Winter – 2019 Examinations

Model Answers

Subject & Code: Elements of Industrial Automation (22526)

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 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.

Winter – 2019 Examinations

Model Answers

Subject & Code: Elements of Industrial Automation (22526)

1 Attempt any FIVE of the following: 10

1 a) State the need of automation.

Ans:

Need of Automation in Process :

- To fulfill the demand of product at right time.
- To reduce the human errors and involvement of human being in the process.
- For better productivity.
- For better control of process.
- For better quality.
- For reducing man power.
- For reducing cost of product.

½ Mark for each of any four needs = 2 Marks

OR

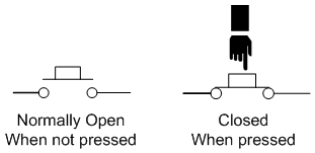
Any other relevant points shall be considered

1 b) Draw the symbol of following:

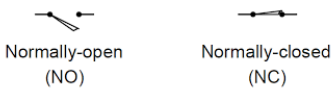
(i) Push button
(ii) Limit switch
(iii) Proximity switch
(iv) Pressure switch

Ans:

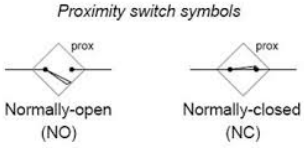
Push Button



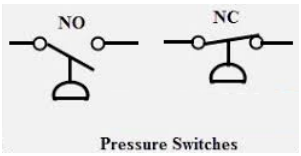
Limit Switch



Proximity Switch



Pressure Switch

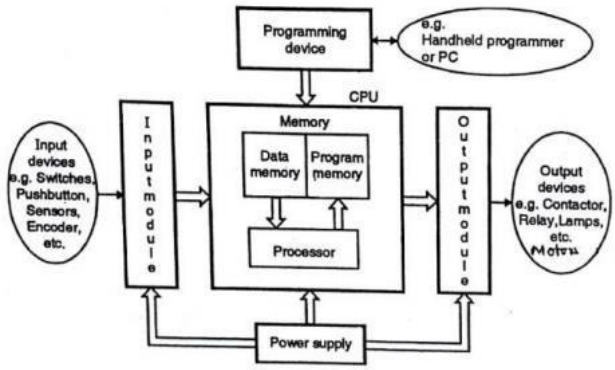


½ Mark for each symbol

1 c) Draw the block diagram of PLC.

Ans:

Block diagram of PLC:



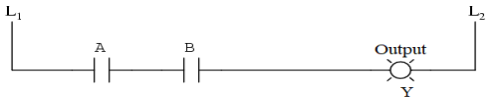
Block diagram of PLC

2 Marks for labelled block diagram

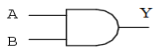
1 d) Draw and explain ladder diagram for AND Operation.

Ans:

Ladder Diagram for AND Operation:



A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1



1 Mark for ladder diagram
1 Mark for symbol and truth table

1 e) List types of timers.

Ans:

Types of Timers:
Retentive Timers:
1. ON Delay
2. OFF Delay

Non Retentive Timers:
1. ON Delay
2. OFF Delay

1 Mark for main types
1 Mark for subtypes

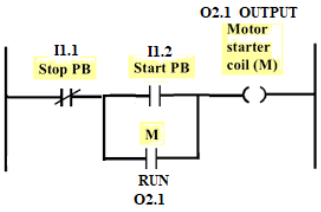
1 f) State the function of seal in circuit w.r.t. PLC.

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).
- 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.

1 Mark description



1 Mark ladder diagram

1 g) Give the full form of SCADA & HMI.

Ans:

Full Form of SCADA and HMI:

SCADA:-Supervisory Control and Data Acquisition

HMI :- Human Machine Interface

1 Mark for each full form = 2 Marks

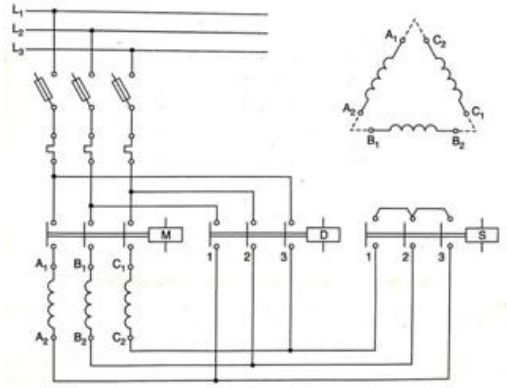
2 Attempt any THREE of the following: 12

2 a) Develop the control circuit for star-delta starter used for starting a 3 ∅ induction motor.

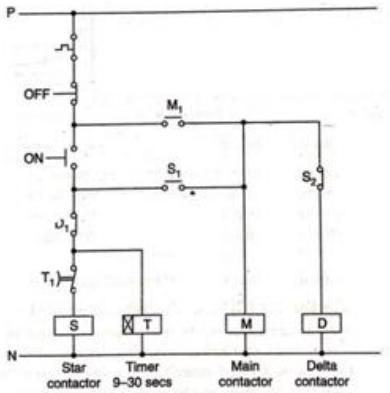
Ans:

Control Circuit for Star-Delta Starter:

1) Automatic Star-Delta Starter:



(a) Power circuit diagram for a star-delta starter



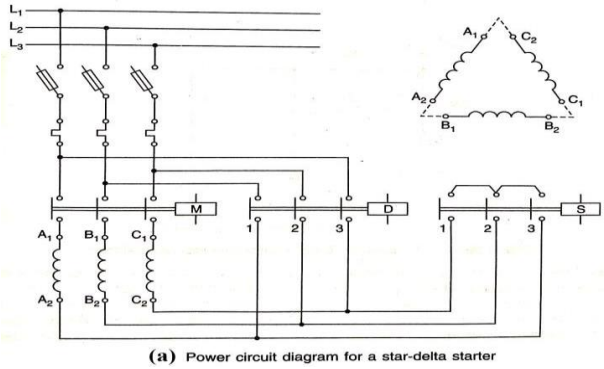
(b) Control circuit for an automatic star-delta starter

4 Marks for control circuit diagram

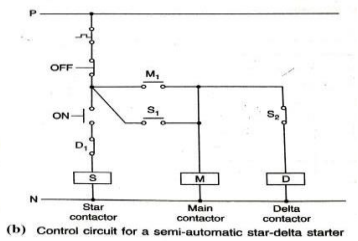
OR

OR

2) Semi- automatic Star-Delta Starter:



(a) Power circuit diagram for a star-delta starter



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

4 Marks for control circuit diagram

2 b) State the function of PLC memory w.r.t. types, speed of execution.

Ans:

PLC memory cab be divided into two major types:

1) System memory:

a) Executive Memory: The executive is a permanently stored collection of programs that are considered part of the system itself. These supervisory programs direct system activities, such as execution of the control program, communication with peripheral devices, and other system housekeeping activities. — 1 Mark

b) Scratch Pad Memory: This is a temporary storage area used by the CPU to store a relatively small amount of data for interim calculations and control. The CPU stores data that is needed quickly in this memory area to avoid the longer access time involved with retrieving data from the main memory. — 1 Mark

2) Application Memory:

a) Data Table Memory This area stores all data associated with the control program, such as timer/counter preset values and other stored constants and variables used by the control program or CPU. The data table also retains the status information of both the system inputs and the system outputs. — 1 Mark

b) User Program Memory: This area provides storage for programmed instructions entered by the user. The user program area also stores the control program. — 1 Mark

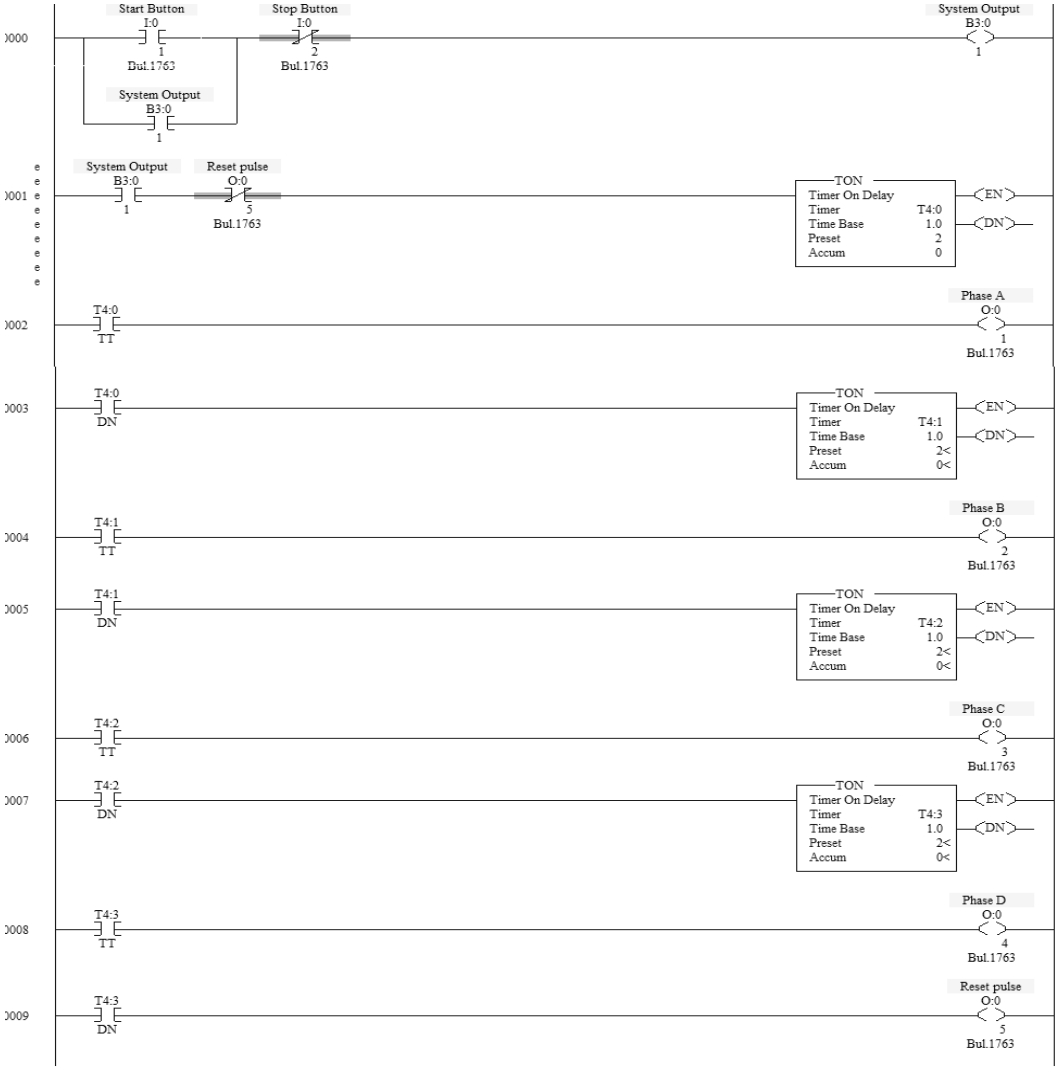
Executive memory is read only memory (ROM) type memory. Scratch pad, data table memory are random access memory (RAM) type memory. Program memory is flash ROM type memory. RAM memory is fastest amongst all type of memory. Flash ROM memory is faster than ROM memory.

2 c) Develop the ladder diagram for stepper motor control.

Ans:

Ladder diagram for Stepper Motor Control:

Start Button:- I:0/1, Stop button:-I:0/2, System output:-B3/1, Phase A:- O:0/1 Phase B:- O:0/2, Phase C: O:0/3, Phase D: O:0/4. — 1 Mark for addressing



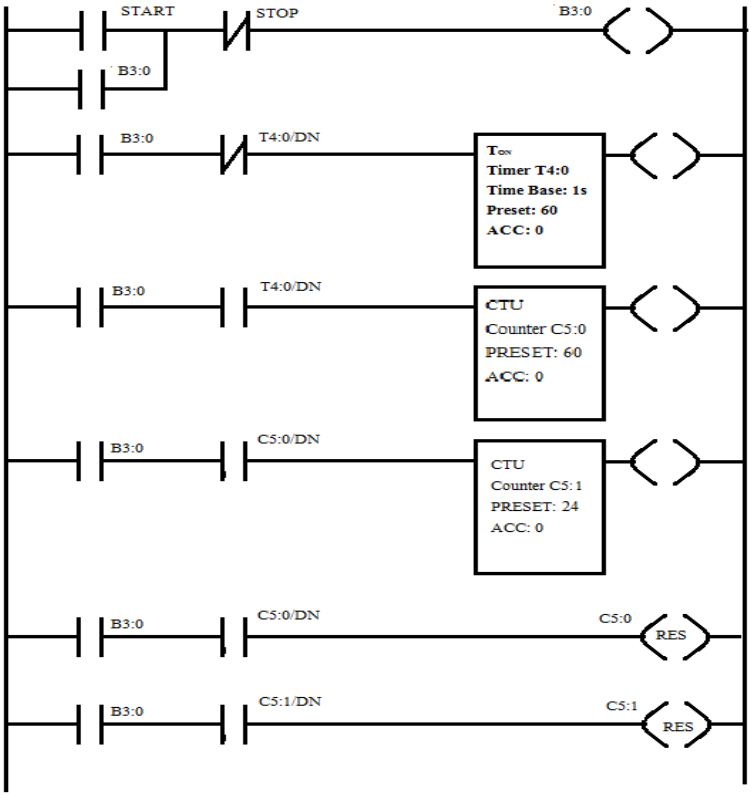
3 Marks for ladder diagram

OR Any Other Equivalent Answer

2 d) Write the ladder program for 24 hour clock.

Ans:

Ladder Program for 24 hour clock:



4 Mark for Ladder diagram

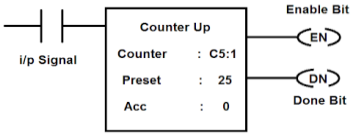
OR Any Other Equivalent Answer

3 Attempt any THREE of the following: 12

3 a) Explain count up (CTU) instruction with timing diagram.

Ans:

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.



1 Mark for description

	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															

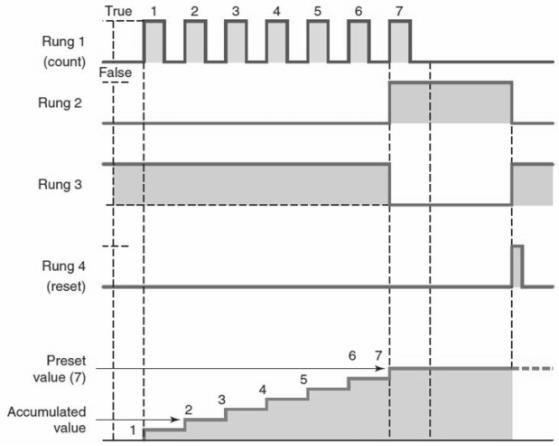
- **CU Bit:** This status bit is true when UP counter instruction is true.
- **DN bit:** This bit is true when accumulated value is equal to or greater than the

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 control bit description

Timing Diagram of Counter up(CTU) Instruction:

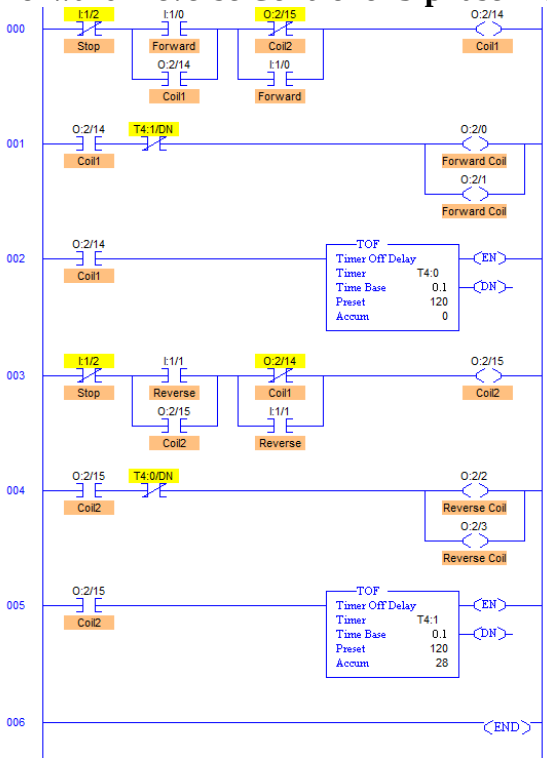


1 Mark for timing diagram

3 b) Develop a ladder diagram for forward-reverse control of a 3 ϕ induction motor.

Ans:

Ladder Diagram for Forward-Reverse Control of 3-phase Induction Motor:



4 Marks for ladder diagram

- For any three-phase AC motor, reversing can be accomplished by reversing any two leads.
- Reversing Contactor is used to reverse Three-Phase AC motors.
- Reversing any two leads will drive the three-phase induction motor in reverse direction.
- Contactor is an electrical switch used for switching an electrical power circuit. Two magnetic contactors are used, one for forward connections and the other for reverse connections.
- Only Push Button switches are used to control the direction of this three-phase AC motor.
- Configure forward and reverse wiring of the motor with contactors such that forward contactor is connected directly in the normal direct phasing of the motor terminal and reverse contactor is connected with two of the motor terminals in the opposite phase.
- When it is switched to reverse direction, forward rotation does not stop instantaneously hence we have to determine what time it takes to completely stop one particular direction. Then provide time delay of a second or two and activate the other contactor.

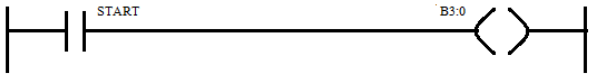
3 c) Explain instruction:
(i) If-closed
(ii) If-open

Ans:

1. **Examine if Closed [XIC]:** Examines a bit for an On (set, high) condition.

When the instruction is executed, if the bit addressed is on (1), then the instruction is evaluated as TRUE. When the instruction is executed, if the bit addressed is off (0), then the instruction is evaluated as FALSE.

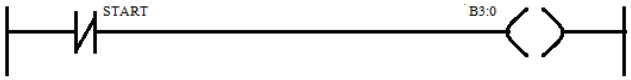
2 Marks for description



2. **Examine if open [XIO]:** Examines a bit for an Off (cleared, low) condition.

When the instruction is executed, if the bit address is off (0), then the instruction is evaluated as TRUE. When the instruction is executed, if the bit addressed is on (1), then the instruction is evaluated as FALSE.

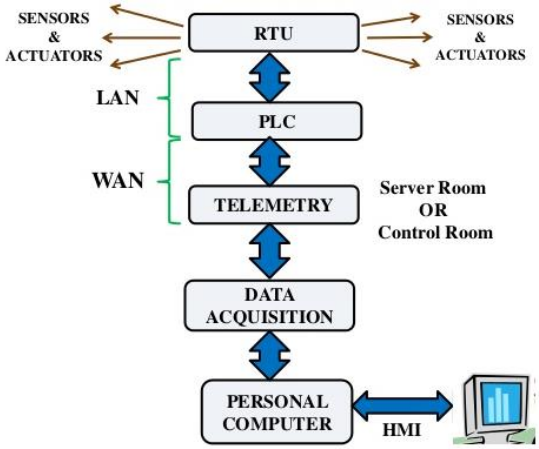
2 Marks for description



3 d) Explain block diagram of SCADA. Identify different components of it.

Ans:

Block Diagram of SCADA:



2 Marks for block diagram

2 Marks for identification of components

RTU: Remote Terminal Unit [sensors, transducers interface terminal located in plant]
MTU: Mater Terminal Unit [Controller, PLC]
Data Telemetry System: Transmission and reception.
Data Acquisition: multiple data collection
Server: Computers
HMI: SCADA software operating terminal**.**

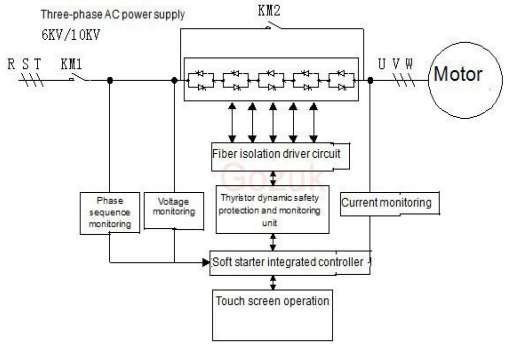
OR Any Other Equivalent answer

4 Attempt any THREE of the following: 12

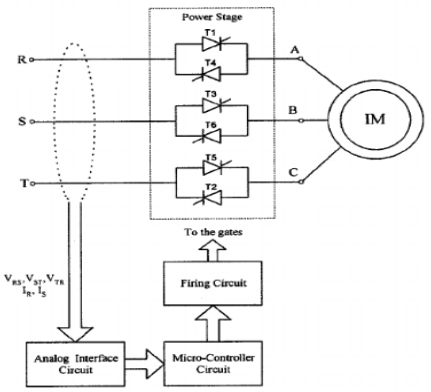
4 a) Explain with block diagram, the working of soft starter.

Ans:

Block Diagram of Soft Starter:



OR



2 Marks for block diagram

Working of Soft Starter:

- Soft starter is a device which reduces initial inrush current. In soft starter three pairs of back to back connected SCRs are used to start and stop the motor
- The back to back orientations of the SCRs allows the AC voltage to be controlled by changing the firing angle in every half cycle
- Firing of SCRs is triggered at heavily delayed firing angle initially during starting and then gradually reducing the delay till it reaches to zero voltage triggering.
- This result in low applied voltage across the motor terminal at the beginning and

2 Marks for working of soft starter

the gradually increasing it to full voltage.

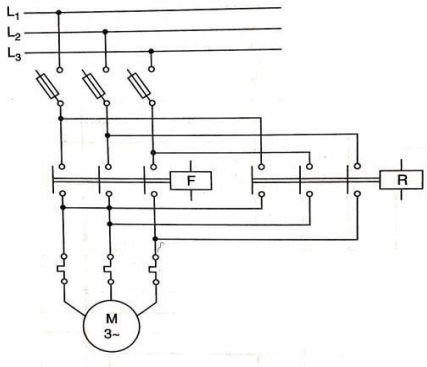
- Thus motor starts slowly and then pickup to full speed.
- Once the motor is upto speed the soft starter is bypass and the motor is connected across the line.

OR Any Other Equivalent Answer

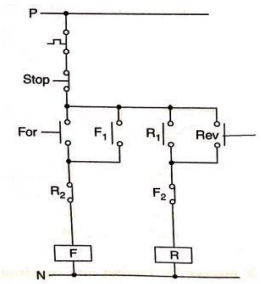
4 b) Explain the working of FRD-STOP-REV control circuit of an induction motor.

Ans:

Working of FRD-STOP-REV Control Circuit:



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



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

1 Mark for power circuit diagram

1 Mark for control circuit diagram

The power and control circuit of 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 L1-L2-L3 is provided to motor and it runs in Forward direction. However, when contactor R is ON, the three-phase supply with reversed phase sequence L1-L3-L2 is provided to motor and it runs in Reverse direction.

2 Marks for working.

In control circuit, when push-button 'For' is pressed, the contactor coil 'F' get energized through 'Stop' push-button, pressed 'For' push-button and R2 NC contact. Therefore, the contactor 'F' get closed and in power circuit, the three phase supply with phase sequence L1-L2-L3 is provided to motor and it runs in Forward direction. The operation of contactor 'F' causes closing of NO contact 'F1' and opening of NC contact 'F2'. The contact F1 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 F2 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 F2 regains its original closed state.

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 L1-L3-L2 to motor and it runs in Reverse direction.

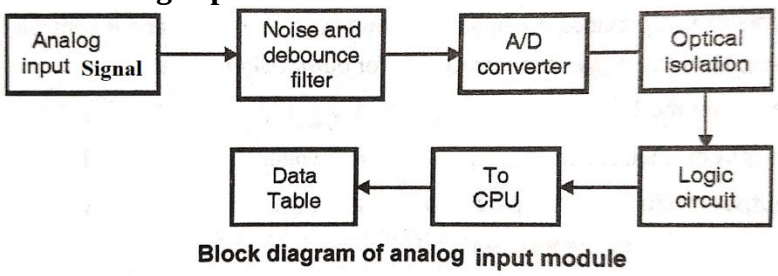
Thus during transition from Forward to Reverse or vice-versa, we need to Stop the

motor, hence this control is referred as 'Forward-Stop-Reverse' control.

4 c) Draw the block diagram of analog input module of PLC. State the function of each block.

Ans:

Block Diagram of Analog Input Module of PLC:



Block diagram of analog input module

2 Marks for block diagram

1) **Analog input Signal:** Function of this block is to give analog signal to analog input module.
2) **Noise and debounce filter:** The input signal is made free from noise signal using noise and debounce filter circuit and applied to digital converter.
3) **A/D Converter:** A/D converter which converts the analog input signal to a digital signal.
4) **Optical isolation:** Provide protection to CPU from high voltages.
5) **Logic Circuit:** The logic section allowed digitized signal to CPU.
6) **Data Table:** For storage of input digital signal.

2 Marks for function

4 d) Explain the function of
(i) Communication Module
(ii) PID controller module

Ans:

(i) Communication Module:

a) ASCII I/O module:

- ASCII I/O module accept and processes on only ASCII data.
- It is used to interface the peripheral devices like barcode reader, printers, meters etc which uses ASCII data with the PLC

1 Mark

b) RS-232 Interface modules:

- Communication modules are available that are inherent in the PLC chassis itself.
- They used to connect a PLC to telephones lines using a modem.
- PLC connected to telephone lines allow central control room operators to examine ladder programs to modify or edit at remote PLC sites.

1 Mark

(ii) PID Controller module:

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,

2 Marks

which in turn causes the derivative to more aggressively counteract the P and the I.

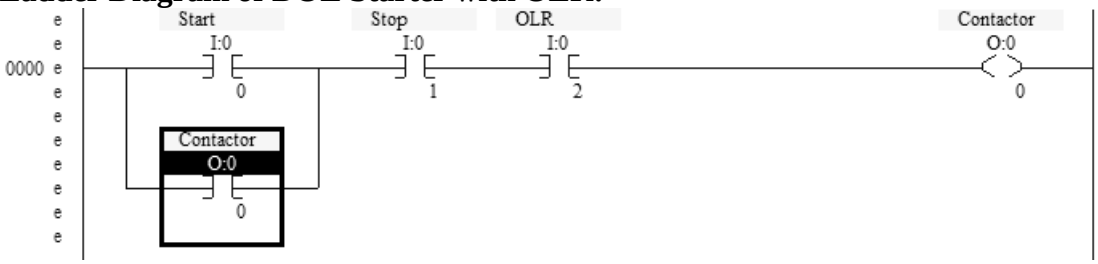
$$P_o = K_P E_P + K_P K_i \int E_P dt + K_P K_d \frac{dE_P}{dt} + P_i(0)$$

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

4 e) Develop ladder and wiring diagram of DOL starter with OLR.

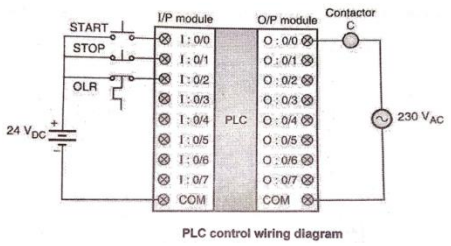
Ans:

Ladder Diagram of DOL Starter with OLR:



2 Marks for ladder diagram

Wiring Diagram of DOL Starter with OLR:

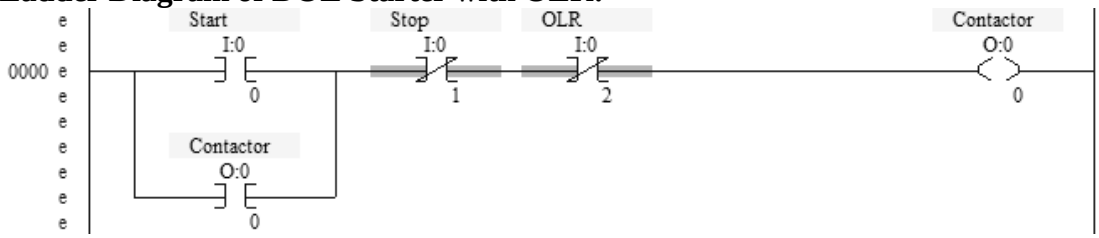


PLC control wiring diagram

2 Marks for wiring diagram

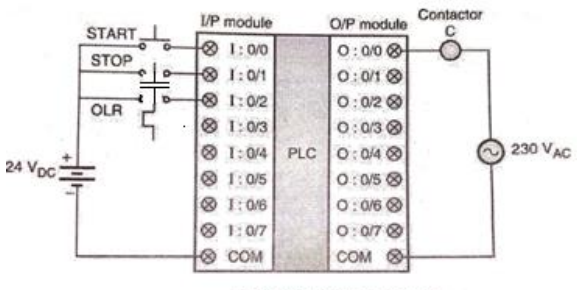
OR

Ladder Diagram of DOL Starter with OLR:



2 Marks for ladder diagram

Wiring Diagram of DOL Starter with OLR:



PLC control wiring diagram

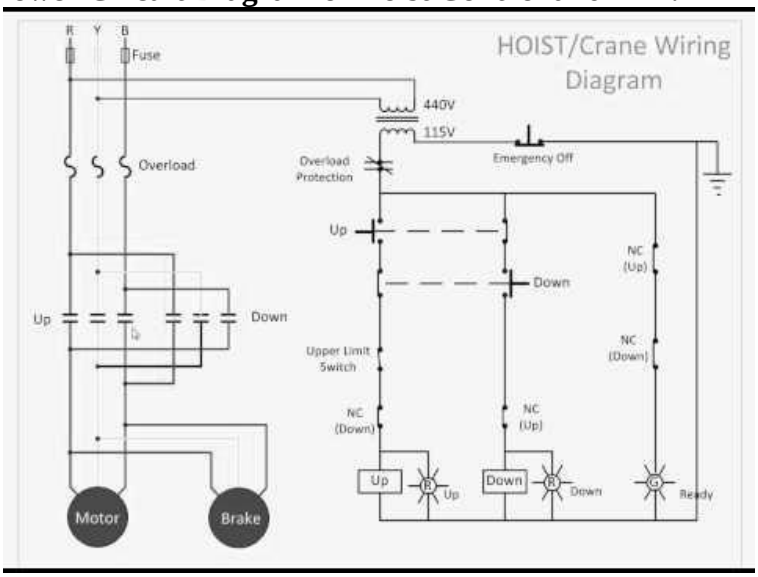
2 Marks for wiring diagram

5 Attempt any TWO of the following: 12

5 a) Develop control and power circuit diagram of hoist control and mill.

Ans:

Control and Power Circuit Diagram of Hoist Control and Mill:



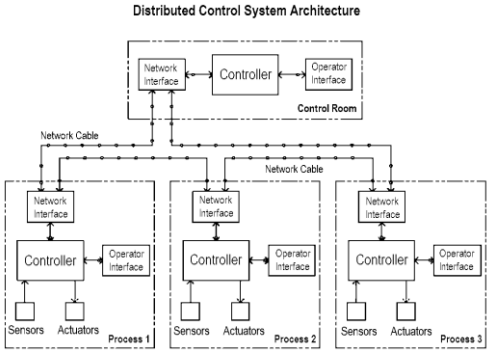
3 Marks for power circuit

3 Marks for control circuit

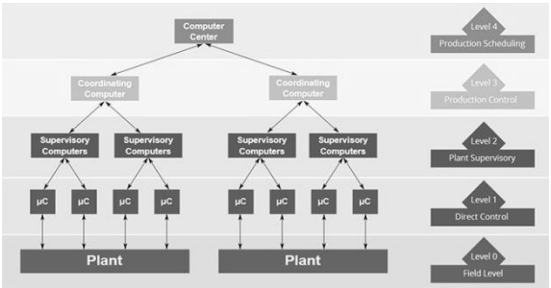
5 b) Develop a generalised DCS architecture for control of a plant.

Ans:

Generalized DCS architecture:



OR



4 Marks for architecture diagram

Level 0: It consists of the field devices such as temperature sensors, flow, and final control elements such as control valves.

Level 1: It consists of the industrialized Input / Output (I/O) modules, and their associated distributed electronic processors.

Level 2: It is included with supervisory computers that help to gather information from processor nodes on the system, and provide the operator control screens.

Level 3: It is the production control level, which does not directly control the process, but is concerned with monitoring production and monitoring targets.

Level 4: It is the production scheduling level.

2 Marks for description

OR Any Other Equivalent Answer

5 c) Explain the working of PLC based bottle filling system with the help of ladder diagram.

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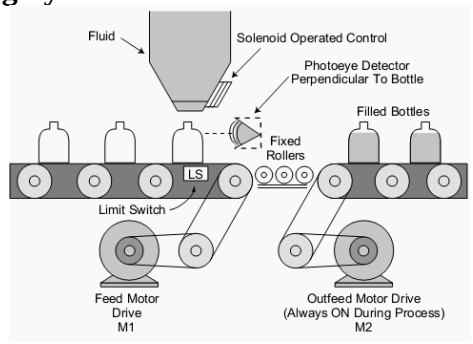
Model Answers

Subject & Code: Elements of Industrial Automation (22526)

Ans:

PLC Based Bottle Filling System:



Description:

Inputs:

Start : I:0/0, Stop: I:0/1, Limit Switch[LS]: I:0/2, Photo detector[PE]: I:0/3

Outputs:

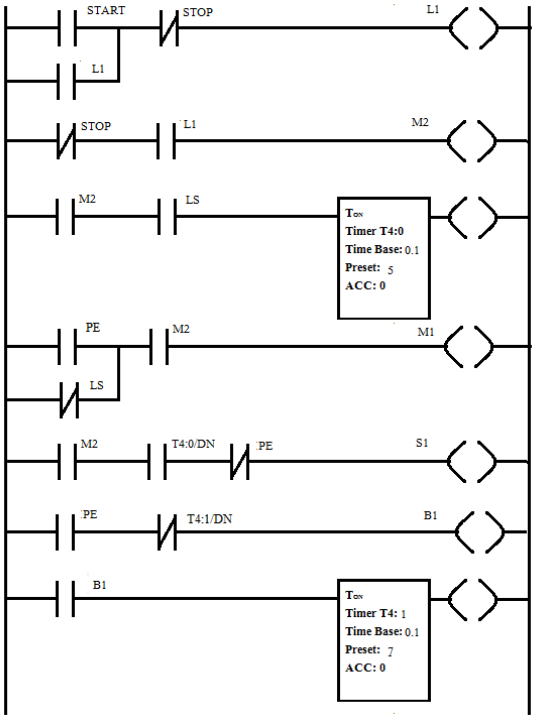
Feed Motor[M1]: O:0/0, Outfeed Motor[M2]: O:0/1, Solenoid Valve[S1]: O:0/2
Light[L1]: O:0/3, Buzzer[B1]: O:0/4

3 Mark for description

Let's consider a bottle filling plant with the following logic.

Detect the position of a bottle via a limit switch then waits for 0.5 secs, and then fills the bottle until a photodetector detects the filled condition of the bottle. After the bottle is filled, the buzzer sounds and the control program will again wait for 0.7 secs. before moving to the next bottle .Until the limit switch signals ,the feed motor,M1 runs while there are fixed rollers which carries the filled bottles. Motor,M2 keeps running after the process has been started.

Ladder Diagram:

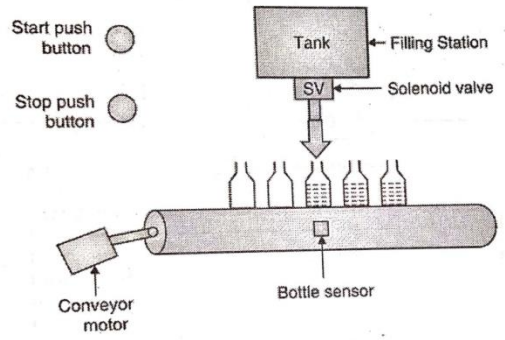


3 Mark for ladder diagram

When start button is pressed the green light (L1) turns ON and remains ON till stop

button is pressed. The out feed motor(M2) starts running. If limit switch(LS) is LOW or filled bottle condition is fulfilled motor(M1) starts. When limit switch is ON timer, T0 gets activated. After delay, T0 gives done (DN) signal and photo detector (PE) is disabled, solenoid valve gets turn ON. As PE signals solenoid stops and buzzer (B1) sounds after which timer, T1 gets enabled which stops the process for 0.7 seconds. Once the filled bottle condition is activated the cycle starts again.

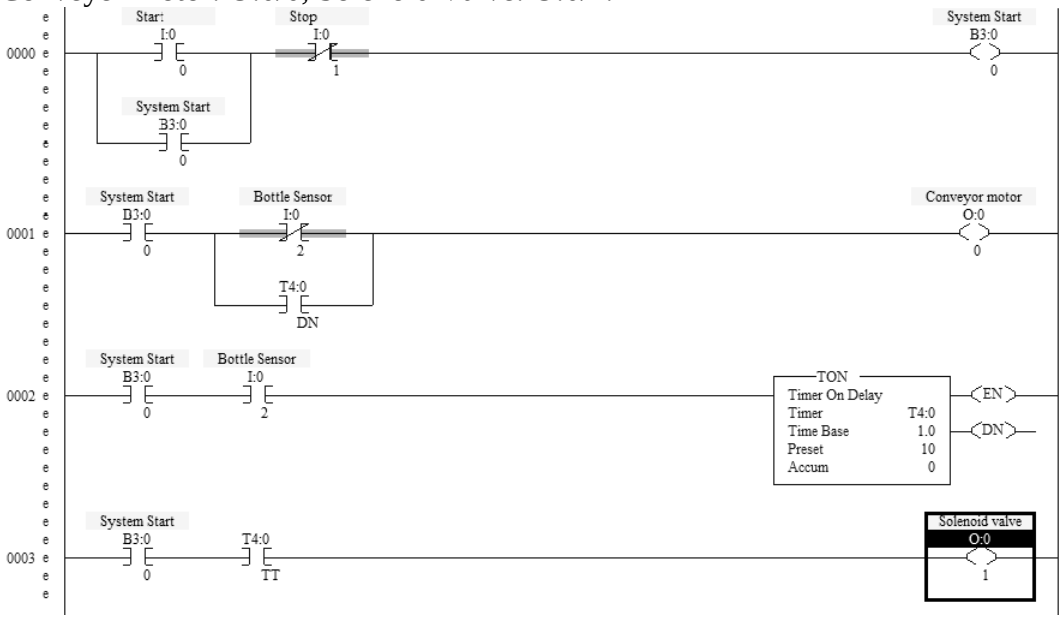
OR



Bottle filling system

Ladder Diagram Bottle Filling System:

Start: I:0/0, Stop: I:0/1 System Start: B3:0, Bottle Sensor: I:0/2,
Conveyer Motor: O:0/0, Solenoid Valve: O:0/1.



OR
1 Mark

3 Mark for ladder diagram

- When start button is pressed, system starts and conveyor motor also start.
- Bottle moves on conveyor belt, when bottle reaches to filling stations, it is senced by bottle sensor.
- When Bottle is senced by sensor, conveyor belt stops rotating and timer T4:0 starts for 10 sec.
- When timer start, it opens solenoid valve for 10 second to fill bottle upto predetermined level.
- After 10 second, solenoid valve gets closed and conveyor belt again start rotating.
- Same cycle repeats for next bottle sensed by bottle sensor or till stop button is not Pressed.

2 Mark for explanation

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OR Any Other Equivalent Answer

6 Attempt any TWO of the following: 12

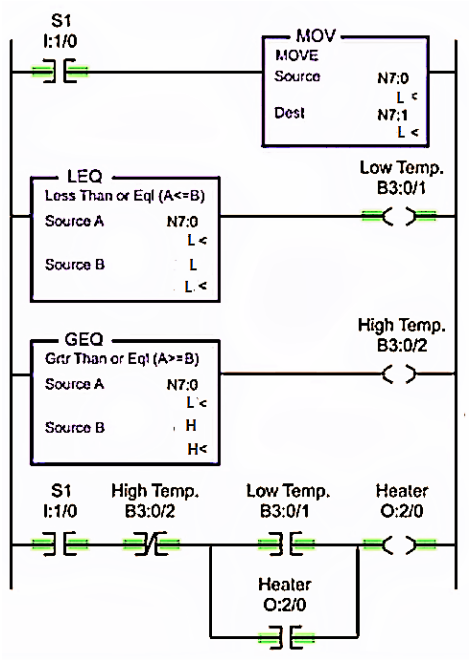
6 a) Develop a ladder diagram for ON/ OFF temperature control.

Ans:

Ladder Diagram for ON/OFF Temperature Control:

- If source A < source B of the LEQ logic, then the low temp and heater output becomes TRUE. The heater remains to ON as long as this two condition satisfies - Low temp output is TRUE and High temp output is FALSE.
- Even if the Low temp output turns FALSE the heating continues until the High temp turns TRUE. Look at the latch in the last line of the ladder diagram.
- The heater continue to be ON until the temperature reaches the upper range value.
- When the temperature reaches higher range value, the source A will be equal to source B of the GEQ logic. Then the High temp becomes TRUE.
- The heater turns OFF when the High temp becomes TRUE.
- The heater remains OFF until the temperature reaches the lower range value. And starts again.

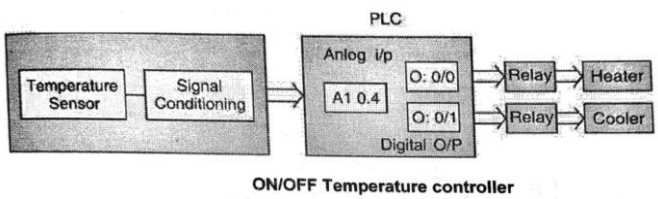
3 Marks for description



3 Marks for ladder diagram

OR

OR



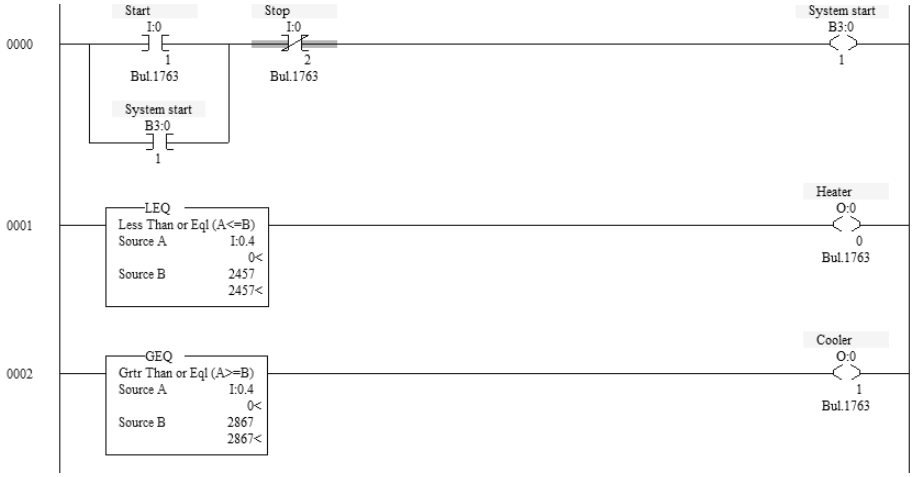
ON/OFF Temperature controller

1 Mark

- Let us assume the temperature range is 0°C to 100℃ and it's integer temperature range (12 bit) is 0 to 4095 and we have to maintain temperature range between 60℃ to 70℃.
- Lower set point is 60℃ (2457) i.e below this temperature heater turn ON and cooler turns OFF.
- Higher set point is 70℃ (2867) i.e above this temperature heater turn OFF and cooler turns ON.

1 Mark for Description

Ladder Diagram for Temperature Control:
Heater=O:0/0, Cooler= O:0/1, Input= I:0.4



3 Mark for ladder diagram

- In above ladder diagram, the temperature is continuously monitored and when it goes below or equal to set point value 60℃ (2457) LEQ instruction will energize output coil O:0/0 i.e heater turns ON.
- When temperature value goes above set point value 70℃, GEQ instruction will energize output coil O:0/1 i.e cooler turns ON
- So here temperature is controlled between the range 60℃ to 70℃.

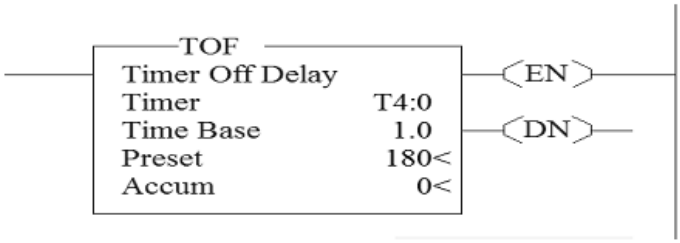
1 Mark for ladder diagram explanation

OR Any Other Equivalent Answer

6 b) Explain the instruction T_{on} and T_{off} with timing diagram.

Ans:

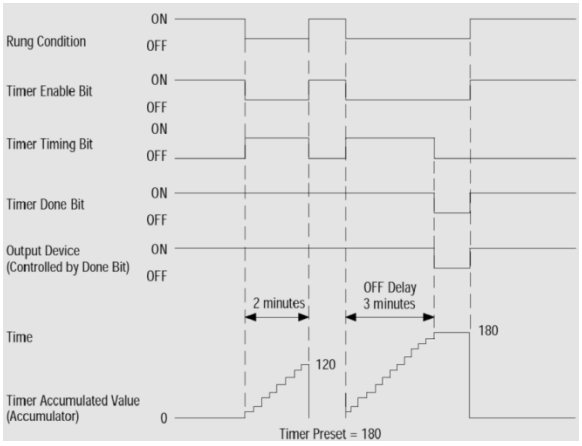
OFF-Delay Timer:



1½ marks for description

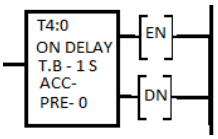
Preset value: It is multiplied by the time base of the timer to specify the time delay. **Accumulated value:** It specifies the time from the moment that was disabled up to the current moment. The address is for accumulators as follows T4: 0.ACC **Enabled bit:** It is set when the line is true, indicates 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: It 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: It 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.



1½ marks for timing diagram

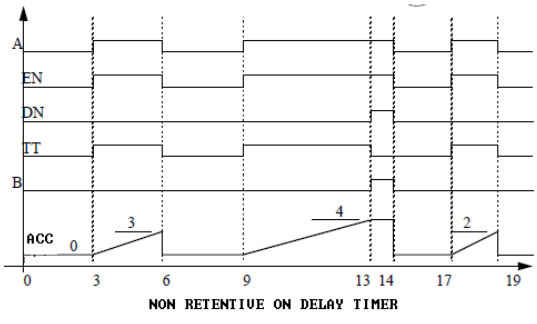
ON Delay Timer:



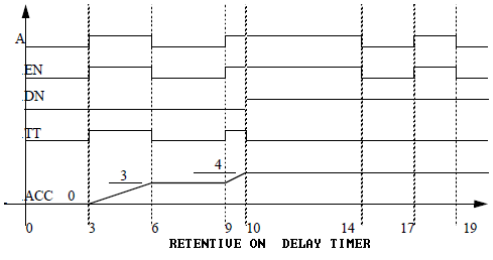
An on-delay timer will wait for a set time after a line of ladder logic has been true before turning on, but it will turn off immediately. An ON-delay energize timer(TON) either provides time delayed action or measures the duration for which some event occurs. Once the rung has continuity, the timer 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.
The control registers and bits used in timers are as follows:

1½ marks for 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



1½ marks for timing diagram

6 c) Draw the block diagram of digital output module of PLC and explain the function each block.
Ans:

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Model Answers

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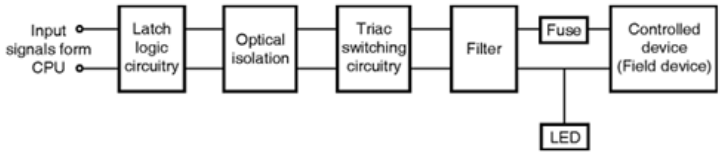
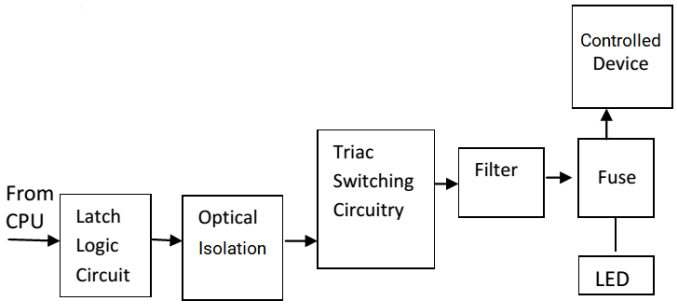
Block diagram of digital output module of PLC:



Block diagram of AC output module

3 Mark for block diagram

OR



Block diagram of DC output module

Latch logic circuit and optical isolation circuit:

i) If the status of output terminal is one and if CPU sends low voltage signal (12-18 V DC) to the latching circuit.
ii) Latching circuit will latch that logic signal as a ON state and then send it to the optical isolation circuitry.
iii) Same operation is performed for status is zero.
iv) Optical isolation circuit will isolate low voltage signal of CPU and high voltage operating field devices.

3 Mark for function

Switching and filtering circuitry:

i) In this block, power transistor/TRIAC is a solid state switching device used to provide high voltage operating signal to output field devices.
ii) Power transistor /TRIACs are switched ON or OFF by the signal from optical isolation circuit.
iii) DC/AC signals switched by power transistor/TRIAC are filtered to a safe level by filtering circuitry.
iv) To indicate the status of the output LED is provided on output module
v) In some output module circuit, fuse is provided to protect the circuit from drawing higher current.

Controlled device(Load):

i) Controlled device are the field output devices may operate from different voltages.
ii) When the status of output is one in output data table then controlled device turns ON and when status is zero, then device turns OFF.