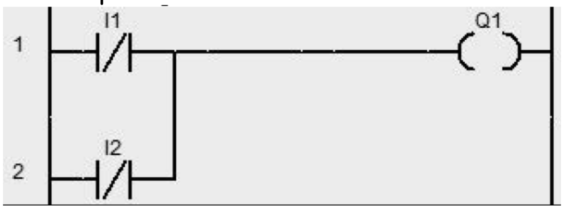
$$Mp = 100\times e^{-\frac{1.962}{0.781}} = 100\times e^{-2.51}$$

Mp = 8.12%

(iv) Settling time is given by ts = $\frac{4}{\xi.Wn} = \frac{4}{0.625\times 4}$ = 1.6 sec

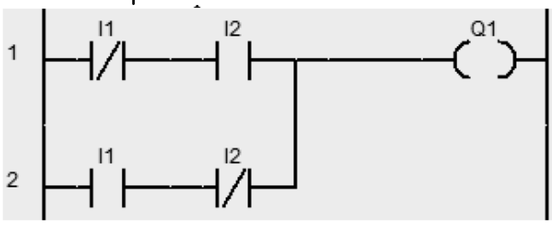
Q.2 (c) Draw ladder diagram to verify following logic gates truth table : [8]
(i) NAND gate (ii) EXOR gate (iii) NOR gate (iv) AND gate

Ans.: (i) NOR Gate for I1 & I2 Inputs



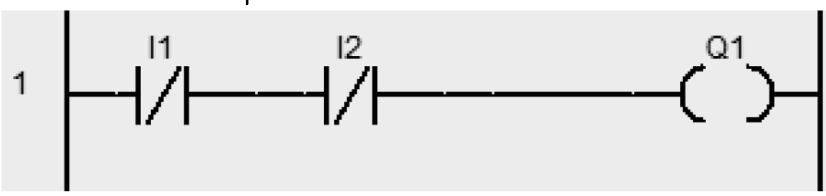
I1	I2	Q1
0	0	1
0	1	1
1	0	1
1	1	0

(ii) Ex-OR Gate for I1 & I2 Inputs



I1	I2	Q1
0	0	0
0	1	1
1	0	1
1	1	0

(iii) NOR Gate for I1 & I2 Inputs



I1	I2	Q1
0	0	1
0	1	0
1	0	0
1	1	0

(iv) AND Gate for I1 & I2 Inputs

I1	I2	Q1
0	0	0
0	1	0
1	0	0
1	1	1

Q.3 Attempt any FOUR of the following : [16]

Q.3 (a) Compare linear and non-linear system (four points). [4]

Ans.:

Linear System	Non-Linear System
Obey superposition theorem/principle.	Do not obey superposion theorem/principle.
Can be analyzed by standard test input signal	Cannot be analyzed by standard test input signal
Do not exhibit limit cycles	exhibit limit cycles
Do not exhibit Hysteresis/ jump resonance.	Exhibit Hysteresis/ jump resonance.
Stability depends only on root location	Stability depends only on root location, initial condition and type of input.
Can be analyzed by Laplace, Fourier, Z transform	Cannot be analyzed by these methods.
e.g Potentiometer	e.g Logarithmic amplifier

Q.3 (b) Explain the functions of output module of PLC. [4]

Ans.:
- Output devices are connected to PLC through output modules, that means it function as a medium that connects the external output devices such as Lamp, motor or solenoid etc. to the CPU within PLC.
- Information from PLC is always in the form of digital signals such as high or low, true or false or zero or one. This module is connecting the PLC to the output field devices.
- Output devices used with PLC are Motor, display, solenoid, heater, lamps, relays, buzzer etc.
- Output module also performs the four important functions.
  1. Signal conditioning
  2. Indication
  3. Termination
  4. Isolation

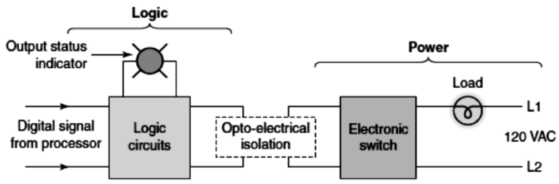


Fig- Output module of PLC

Q.3 (c) Draw neat sketch of unit step response of a second order system with neat labeling. [4]

Ans.:

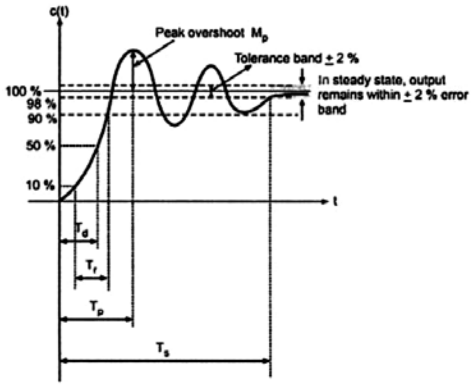


Fig- Unit step response of second order system

Where,

Tp- Peak time(sec)

Ts-Settling time(sec)

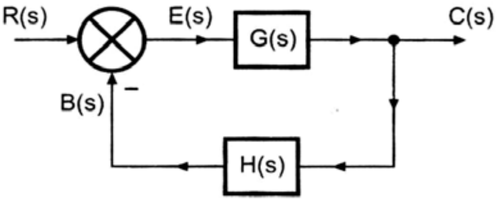
Tr-Rise time(sec)

Td-Delay time(sec)

Mp-maximum peak overshoot(%)

Q.3 (d) Derive an expression for T.F. of closed loop system. **[4]**

Ans.: Consider a simple closed loop system using negative feedback as shown



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 $C(s)H(s)$

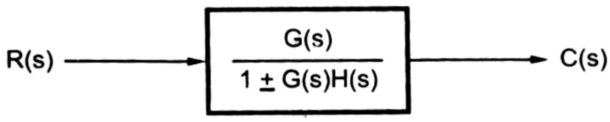
$$E(s) = \frac{C(s)}{G(s)}$$

$\frac{C(s)}{G(s)} = R(s)$ m $C(s)H(s)$

$$C(s)[1 \pm G(s)H(s)] = R(s)\,G(s)$$

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

Use + sign for negative feedback and Use – sign for positive feedback.
This can be represented as in the figure.



Closed Loop T.F.

Q.3 (e) Explain memory organization of PLC. **[4]**

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.

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.

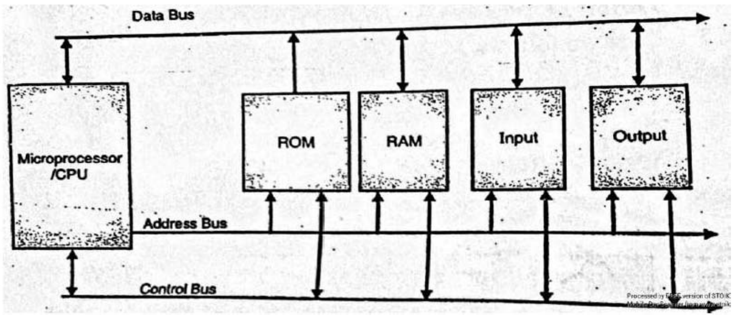
OR

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.



Q.4(a) Attempt any THREE of the following : [12]
Q.4(a) (i) Differentiate between Fixed & Modular PLC. [4]
Ans.:

Sr. No.	Fixed PLC	Modular PLC
(i)	Elements are fixed on main board of PLC.	Elements are modular form, mounted on chasis (rack)
(ii)	I/O count is 32 or less than 32	I/O count is more than 32
(iii)	Small in size	Size is more
(iv)	Easy to install.	Complex installation process
(v)	Memory capacity is less.	Memory capacity is more
(vi)	It can not be repaired.	It can repaired as modules are in modular form.
(vii)	Generally digital devices are connected to it.	Analog & digital devices are connected to it.
(viii)	Cost is less.	Cost is more.
(ix)	Less input output devices are connected.	More input output devices are connected
(x)	Application-Tea-coffee vending m/c, Washing m/c	Application-Cement, rubber, Chemical fertilizer industries.

Q.4(a) (ii) List any four specifications of AC input module. [4]
Ans.:

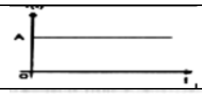
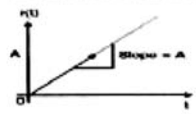
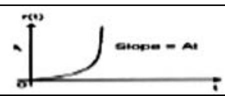
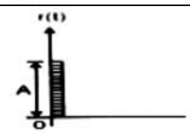
Item	Typical Value for 120/230 V AC
Rated voltage and current	120V at 64mA 230V at 9 mA
Specified operational voltage range	264 V AC
Signal delay	15.0 ms ON to OFF or OFF to ON
Logic 1 minimum(Threshold values for ON and OFF conditions)	790 V AC at 2.5 mA
Logic 0 minimum (Threshold values for ON and OFF conditions)	20 V AC at 1 mA
Isolation between field to logic	1500 V AC for 1 sec.

Q.4(a) (iii) State the principle of ON-OFF control action. Write its standard equation and define neutral zone. **[4]**

Ans.:
- This is one of the most common & simplest mode of controller.
- 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.
- This controller mode has two possible output states namely 0 % & 100%.
- Mathematically this can be expressed as
  P (t) = 0% (OFF) for ep < 0
  100% (ON) for ep > 0
  Where p (t) – Controlled output
  ep - Error based on % of span
- 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%.

Q.4(a) (iv) Write the Laplace transform for the following input signal. **[4]**
(1) step (2) ramp (3) parabolic (4) impulse

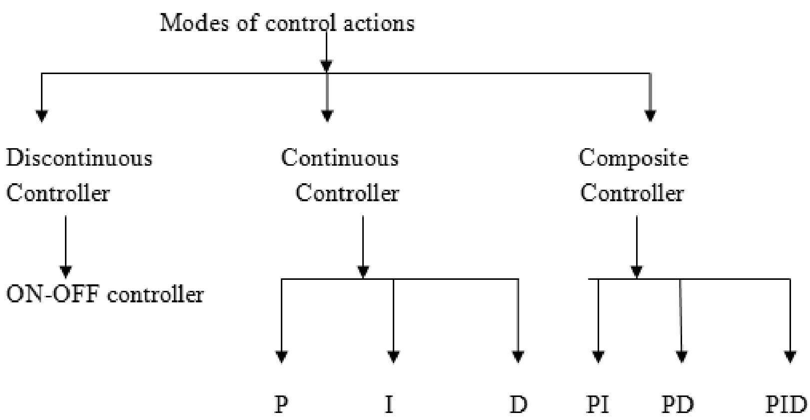
Ans.:

Standard test input	Laplace Representation	Waveforms
Step input (position function) r(t)	L. T of r(t) = R(s) = A/s	
Rampinput (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	

Q.4(b) Attempt any ONE of the following : **[6]**

Q.4(b) (i) List types of control actions. Give its output equation and corresponding laplace transforms. **[6]**

Ans.:



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 Initial value of the o/p at t=0

3) O/P equation of PD controller

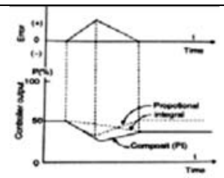
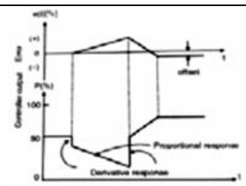
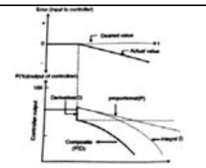
$$p(t) = k_p e(t) + k_p k_d \frac{de(t)}{dt} + p(0)$$

4) O/P equation of PID controller

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

Q.4(b) (ii) Compare PL, PD and PID controller (four points). **[6]**

Ans.:

Sr. No.	PI	PD	PID
1	It is the combination of Proportional control and integral and integral control action	It is the combination of Proportional control and derivative control action	It is the combination of Proportional control, integral control and derivative control action
2	The proportional controller stabilizes the gain but produces steady state error and integral control minimize the error.	The proportional controller stabilizes the gain but produces steady state error and derivative control minimize the error.	The proportional controller stabilizes the gain but produces steady state error and integral and derivative control minimizes the error.
3	$P = Kp \,.\, e_p + K_p\, k_i \int_p^t e_p(t)\,.\, dt + P_I(0)$	$P = K_p \,.\, e_p + K_p\, K_D \frac{d}{dx}(\theta p) + P_{(0)}$	$P(t) = K_p e(t) + k_p k_i \int_0^t e(t)dt + k_p d_d \frac{de(t)}{dt} + p(0$
4			
5	It eliminate steady state error.	It compensate rapidly changing error.	It eliminate steady state and rapidly changing error.
6	It stabilize controller gain.	It increase controller gain during error change.	The gain of controller is stable.
7	It require Expensive stabilization when process has many energy storage elements.	It cannot eliminate offset of proportional controller.	More effective for control process when many energy storage element than PI.
8	It is used in control systems with large load changes.	It is used in temperature cascade systems and batch neutralization.	A PID controller can be used for regulation of speed, temperature, flow, pressure and other process variables.

Q.5 Attempt any TWO of the following : [16]

Q.5(a) Draw the ladder diagram for 2 motor operation : [8]

(i) When start button is pushed motor M1 and M2 start.

(ii) After 10 sec. motor M1 stops.

(iii) Motor M2 stops 15 sec. after motor M1 has stopped.

(iv) Both M1 and M2 will stop when stop push button is pressed.

Ans.: List of inputs and there addresses

Start button - 0/0

Stop button - 0/1

List of outputs and their addresses

Motor (M1) = 0; 0/0

Motor (M2) = 0; 0/1

Off delay timer – T_4:1

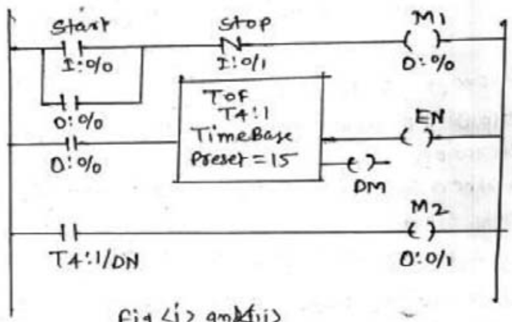


Fig (i) and (ii)

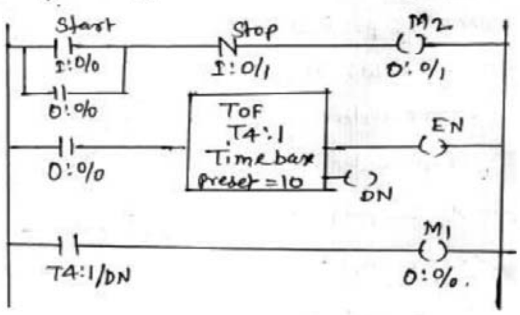
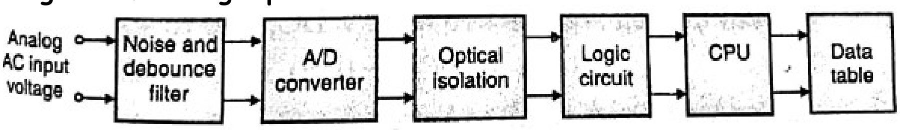


Fig (ii) and (v)

Q.5(b) Explain Analog input module. [8]

Ans.: Block diagram of analog input module



- 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.
- 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.

Q.5(c) State Advantage & Disadvantage of Routh Array **[8]**

Ans.: **Advantages:**

- It is a simple algebraic method to determine the stability of closed loop without salving for roots of characteristics equation.
- It is very useful for single variable, multivariable and loop systems.
- It progresses systematically.
- It can determine the range of k for stable operator.
- It can judge very easily the relative stability of a system.
- It is not tedious or time consuming method.
- It helps to determine the conditions of absolute and relative stability of a system.
- It can give the number of roots of the characteristics equation having positive real part in the unstable systems.

Disadvantages

- It becomes complex for system of order more than 6 or 7.
- It 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.

Q.6 Attempt any FOUR of the following : **[16]**

Q.6(a) Why 'D' control action is not used alone? Justify. **[4]**

Ans.: Significance of why Derivative mode cannot used alone are

(i) It can't not give any output for zero or constant error

(ii) It is ineffective for slowly changing error & hence causes the drift.

(iii) It amplifies the noise signal & causes saturation effect on the system

(iv) It does not eliminate the steady state error(offset)

Q.6(b) State Routh's criteria. Describe different cases to find stability of system (any two). **[4]**

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

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.

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 S4- row which is given by
$A(S) = S^4 + 3S^2 + 3$.
Differentiate this equation w.r.t S
$$\frac{dA(s)}{ds} = 4s^3 + 65 + 0 = 45^3 + 65$$
Zeros in S^3 row are how replaced by the co-efficient 4 & 6.

Q.6(c) With the help of neat diagram explain the concept of sourcing and sinking DC input module of PLC. [4]

Ans.: Diagram:

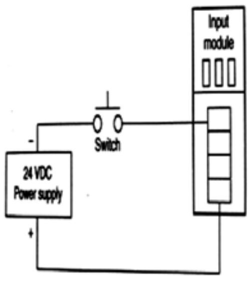


fig 1-Sourcing D.C input module with a sinking switch

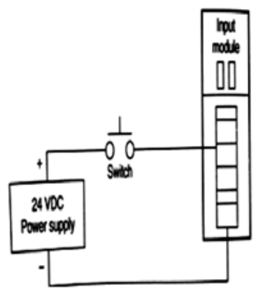


Fig 2 - Sinking D.C input module with a sourcing switch

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.
4. 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.

Q.6(d) Define : (i) Linear and Non-linear system. [4]
(ii) Time varying and Time in-varying system.

Ans.: (i) Linear & Nonlinear system.
- Linear system is defined as a system which satisfies the following properties:

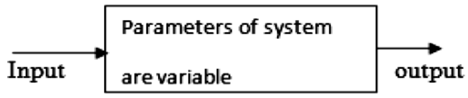
1. Additivity property – $f(x + y) = f(x) + f(y)$
2. Homogenity property – 2Homogenity property$(\alpha.x) = \alpha.f(x)$

The above equations constitute a principle of superposition.

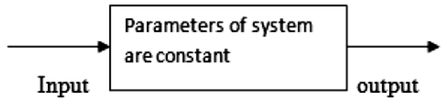
- **Nonlinear system**- It is the system which does not follow the principle of supeposition.

(ii) Time varying & Time in-varying system

- Time varying system – A time variant system is defined as a control system in which parameters of the system are varying with time that means as time passes parameters varies.



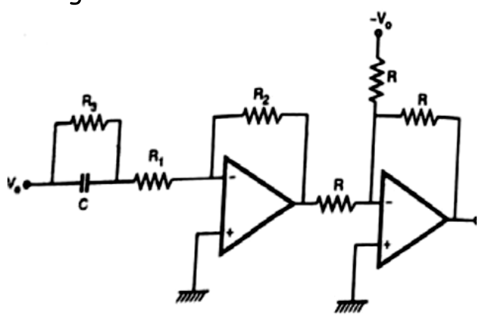
- Time in-varying system-Atime in - variant system is defined as a control system in which parameters of the system does not vary with time.



Q.6(e) Draw electronic PD-controller. State its equation. Explain PD controller in brief. [4]

Ans.: (1) The combination of proportional plus derivative mode gives PD controller.

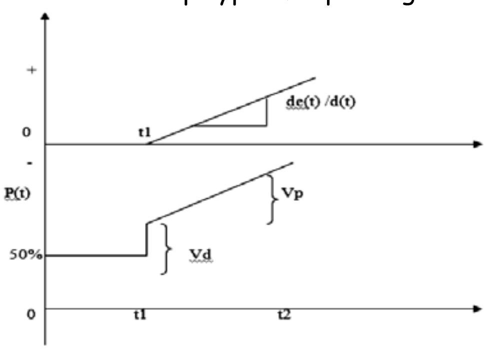
(2) Diagram of PD controller is given as



(3) The mathematical expression of PD mode is given as

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

(4) The behavior of such PD mode to ramp type of input is given as follows



The ramp function of error occurs at t=t1.The derivative mode causes a step Vd at t1 & proportional mode causes a rise of Vp equal to Vd at t2.

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