Model Answer
Summer – 2019 Examinations
Subject & Code: ELEMENTS OF INDUSTRIAL AUTOMATION (17641)

Important Instructions to examiners:

1) The answers should be examined by key words 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 should assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given 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 should give credit for any equivalent figure/figures drawn.
5) Credits to 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 (as long as the assumptions are not incorrect).
6) In case of some questions credit may be given by judgment 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

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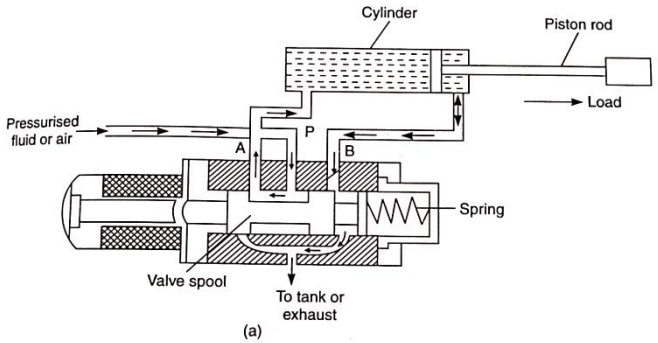
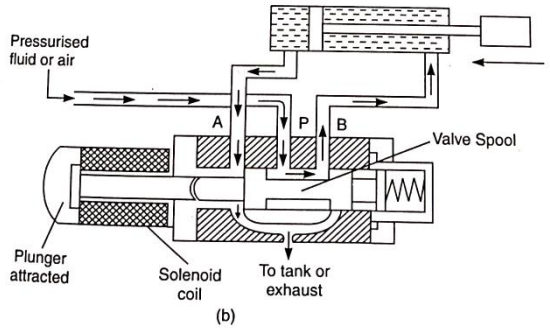
1 Attempt any FIVE of the following: 20

1 a) Describe operation of solenoid valve with neat diagram**.**

Ans:

Solenoid valves:





Single solenoid spring return valve

2 marks for diagram

A solenoid valve is an electromechanical device used to obtain mechanical movement in machinery by utilizing fluid or air pressure. The fluid or air pressure is applied to the cylinder piston through a valve operated by a cylindrical electrical coil. The electrical coil along with its frame and plunger is known as the solenoid and the assembly of solenoid and mechanical valve is known as solenoid valve.

2 marks for description

In fig (a) is shown a single solenoid spring return valve in its de-energized condition. In this condition the plunger and valve spool position are as shown, port P is connected to port A and port B is connected to tank or exhaust, if air is used. The spring(S) pressure keeps the spool in this condition as long as the coil is de-energized. Fluid pressure from port P through port A is applied to the left side of the cylinder piston. Thus the cylinder piston moves in the right direction.

In fig (b) is shown a single solenoid spring return valve in its energized condition. When solenoid coil is energized, plunger is attracted and it pushes the spool against spring pressure. In this position of spool, port A gets connected to tank and port P gets connected to port B . Fluid pressure from port P through port B is applied to the right side of the cylinder piston. Thus the cylinder piston moves in the left direction. At the same time fluid in the other side is drained out to the tank. When the solenoid coil is again de-energized, spring (s) will move the spool to its original position.

1 b) Explain construction and working of Electronic overload relay.

Ans:

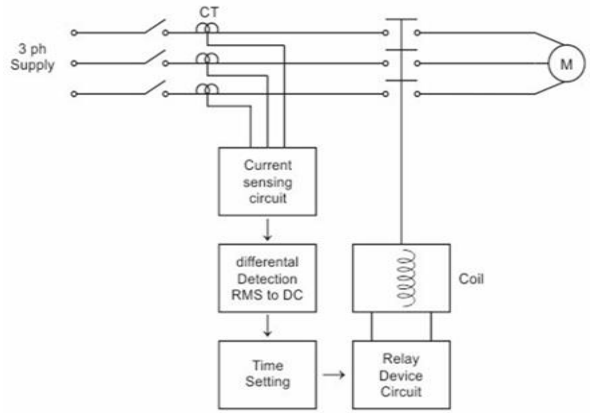
Electronic Overload Relay:

- Electronic overload relay consists of a solid state circuit which operate the

electromagnetic switching device to protect the load from overload.

- The load current is sensed by using a transducer such as current transformer (CT).
- The output of current transformer is converted to voltage signal as required by electronic circuit.
- The electronic circuit consists of RMS-to-DC conversion, threshold detection, time-setting & relay driver sections.
- The output of relay driver section sends trip signal to electromagnetic switching device.
- On the occurrence of over-load, the current magnitude is sensed by CT and current sensing circuit. The difference between full-load and over-load current is determined by electronic circuit. The differential current RMS value is converted to DC and according to this differential current value and time-setting, the relay driver section trips the electromagnetic switch with time dealy.

2 marks for explanation

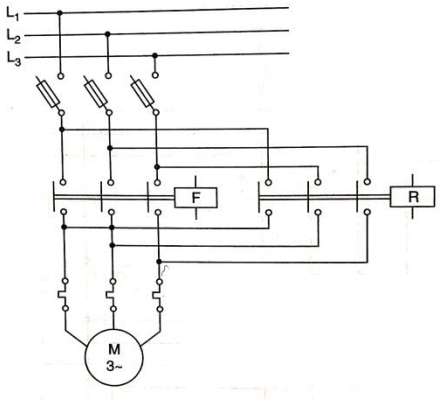


2 marks for schematic diagram

1 c) Draw diagram of DOL starter power & control circuit for 3-phase Induction Motor for forward-stop-reverse operation. Explain its working.

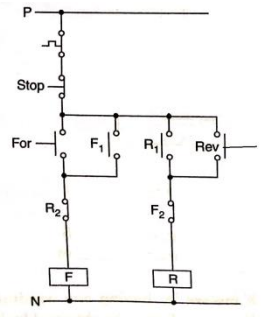
Ans:

Forward-Stop-Reverse type DOL starter for 3-phase Induction Motor:



(a) Power Circuit for Forward-Stop-Reverse Control

1 mark for power circuit



(b) Control Circit for Forward-Stop-Reverse Control

1 mark for control circuit

The power and control circuit of DOL starter with Forward-Stop-Reverse control are shown in figures (a) and (b) above respectively. In power circuit, two contactors (F and R) are used to provide electric supply with opposite phase sequence to motor. When contactor F is ON, the three-phase supply with phase sequence L_1-L_2-L_3 is provided to motor and it runs in Forward

direction. However, when contactor R is ON, the three-phase supply with reversed phase sequence L_1-L_3-L_2 is provided to motor and it runs in Reverse direction.

In control circuit, when push-button 'For' is pressed, the contactor coil 'F' get energized through 'Stop' push-button, pressed 'For' push-button and R_2 NC contact. Therefore, the contactor 'F' get closed and in power circuit, the three phase supply with phase sequence L_1-L_2-L_3 is provided to motor and it runs in Forward direction. The operation of contactor 'F' causes closing of NO contact 'F_1' and opening of NC contact 'F_2'. The contact F_1 being connected in parallel with push-button 'For', it holds ON the contactor 'F' after releasing push-button 'For'. Now even if somebody presses push-button 'Rev', the contactor 'R' cannot be energized as the NC contact F_2 is open. So if we wish to reverse the direction of rotation, we need to press 'Stop' push-button first to stop the motor. Pressing of 'Stop' push-button causes interruption of current of forward contactor coil 'F'. Therefore, the contactor 'F' gets de-energized and NC contact F_2 regains its original closed state. 2 marks for explanation

Then only the direction of rotation can be reversed by pressing push-button 'Rev'. It causes the current to flow through contactor coil 'R', energizing contactor 'R' and closing its NO contacts. In power circuit, the contactor R get closed providing three-phase supply with reversed phase sequence L_1-L_3-L_2 to motor and it runs in Reverse direction.

Thus during transition from Forward to Reverse or vice-versa, we need to Stop the motor, hence this control is referred as 'Forward-Stop-Reverse' control.

1 d) State operating principle of dc servo-motor**.**

Ans:

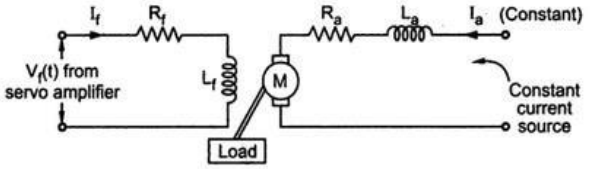
DC Servo-motor:

The motors which are utilized as DC servo motors, generally have separate DC source for field winding and armature winding. The control can be achieved either by controlling the field current or armature voltage. Field control has some specific advantages over armature control and on the other hand the armature control also has some specific advantages over field control. The type of control to be applied to the DC servo motor, is being decided depending upon its specific application.

The direction of rotation can be changed by changing polarity of the field. The direction of rotation can also be altered by using split field DC motor, where the field winding is divided into two parts, one half of the winding is wound for clockwise direction and other half is wound for anticlockwise direction. The amplified error signal is fed to the junction point of these two halves of the field. The magnetic field of both halves of the field winding opposes each other. During operation of the motor, magnetic field strength of one half dominates other depending upon the value of amplified error signal fed between these halves. Due to this, the DC servo motor rotates in a particular direction according to the amplified error signal voltage. The main disadvantage of field controlled DC servo motor, is that the dynamic response to the error is slower because of longer time constant of inductive field circuit. The field being an electromagnet, it is basically a highly inductive circuit. Due to sudden change in error signal voltage, 2 marks for explanation of any one type

the current through the field cannot change suddenly, but reach to its steady state value after certain period depending upon the time constant of the field circuit. That is why field controlled DC servo motor arrangement is mainly used in small servo motor applications.

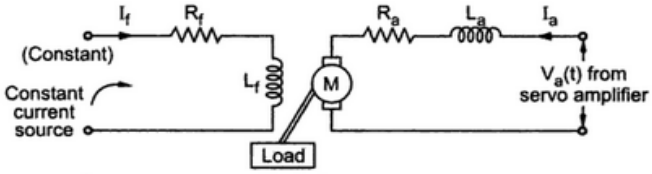
The figure below illustrates the schematic diagram for a field controlled DC servo motor. In this arrangement the field of DC motor is excited by the amplified error signal and armature winding is energized by a constant current source.



Field controlled d.c. servomotor

2 marks for any one diagram

The figure below shows the schematic diagram for an armature controlled DC servo motor. Here the armature is energized by amplified error signal and field is excited by a constant current source.



Armature controlled d.c. servomotor

1 e) State any four advantages of PLC.

Ans:

Advantages of PLC:

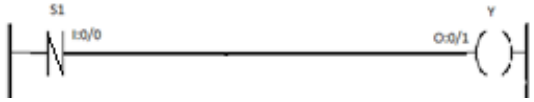
1. Increased productivity.
2. Improved product quality.
3. Increased flexibility and convertibility
4. Increased accuracy.
5. Reduced manpower.
6. Reduction in personal injury or accidents.
7. Reduction in the cost of product due mass production.
8. Better inventory control
9. Increased profit.
10. Achieves consistency in the manufacturing.
11. Centralized control of plant is possible.
12. Smaller physical size than hard-wire solutions
13. Diagnostics are centrally available
14. Applications can be duplicated faster and less expensively
15. It is capable to communication with computer in plant.

1 mark for each of any 4 advantages = 4 marks

1 f) Draw ladder diagram for NOT and EXOR gate.

Ans:

NOT gate: $Y = \bar{A}$



EX-OR Gate: $Y = \bar{A}B + A\bar{B}$

2 marks for truth-tables

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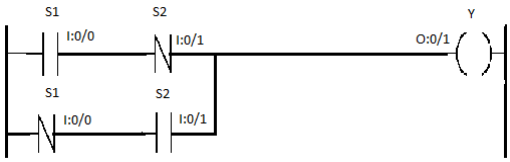
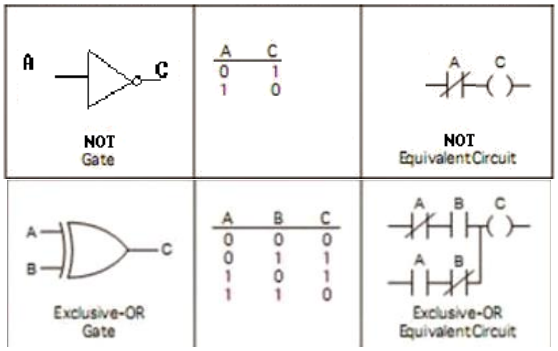


OR



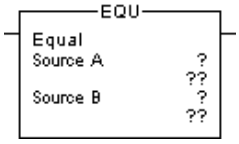
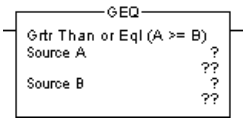
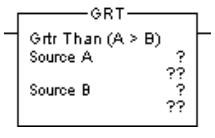
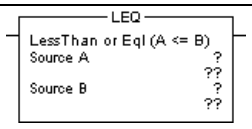
(Symbols of gates are optional: NO marks)

2 marks for ladder diagrams

1 g) Explain any two PLC input instructions.

Ans:

Input Instructions:

Mnemonic	Name	Symbol	Description
XIC	Examine If Closed		Examines a bit for an On (set, high) condition.
XIO	Examine If Open		Examines a bit for an Off (cleared, low) condition.
EQU	Equal		This instruction is used to test whether two values are equal. If Source A is equal to Source B, the instruction is logically true.
GEQ	Greater Than or Equal To		Determines whether Source A is greater than or equal to Source B. If the value at Source A is greater than or equal to the value at Source B, then the instruction is true.
GRT	Greater Than		This instruction is used to test whether one value (Source A) is greater than another value (Source B).
LEQ	Less Than or Equal To		Determines whether one value (Source A) is less than or equal to another (Source B).

Any two instructions

[½ mark Mnemonic/ name
½ mark Symbol
1 mark description for each instruction]

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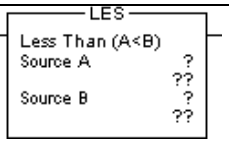
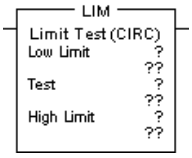
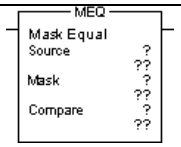
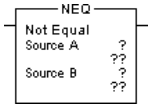
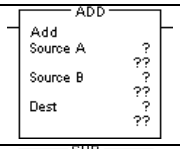
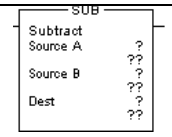
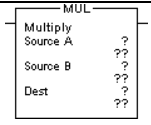
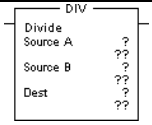
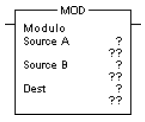
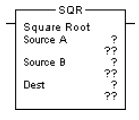
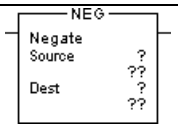
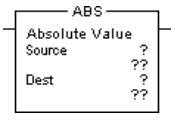
LES	Less Than		This instruction determines whether Source A is less than Source B.
LIM	Limit		This instruction is used to test for values within the range of the Low Limit to the High Limit.
MEQ	Mask Equal To		Passes the Source and Compare values through a Mask and compares the results.
NEQ	Not Equal To		This instruction tests whether Source A is not equal to Source B.
ADD	Add		Adds Source A to Source B and stores the result in the Destination.
SUB	Subtract		Subtracts Source B from Source A and places the result in the Destination.
MUL	Multiply		Multiplies Source A by Source B and stores the result in the destination.
DIV	Divide		Divides Source A by Source B and places the result in the Destination.
MOD	Modulo		Divides Source A by Source B and stores the remainder in the Destination.
SQR	Square Root		Calculates the square root of the source and places the integer result in the Destination.
NEG	Negate		Changes the sign (+, -) of the Source and stores the result in the Destination.
ABS	Absolute		Takes the absolute value of the Source and places the result in the Destination.

2 Attempt any <u>TWO</u> of the following: 16

2 a) Describe working of AC servomotor with neat diagram. State their application.
Ans:

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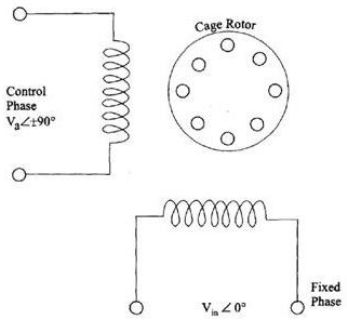
AC servo motor:



3 marks for circuit diagram

There are some special applications of electrical motor where rotation of the motor is required for just a certain angle and not continuously for long period of time. For these applications some special types of motor are required with some special arrangement which makes the motor to rotate a certain angle for a given electrical input (signal). Such motors can be ac or dc motors. These motors are used for position control or in servo mechanisms, hence are termed as servomotors.

2 marks for construction

The AC servomotor consists of main and control winding and squirrel cage / drag cup type rotors. These two windings are placed with 90° displacement in space. The reference voltage V_r is applied to the main or reference winding while the control voltage V_c is applied to control winding which controls the torque-speed characteristics. The rotor is squirrel cage with longer length and small diameter. The rotor has high resistance to increase starting torque and linear torque speed characteristics. The 90° space displacement of the two coils/windings and the 90° phase difference between the voltages applied to them result in production of rotating magnetic field in the air gap. This rotating magnetic field is cut by rotor conductors & the emf is induced in them, which circulates current through them. According to the basic motor principle, force is exerted on the current carrying conductors when they are in the magnetic field. Thus the force or torque is exerted on rotor and is set in motion.

2 marks for explanation of working

Applications :

1. Process control equipment.
2. Machine tools.
3. Robotics.
4. Process Controllers.
5. AC position control applications.
6. Portable drilling machine.
7. Sewing machine.
8. CNC machines.
9. Robotic hands.
10. Conveyers which require precise control
11. Fluid dispensing machines
12. Precision instruments such as camera, printers

1 mark for any one application

2 b) Draw and explain block diagram of PID.

Ans:

Block diagram of PID Controller:

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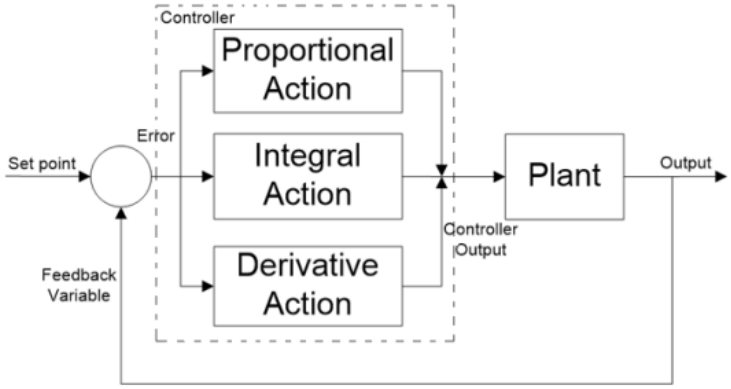
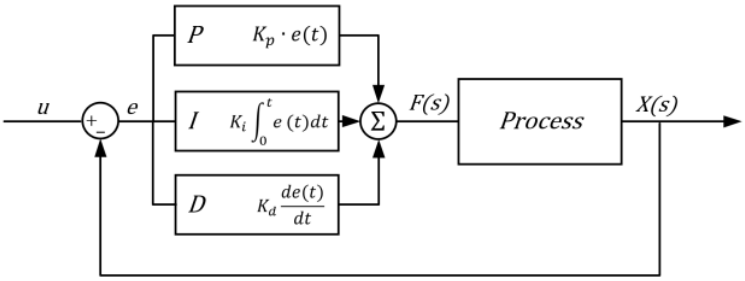


4 marks for any equivalent block diagram

OR



Explanation:
PID is combination of three control actions: **P**roportional + **I**ntegral + **D**erivative. The proportional corrects instances of error, the integral corrects accumulation of error and the derivative takes the corrective action in anticipation. The effect of the derivative is to counteract the overshoot caused by P and I. When the error is large, the P and the I will push the controller output. This controller response makes error change quickly, which in turn causes the derivative to more aggressively counteract the P and the I.

3marks for explanation

$$P_o = Kp\ Ep + Kp\ Ki \int Ep\ dt + Kp\ Kd \frac{dEp}{dt} + P_i(0)$$

1 mark equation

Where, Kp = Proportional gain
Kd= Derivative gain
Ki = Integral gain
Ep = Error signal
P_o = Controller output
$P_i(0)$ = Controller output at t = 0

Advantages of PID:

(Advantages optional)

i. Offset error is eliminated.
ii. Settling time is less.
iii. Provides a fast response.
iv. One of the most powerful mode of controllers.
v. No oscillations
vi. Can be used to control all process conditions.
vii. Zero steady state error.
viii. Eliminates overshoot in the output response of the system.

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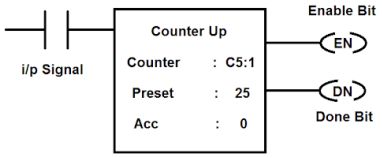
2 c) List types of counters available in PLC. Explain any one with example.

Ans:

Types of Counters:

i. UP Counter
ii. DOWN Counter

UP Counter:



2 marks for description

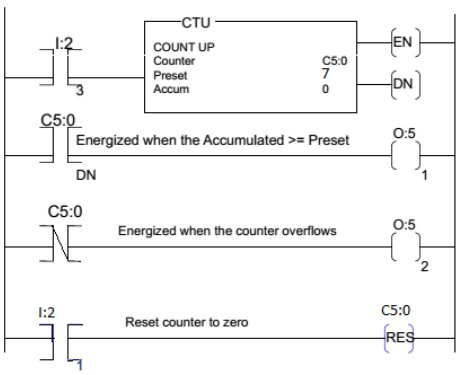
The CTU is an instruction that counts false-to-true rung transitions. Rung transitions can be caused by events occurring in the program. When rung conditions for a CTU instruction have made a false-to-true transition, the accumulated value is incremented by one count, provided that the rung containing the CTU instruction is evaluated between these transitions. The accumulated value is retained when the rung conditions again become false. The accumulated count is retained until cleared by a reset (RES) instruction that has the same address as the counter reset. The control word for counter instructions includes six status bits, as indicated below.

	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
Word 0	CU	CD	DN	OV	UN	UA	Not Used									
Word 1	Preset Value															
Word 2	Accumulator Value															

- **CU Bit:** This status bit is true when UP counter instruction is true.
- **DN bit:** This bit is true when accumulated value is equal to or greater than the present value of the counter.
- **OV(Overflow) bit:** when counter count value exceeds 32,767,this bit becomes true.
- **UN(Underflow):**It will go true when counter counts below -32,768.
- **Accumulator Value (ACC):** This is the number of false-to-true transitions that have occurred since the counter was last reset.
- **Preset Value (PRE)**: Specifies the value which the counter must reach before the controller sets the done bit.

2 marks for bit description

In the following example count up counter is used to control the Red and Green lamps. Operating pushbutton I:2/3 provides the off-to-on transition pulses that are counted by the counter. The preset value of the counter is set for 7. Each false-to-true transition of rung 1 increases



2 marks for example

2 marks for ladder diagram

the counter's accumulated value by 1. After 7 pulses, or counts, when the preset counter value equals the accumulated counter value, output DN is energized.

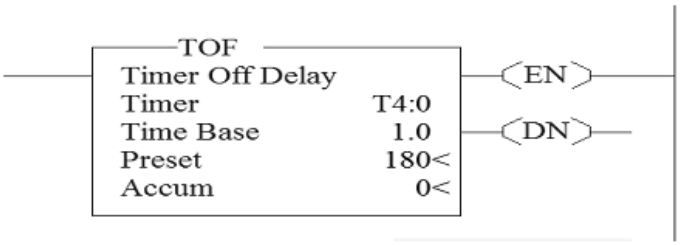
As a result, rung 2 becomes true and energizes output O:5/1 to switch the red pilot light on. At the same time, rung 3 becomes false and de-energizes output O:5/2 to switch the green pilot light off. The counter is reset by closing pushbutton I:2/1, which makes rung 4 true and resets the accumulated count to zero. Counting can resume when rung 4 goes false again.

3 Attempt any <u>FOUR</u> of the following: 16

3 a) Explain OFF Delay Timer operation with neat diagram.

Ans:

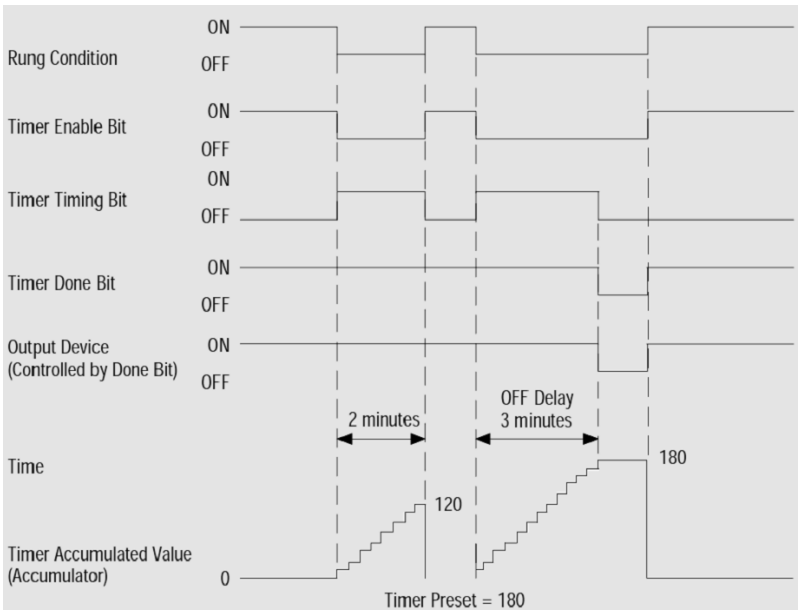
OFF-Delay Timer:



Preset value: It is multiplied by the time base of the timer to specify the time delay.

Accumulated value: It specifies the time from the moment that was disabled up to the current moment. The address is for accumulators as follows T4: 0.ACC **Enabled bit** is set when the line is true, indicates that the timer is enabled. It is clear when the line is false. The address for these bits is T4: 0 / EN. **Timing timer bit** is set in the time interval that occurs between the timer is disabled and when the accumulated value reaches the preset(here=180 seconds) value. The rest of the time this bit is clear. The address for these bits is T4: 0 / TT. **Done bit** is set when the accumulated value is equal to the preset value and the timer is disabled. It is clear when the timer is enabled. The address for these bits is for example T4: 0 / DN.

2 marks for description



2 marks for waveforms

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3 b) Draw a ladder diagram of star delta starter..

Ans:

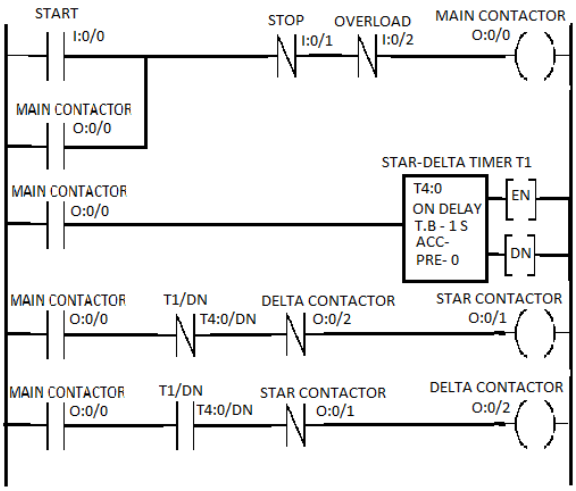
Ladder diagram for Automatic star-delta starter:

Inputs: Start switch- I:0/0 Stop Switch- I:0/1 Overload: I:0/2

Outputs: Main Contactor- O:0/0 Start Contactor- O:0/1 Delta Contactor- O:0/2

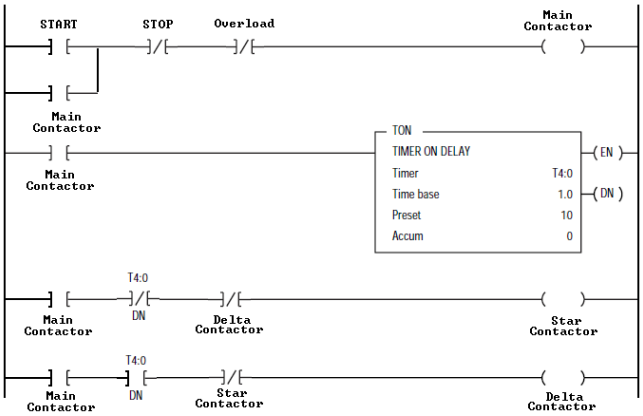
Timer: Star-Delta Timer- T4:0 (On Delay)

1 mark for addressing

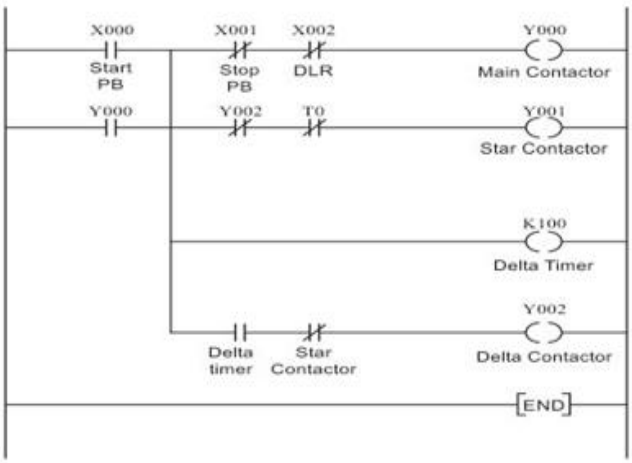


3 marks for ladder diagram

OR



OR



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3 c) List the specification of digital I/O module.

Ans:

Specifications of Digital Input Module:

i) Rated voltage & current: +24V DC at 4mA/120V AC at 6mA/230V AC at 9mA
ii) Specified operational voltage range: 0-30V DC/ 264V AC.
iii) Absolute maximum input voltage: +35V DC for 0.5sec.
iv) Signal Delay: 5.0 msec for DC/ 15 msec for AC ON to OFF or OFF to ON.
v) Logic 1: 15V DC at 2.5mA/ 79V AC at 2.5mA.
vi) Logic 0: 5V DC at 1mA/ 20V AC at 1mA.

2 marks for any two specs of Digital Input module

Specifications of Digital Output Module:

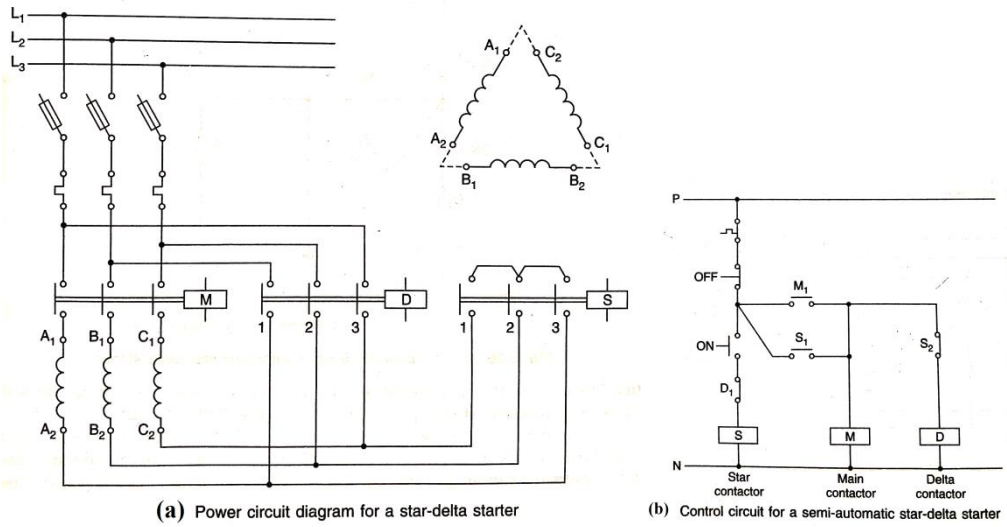
i) Rated voltage: +24V DC/+24VDC or 250V AC relay type/120V/230V AC
ii) Voltage range: 20.4-28.8V DC/5-30V DC or 5-250VAC relay type/40-264V AC
iii) Logic 1: 20V DC min./ 24VDC or 250V AC/120V/230V AC
iv) Logic 0: 0.1V DC max./0 VDC or AC/0VAC
v) Rated current/point: 0.75A DC/ 2A for relay type/0.5A AC
vi) Rated current/common: 6A DC/8A for relay type/0.5A AC

2 marks for any two specs of Digital Output module

3 d) Draw star/delta starter circuit diagram for 3-phase induction motor semi-automatic type. Explain its working.

Ans:

Semiautomatic Star-Delta Starter for 3-ϕ Induction Motor:



(a) Power circuit diagram for a star-delta starter (b) Control circuit for a semi-automatic star-delta starter

1 mark for power circuit

1 mark for control circuit

The power and control circuit of Semiautomatic Star-Delta starter for 3-ϕ induction motor is shown in the figure (a) and (b) respectively. In power circuit, three contactors are required to connect motor to supply and to connect its windings first in Star and then in delta.

Referring to the control circuit, the motor is operated in following sequence:

i) When ON push-button is pressed, the Star-contactor coil S is energized through normally-closed OFF push-button, pressed ON push-button and NC contact D_1. Therefore, Star contactor S is opearted and motor windings are connected in star.
ii) After energizing Star-contactor S, the NO contact S_1 get closed and the Main-

2 marks for explanation of working

contactor M get energized. In power circuit, the closing of M contactor connects the motor to supply and it is started as star-connected motor. The M-contactor is held ON through the closed NO contact M_1.

iii) The motor continues to run in star-connection as long as ON push-button is kept pressed.

iv) When it is ensured that the motor has picked up 75% of its rated speed, the pressed ON push-button is released. The opening of ON push-button causes interruption of current in coil S and Star-contactor is de-energized. Therefore, the contact S_1 is opened, however contactor M is held ON through closed NO contact M_1.

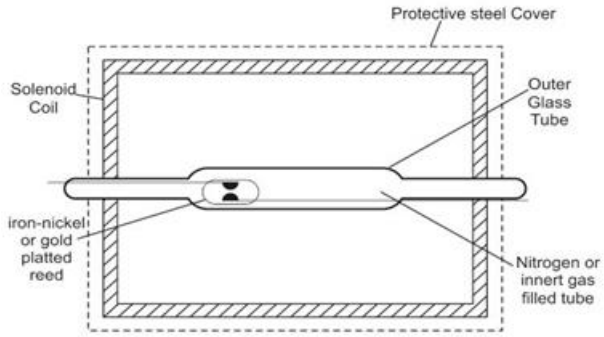
v) After de-energizing Star-contactor S, the motor winding is disconnected from star-connection and due to closing of NC contact S_2, the Delta-contactor D is energized.

vi) On energizing contactor D, the motor is reconnected in delta-connection. Thus motor then continues to run as delta-connected motor.

3 e) Explain working of reed switch. State its advantages.

Ans:

Reed Switch:



2 marks for diagram

Working

- When two solenoid coils are connected in series addition and when excited/energized the flux produced by both coil is added and it produces operating force on reeds and the contacts are closed.
- When coils are de-energized contact returns to original position due to spring action of reed itself – no separate spring is required.

1 mark for working

Advantages

- Very low contact resistance, hence negligible voltage drop
- Due to inert gas, no corrosion of contacts
- Long Life
- Weight of moving part is negligible hence high operating speed as compare to electromagnetic relays

1 mark for any two advantages

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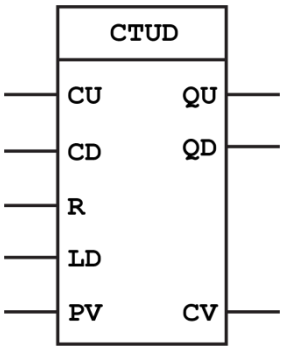
3 f) **Describe working of up/down counter.**

Ans:

Up/Down Counter:



1 mark for symbol

Count up and down instruction is used to increment and decrement the count value at the CV output. If the signal state at the CU input changes from 0 to 1(positive signal edge), the current count value is incremented by one and stored at the CV output. If the signal state at the CD input changes from 0 to 1(positive signal edge), the count value at the CV output is decremented by one. If there is a positive signal edge at the CU and CD inputs in one program cycle, the current count value at the CV output remains unchanged. The count value can be incremented until it reaches the high limit of the data type specified at the CV output. When the high limit value is reached, the count value is no longer incremented on a positive signal edge. When the low limit of the specified data type is reached, the count value is not decremented any further. When the signal state at the LD input changes to 1, the value (count value) at the CV output is set to the value of the PV parameter. As long as the LD input has the signal state 1, the signal state at the CU and CD inputs has no effect on the instruction. The count value is set to zero when the signal state at the R input changes to 1. As long as the R input has signal state 1, a change in the signal state of the CU, CD and LD inputs has no effect on the Count up and down instruction. You can scan the current status of the up counter at the QU output. If the current count value is greater than or equal to the value of the PV parameter, the QU output is set to signal state 1. In all other cases, the QU output has signal state 0. One can also specify a constant for the PV parameter. One can scan the current status of the down counter at the QD output. If the current count value is less than or equal to zero, the QD output is set to signal state 1. In all other cases, the QD output has signal state 0.

3 marks for description

4 Attempt any <u>TWO</u> of the following: 16

4 a) Draw ladder diagram for two motor system with following condition:

i) Starting pushbutton starts motor-1
ii) After 10 sec Motor-2 is ON
iii) Stopping switch stops Motor 1 & 2

Ans:

In the following application motor M1 starts as soon as start pushbutton is pressed and motor M2 starts after 10 seconds.

Rung 1: When START Pushbutton is pressed, the latch B3:0/0 will be set and will remain set till the circuit is break by pressing STOP pushbutton.

Rung 2: When latch B3:0/0 is set, the timer will be enabled. Timer will start to count internal pulses with time base 1 second. The done bit of timer will set after 10 seconds i.e. ACC>=PRE and will remain set till it is reset by RES or if latch is reset.

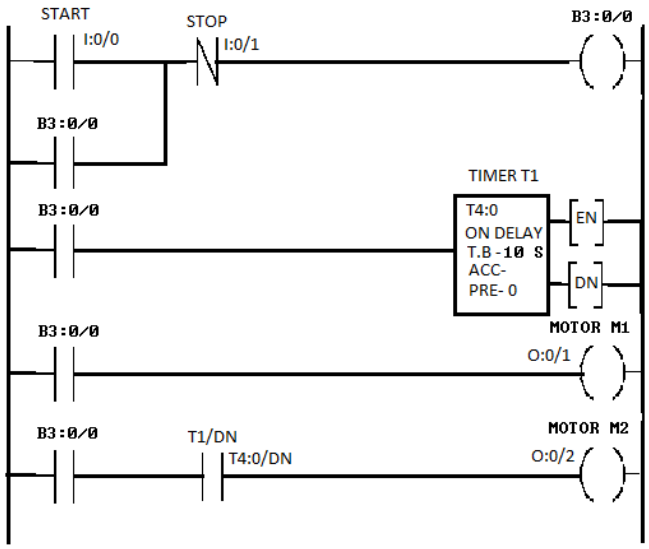
Rung 3: When latch is set, motor M1 will also set till latch doesn't reset.

Rung 4: The motor M2 will start when latch=1 and timer done bit is set i.e. after completion of delay 10 seconds.

4 marks for description

If STOP pushbutton is pressed both motors and timer will turn off.

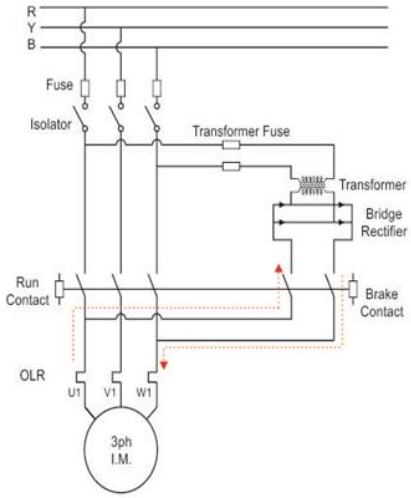
4 marks for ladder diagram

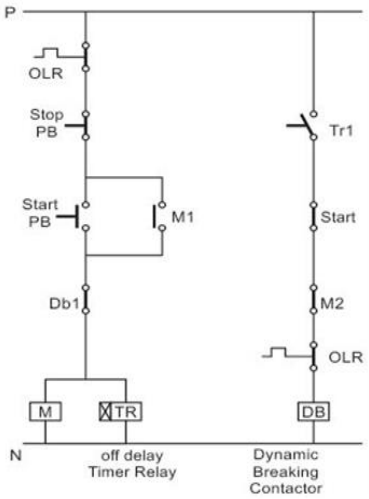


4 b) Draw and explain power and control circuit of dc injection breaking for Induction motor.

Ans:

DC injection breaking for Induction motor:





3 marks for power circuit

3 marks for control circuit

- An induction motor can be brought to rest quickly if ac supply to motor terminals is removed and instead a DC supply is applied.
- The DC current flowing through stator winding would produce the same no. of stationary poles as the no. of poles of the revolving field produced with AC supply.
- The rotor cut the flux of these stationary poles resulting in induced emf and current flow in the rotor winding.
- The current flow in the rotor causes I^2R loss in winding resistance or in external resistance.
- The rotor slows down as result of mechanical energy of rotation being converted into electrical energy and dissipated as heat.
- Energy conversion would be complete when the rotor attains zero speed.

2 marks for description

4 c) Draw and explain block diagram of PI module in PLC.

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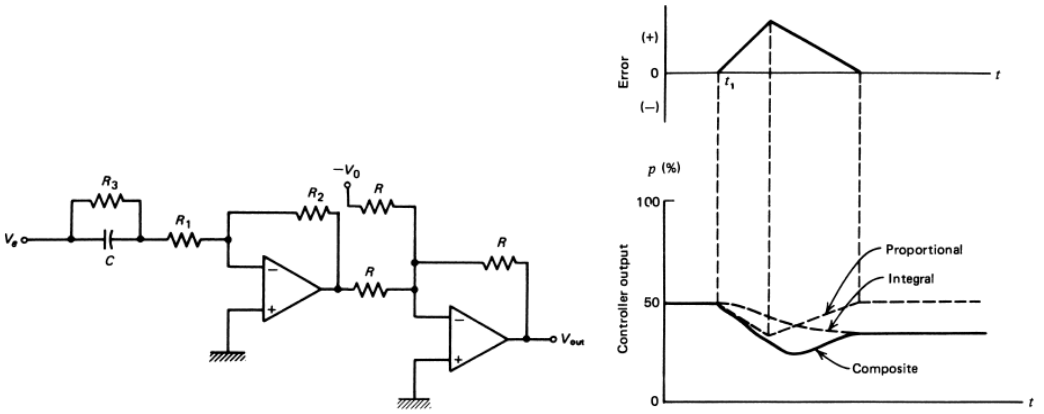
Ans:

PI controller:

2 marks for circuit diagram



2 marks for output graph

PI controller has the cascaded proportional and integral modes. The main advantage of this control mode is that the one-to-one correspondence of the proportional mode is available and the integral mode eliminates the inherent offset. In the present mode, the integral function provides the required new controller output, thereby allowing the error to be zero after a load change. The integral feature effectively provides a reset of the zero error output after a load change occurs. The analytical expression for this mode can be given as

2 marks description

$$p(t) = K_p e_p + K_p K_i \int e_p dt + p(o)$$

2 marks equation

The characteristics of the PI mode:

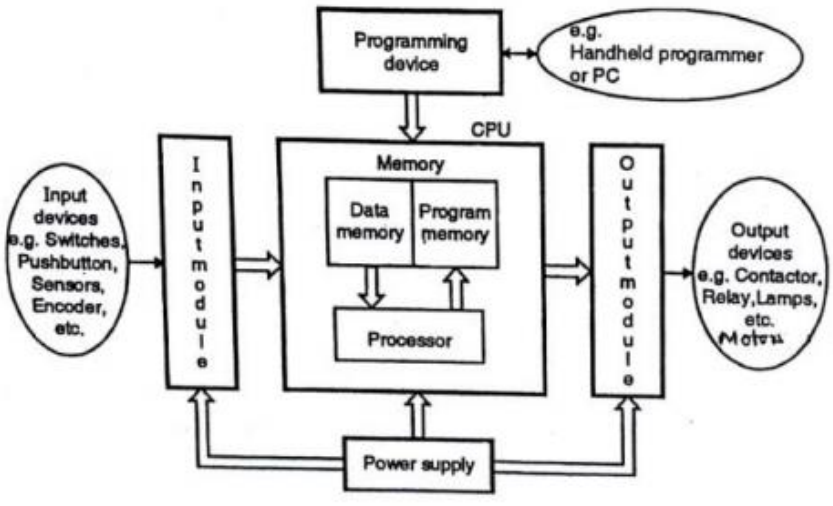
i) When the error is zero, the controller output is fixed at the value that the integral term had when the error went to zero.

ii) If the error is not zero, the proportional term contributes a correction, and the integral term begins to increase or decrease the accumulated value [initially, pI(0)], depending on the sign of the error and the direct or reverse action.

5 Attempt any <u>TWO</u> of the following: 16

5 a) Draw block diagram of PLC. State functions of its components.

Ans:



Block diagram of PLC

4 marks for diagram

Function of CPU:

CPU or the central processing unit is the main part of any PLC. The CPU solves the user program logic by using real time input status from input module and updates the status of output module. The CPU consists of – (i) Processor, (ii) Memory. The processor is a computer that executes a program to perform the operations specified in a ladder diagram or a set of Boolean equations. The processor performs arithmetic and logic operations on input variable data and determines the proper state of the output variables. The processor functions under a permanent supervisory operating system that directs the overall operations from data input and output to execution of user programs.The processor is responsible for the complete program scan in a PLC. During Program scan processor communicate with the memory. Memory is used in CPU, are of two types RAM and ROM. RAM memory is used to store the data related to input status, output status, timers, counters, internal bit relay, numerical values etc. ROM memory is to store system program and user program.

4 marks for description

Input Modules:

The input module provides the interface between the physical input devices in the real world outside the PLC and the digital arena inside the PLC. The input module has bank of terminals for physically connecting input devices, like push buttons, limit switches etc. The input modules examine the state of physical switches andother input devices and put their state into a form suitable for the processor. The PLC is able to accommodate a number of inputs.

Output Modules:

The input module provides the interface between the physical output devices in the real world outside the PLC and the digital arena inside the PLC. The Output module also has bank of terminals that physically connect output devices like solenoids, motor starters, indicating lamps etc. to a PLC. The role of an output module is to translate signals from the PLC's CPU into a form that the output device can use.

Programming Unit:

The Programmer is a device used to communicate with the circuits of the PLC. The programming unit allows the user to enter and edit the program to be executed.The programming unit is an external electronic package, may be computer or HHT, is connected to the programmable controller when programming occurs.The unit usually allows input of a program in ladder diagram symbols. The unit then transmits that program into the memory of the programmable controller.

Power supply:

i) Power supply is provided to the processor unit, input and output module unit. Power supply may be integral or separately mounted unit. This module can be built in to the PLC processor module or be an external unit. Common voltage levels required by the PLC are 5Vdc, 24Vdc, 220Vac. The voltage lends are stabilized and often the PS monitors its own health.

5 b) Draw and explain standard start-stop-seal circuit in details.

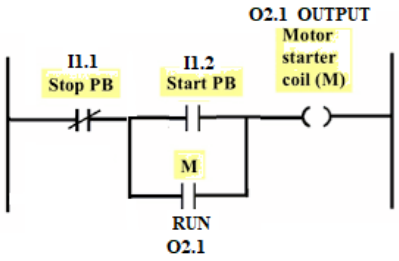
Ans:

Standard Start-Stop-Seal circuit:

- The Start-Stop-Seal circuit is as shown in figure. The power circuit consists of

3ph load (Motor) connected by a main contactor (M) to 3-phase supply. The control circuit consists of Start, Stop push-buttons and main contactor coil (M). — 4 marks for description

- When Start push button is pressed, the contactor coil (M) gets energized and the motor is connected across supply. When Start push-button is released, supply to coil M is maintained through RUN (aux contact of M).
- When STOP is pressed, M gets de-energized and motor gets disconnected from supply.



4 marks for diagram

OR

The inputs to this circuit are the "Start" and "Stop" conditions.
You could imagine both are momentary buttons on an operator screen that are on while the operator is actually pushing the button.
If the operator pushes the Start button, then the main contactor coil (M) will turn on, and it seals itself in until the operator pushes the Stop button.
The reason that this pattern is "stop dominant" is that we want the Stop condition to take priority over the Start condition in the case where both signals are active.
Imagine a case where the Start condition was stuck on for some reason. At least the operator could stop the motor, etc., by holding the Stop button on until they can turn the machine off with the main switch.

5 c) Draw power & control circuit diagram of starter for slip-ring Induction motor with current limiting acceleration starter. Explain its working in details.

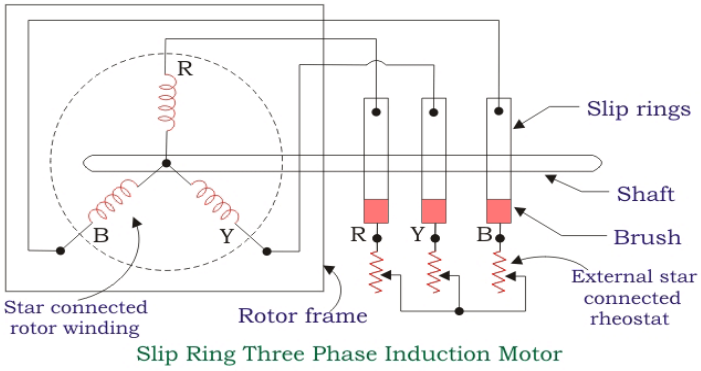
Ans:

Current limiting acceleration starter slip-ring Induction motor:

- Special current limit relay is used it has two coils namely current coil and potential coil, CT produces restraining torque and PT produces operating torque so the relay will operate only when current in current coil is below certain limit and potential coil is excited. — 3 marks for description
- Such relay are used in control circuit namely X and Y, X(c), Y (c) are current coils connected in series and energized from CT secondary, primary of CT is connected to any one phase of stator.
- Auxiliary contact of contactor A, B, C and D are mechanically adjusted such that NO contacts closed before NC contacts are open Ex. A_2 closes 1st then A1 opens when A is excited.
- When ON push button is pressed then main contactor (M) is energized it is hold through its auxiliary contacts (M1) rotor of motor is connected to 3 ph supply and motor will start with all resistances in rotor circuit.
- M2 closes and voltage coil X(v) is energized coil of contactor A and X (v) are in series as impedance of X(v) is very high the current and motor relay X will not operate when motor current falls below determine value the relay X will operate and contact X1 closes. Closing of X1, X(v) and current is directly supplied to A so contactor A closes and it is hold through A2.

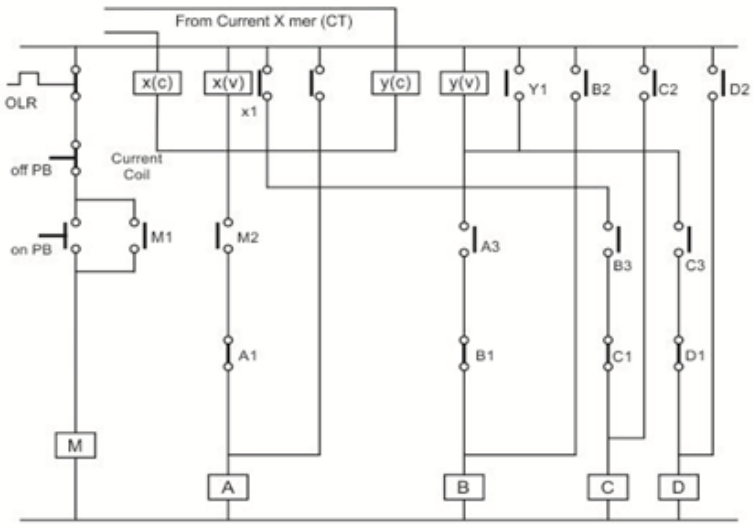
- Then A1 opens and voltage coil X (v) is de-energized X1 also opens.
- As contactor A is closed R1 in rotor circuit is cut off.
- Contact A3 closes which complete circuit of voltage coil Y (B) and coil B, both energized but contactor B will not pick up due to high impedance of Y (v)
- When motor current falls below predetermine value relay Y will operate and closes contact Y1 it bypass Y(v) and so contactor B operates it is hold though B2.
- After that B1 opens and Y(v) is disconnected in rotor circuit is cut off.
- Then contact B3 closes which energized series combination of coil X(v) and coil C, when current reduces to predetermine value relay X operates and X1 closes. It bypass X(v) and contactors C will operate.
- It closes C2 which hold coil C and opens which de-energized X(v).
- Closing of C eliminate R3 from rotor circuit.
- After that C3 closes which energized secondary combination of Y(v) and coil (D) when motor current reduces relay (Y) operates and Y1 closes. It bypass Y (v) and contactor (D) operates.

It closes D2 and hence, coil D is hold through D2, then D1 is opens which de-energized relay. Closing of contactor eliminates all external resistance from rotor circuit.



Slip Ring Three Phase Induction Motor

2 marks for power circuit



3 marks for control circuit

6 Attempt any FOUR of the following: 16

6 a) Explain the following with diagram:

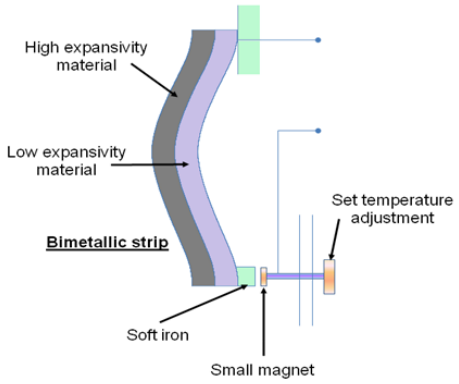
i) Temperature Switch
ii) Pressure Switch

Ans:

Temperature Switch:

A temperature switch is one detecting the temperature of an object. Temperature switches often use bimetallic strips as the temperature-sensing element, the motion of which actuates one or more switch contacts. An alternative design uses a metal bulb filled with a fluid that expands with temperature, causing the switch mechanism to actuate based on the pressure this fluid exerts against a diaphragm or bellows.

1 mark for diagram + 1 mark for description = 2 marks

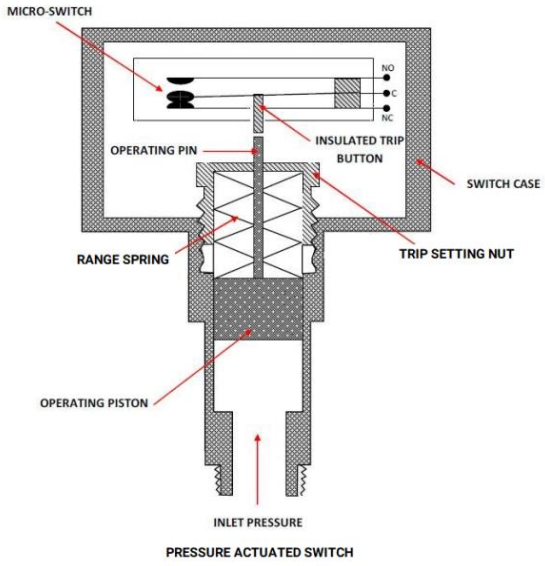


Bimetallic strips are used as thermal switch in controlling the temperature or heat in a manufacturing process or system. It contains two different metal strips bonded together. The metals have different coefficients of expansion. On heating the strips bend into curved strips with the metal with higher coefficient of expansion on the outside of the curve. Figure 2.5.1 shows a typical arrangement of a bimetallic strip used with a setting-up magnet. As the strips bend, the soft iron comes in closer proximity of the small magnet and further touches. Then the electric circuit completes and generates an alarm.

Pressure Switch:

A pressure actuated switch is a device designed to monitor a process pressure and provide an output when a set pressure (setpoint) is reached. A pressure actuated switch does this by applying the process pressure to a diaphragm or piston to generate a force which is compared to that of a pre-compressed range spring. A pressure actuated switch is used to detect the presence of fluid pressure. Most pressure switches se diaphragm or below as the sensing element. The movement of this sensing element is used to actuate one or more switch contacts to indicate as alarm or initiate a control action.

1 mark for diagram + 1 mark for description = 2 marks



6 b) State the function of following:
i) PROM
ii) EPROM

Ans:

Programmable Read-Only Memory (PROM) is a special type of ROM because it can be programmed. Very few of today's programmable controllers use PROM for application memory. When it is used, this type of memory is most likely a permanent storage backup for some type of RAM. Although a PROM is programmable and, like any other ROM, has the advantage of nonvolatility, it has the disadvantage of requiring special programming equipment. Also, once programmed, it cannot be easily erased or altered; any program change requires a new set of PROM chips. 2 marks

Erasable Programmable Read-Only Memory (EPROM) is a specially designed PROM that can be reprogrammed after being entirely erased by an ultraviolet (UV) light source. Complete erasure of the contents of the chip requires that the window of the chip be exposed to a UV light source for approximately twenty minutes. EPROM can be considered a semipermanent storage device, because it permanently stores a program until it is ready to be altered. EPROM provides an excellent storage medium for application programs that require nonvolatility, but that do not require program changes or on-line data entry. 2 marks

6 c) Differentiate between RAM & ROM in PLC memory.

Ans:

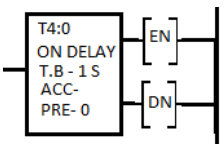
Random-Access Memory (RAM), often referred to as read/write memory (R/W), is designed so that information can be written into or read from the memory storage area. Random-access memory does not retain its contents if power is lost; therefore, it is a volatile type of memory. Random-access memory normally uses a battery backup to sustain its contents in the event of a power outage. Random-access memory provides means for easily creating and altering a program, as well as allowing data entry. In comparison to other memory types, RAM is a relatively fast memory. It can be used as data memory. 2 marks

Read-Only Memory (ROM) is designed to permanently store a fixed program that is not alterable under ordinary circumstances. Its contents can be examined, or read, but not altered once information has been stored. ROMs are generally immune to alteration due to electrical noise or loss of power. ROM does not retain its contents if power is lost; therefore, it is a volatile type of memory. It can be used to store Executive programs. 2 marks

6 d) **Explain ON Delay Timer operation with diagram**

Ans:

ON Delay Timer:



An on-delay timer will wait for a set time after a line of ladder logic has been true before turning on, but it will turn off immediately. An ON-delay energize timer(TON) either provides time delayed action or measures the duration for which some event occurs. Once the rung has continuity, the timer begins counting time-based intervals and counts down until the accumulated time equals the preset time. When these two values are equal, the timer energizes the output and closes the timed out contact associated with the output. The timed contact can be used throughout the program as either a normally open or normally closed contact. If logic continuity is lost before the timer times out, the timer resets the accumulated register to zero. 2 marks for description

The control registers and bits used in timers are as follows:

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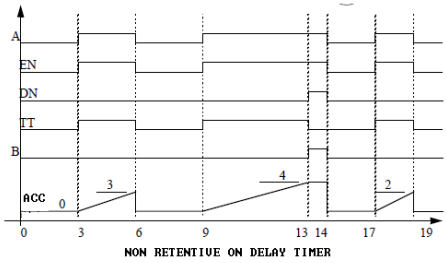
	15 14 13	
Word 0	EN TT DN	Internal Use
Word 1	Preset Value	
Word 2	Accumulator Value	

Bits used in timers:

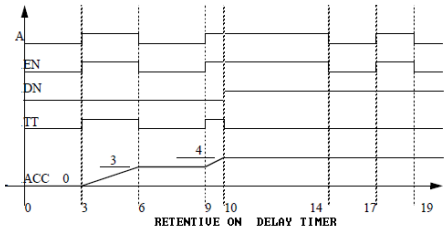
i) T4:0 : This bit indicates timer file4,timer 0 ,it stores timer information
ii) Time base 1.0 : This bit indicates processor increments accumulated values in 1 second intervals.
iii) Preset: It indicates delay for timer
iv) Accumulator value gives current value of the timer as 0 which increases upto the preset value
v) I:010/5 : It is the input to the timer
vi) EN : This bit is set ,when input is true,
vii) TT: This bit is set when timer is running other is reset
viii) DN : This bit is set when accumulator value becomes equal to preset value and then respective output becomes ON

2 marks for bit description

There are two types of ON Delay timers viz. retentive and non-retentive. A retentive timer will sum all of the on or off time for a timer, even if the timer never finished. A non-retentive timer will start timing the delay from zero each time. The timing diagrams of these timers are as shown below.



OR



[Waveforms optional NO marks]

6 e) Define Integral controller. State their advantages.

Ans:

Integral controller:

Integral action accumulates error as a function of time. It sums the error over time, multiplies that sum by a gain, and adds the result to the present controller output. If the error makes random excursions above and below zero, the net sum will be zero, so the integral action will not contribute. But if the error becomes positive or negative for an extended period of time, the integral action will begin to accumulate and make changes to the controller output.

2 marks

Advantages:

i. The controller has the unique ability to return the process back to the exact setpoint.
ii. It can eliminate the offset in proportional control.

1 mark for each advantage

6 f) Explain proportional controller process control action.

Ans:

Proportional Controller:

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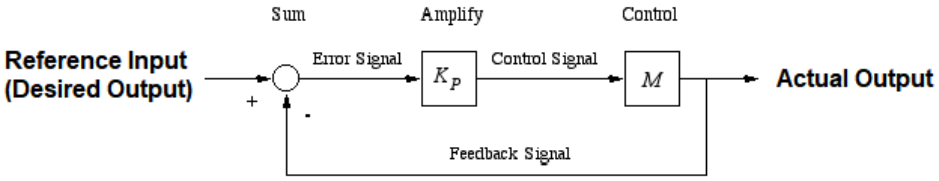
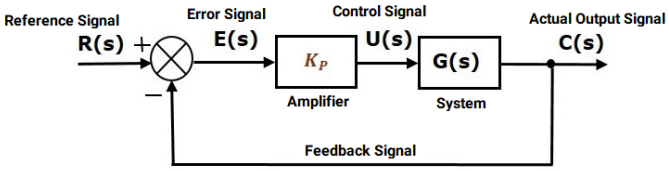
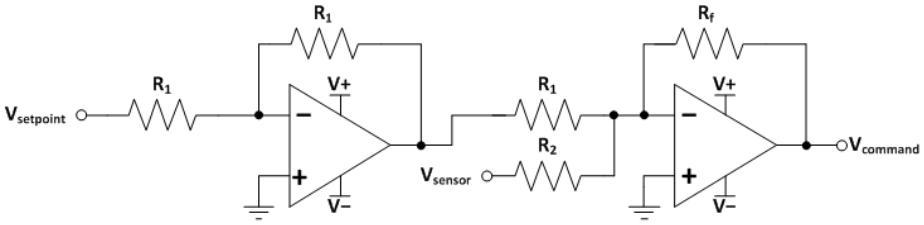


1 mark for diagram

OR

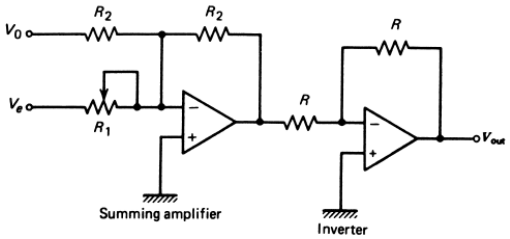


OR



$$V_{command} = \frac{R_f}{R_1}(V_{setpoint} - V_{sensor}) \; if \; R_1 = R_2$$

OR



Proportional controller is a device that produces an output signal proportional to the deviation/error. The proportional control action is a multi position type of controller action in which position of the correcting element is directly proportional to the deviation. It is called as P control action. This action responds to the size and sign of deviation. For each value of deviation, there is a specific value of controller output of controller that correlates with a specific value opening. The proportional band is the range of deviation, in percent scale; that corresponds to the full range of deviations. It is dependant on the gain. The proportional controller amplifies the error signal by Kp.

2 marks for explanation

Mathematically the controller output Po for proportional controller is expressed as,

1 mark for equation

$$Po = Kp.ep + Pn$$

Where, Kp is proportional constant,
Pn is controller output with no error
ep is error expressed as percentage of span