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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.
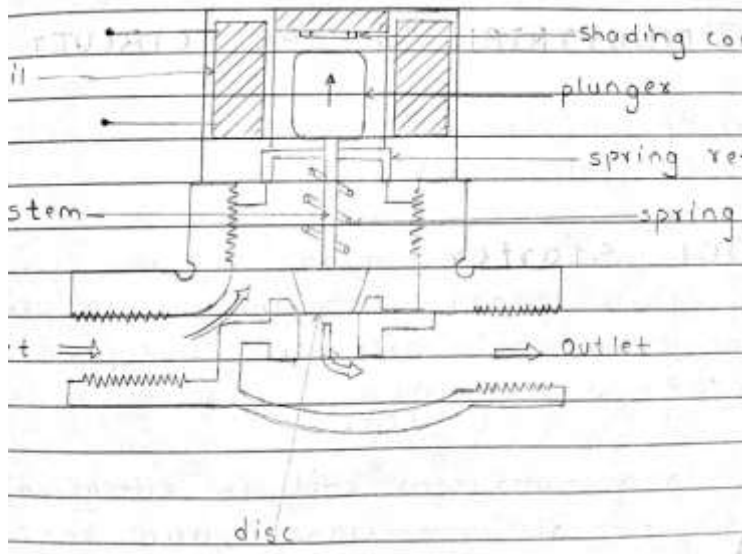7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q1. Atempt any FIVE :	**20**
(a) Explain the concept of NO & NC contact. State its applications. (2 marks diagram + 2 expln) NO and NC contacts are standard set of contacts available with an electromechanical relay. NO contacts are open in normal condition. When the relay coil is energized, NO contacts are closed. NC contacts are closed in normal conditions. When the relay coil is energized, NC contacts are opened. NO contact NC contact NO and NC contacts are most commonly used symbols in PLC ladder logic or any industrial control circuit to indicate digital input. They are derived from relay contacts. The input can be switch closure, push button closure etc. 1) Physical NO/NC contacts are used in relay based control circuits 2) Relay equivalent of NO/NC contacts are used in all ladder diagrams.	**4**

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(b) What is solenoid valve ? Explain its working with the help of diagram. (2 diagram + 2 expln) Solenoid valve is an electromagnetic valve used to control flow of fluid such as air or oil. It consists of a solenoid assembly and valve assembly. When current passes through solenoid, the plunger is lifted upwards and the valve is opened. In normal state, because of return spring force, the valve remains closed. Solenoid valves are used in hydraulic and pneumatic circuits to regulate air/oil flow. 	**4**
(c) List any our applications of servomotor. (2 marks diagram + 2 expln) Servo motors are used in position control mechanisms. 1) CNC machines. 2) Robotic hands. 3) Conveyers which require precise control 4) Fluid dispensing machines 5) Precision instruments such as camera, printers	**4**

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(d) **Draw the block diagram of PLC power supply and explain the function of each block** (2 marks diagram + 2 expln)	**4**
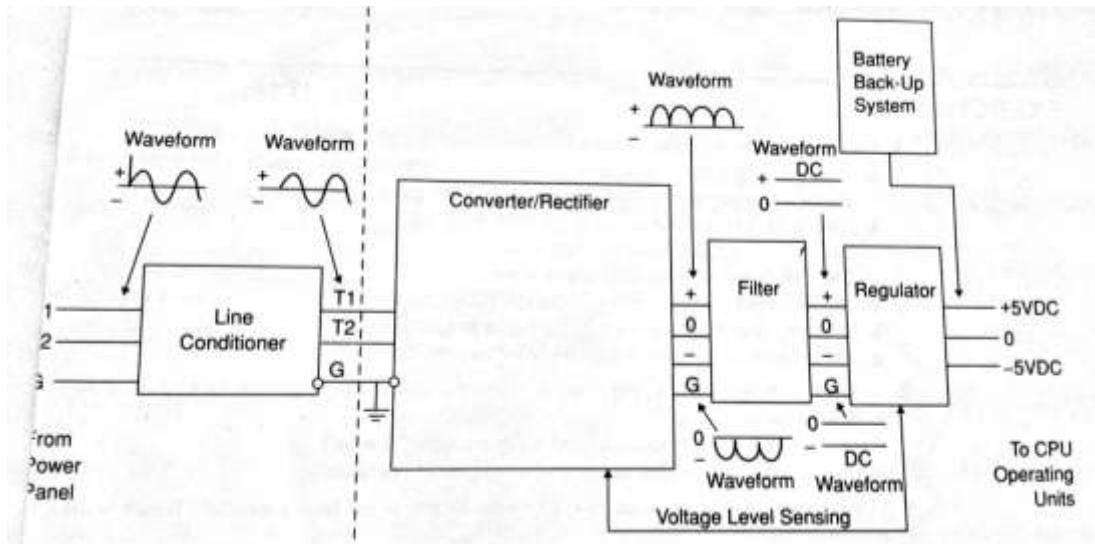
Parts of PLC Power supply are:

1) Line conditioner: Line conditioner unit filters the input AC voltage and removes any glitches, noise, EMI

2) Converter: Converter unit converts AC into DC This is basically a switched mode power supply.

3) Regulator: regulator unit generates the required voltage levels for the PLC internal circuit

4) Battery Backup: for reliable operation of PLC, there is a battery backup. In the event of power failure from AC input, Battery backup becomes active and prevents accidental shut down of PLC

(e) List any our input and output of PLC. (2 inputs + 2 outputs)	**4**

Typical PLC inputs

1) Push Button
2) Selector Switch
3) Proximity switch
4) FOOT switch, level switch
5) Analog input

Typical PLC outputs

1) Contactor Coil, solenoid, relay
2) Indicating Lamp
3) Buzzer
4) Alaram annunciator

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(f) Explain the offset in proportional controller. (2 marks equation + 2 expln)	**4**

Offset is a sustained error that cannot be eliminated by proportional control alone

The basic equation of proportional control is as follows:

$$CO(t) = K_p e(t) + CO(0)$$

Where U(t) is the controller output, U(0) is the zero error controller output.
when PV equals SP, then error is zero: e(t) = 0
if e(t) is zero, then CO equals the CO(0)
if CO is steady at CO(0), then the PV settles to some steady value.
The steady value is known by performing experiment on the system. And value CO(0) is adjusted so that PV settles in the range of set point.

If a process disturbance occurs, CO(0) value will not change and it will cause permanent change in error and this is offset error.

(g) Why derivate action is not used alone ? (2 marks equation + 2 expln)

The basic equation of derivative action is

$$CO_d(t) = K_d \frac{de}{dt}$$

The above equation clearly indicate that derivative mode is active when there is change is error along with time. There is no one-to-one relationship between error and controller output. Using derivative controller alone will not produce any output for constant error and thus will not produce any control action.
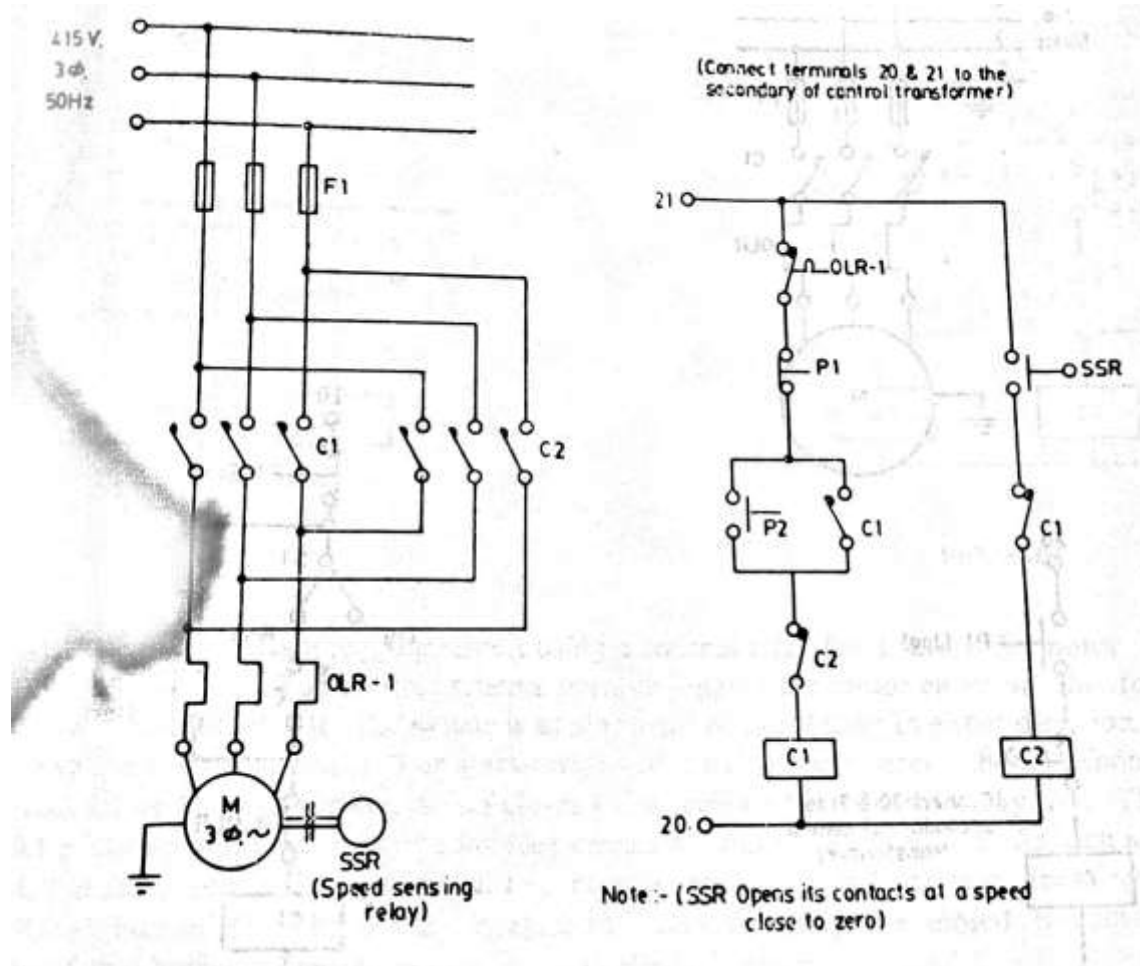
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Q2. Attempt any TWO :	**16**
(a) Draw control and power circuit for plugging of 3-phase induction motor and describe its working. (4 marks control + 4 power circuit)	**8**

(Connect terminals 20 & 21 to the secondary of control transformer)

Note :- (SSR Opens its contacts at a speed close to zero)

The Induction motor can be stopped immediately by just interchanging any two of the stator leads. When an induction motor is rotating at a high speed, during emergency if situation arises that the motor has to be stopped immediately, can be done by interchanging any 2 leads of the stator supply. By doing this, it reverses the direction of the revolving flux, which produces a torque in the reverse direction, thus causing a breaking effect on the rotor.

The control and power circuit are shown in the above diagram. When C2 contactor is ON two supply leads of motor are interchanged causing plugging.

(b) Draw a neat labelled block diagram of PLC. Explain the function of each block. (4 marks diagram + 4 expln)
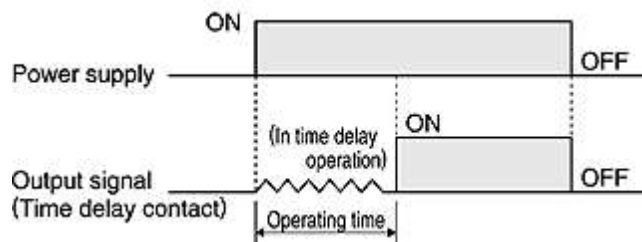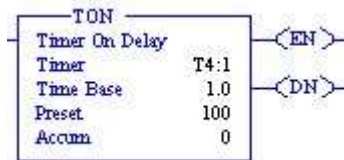
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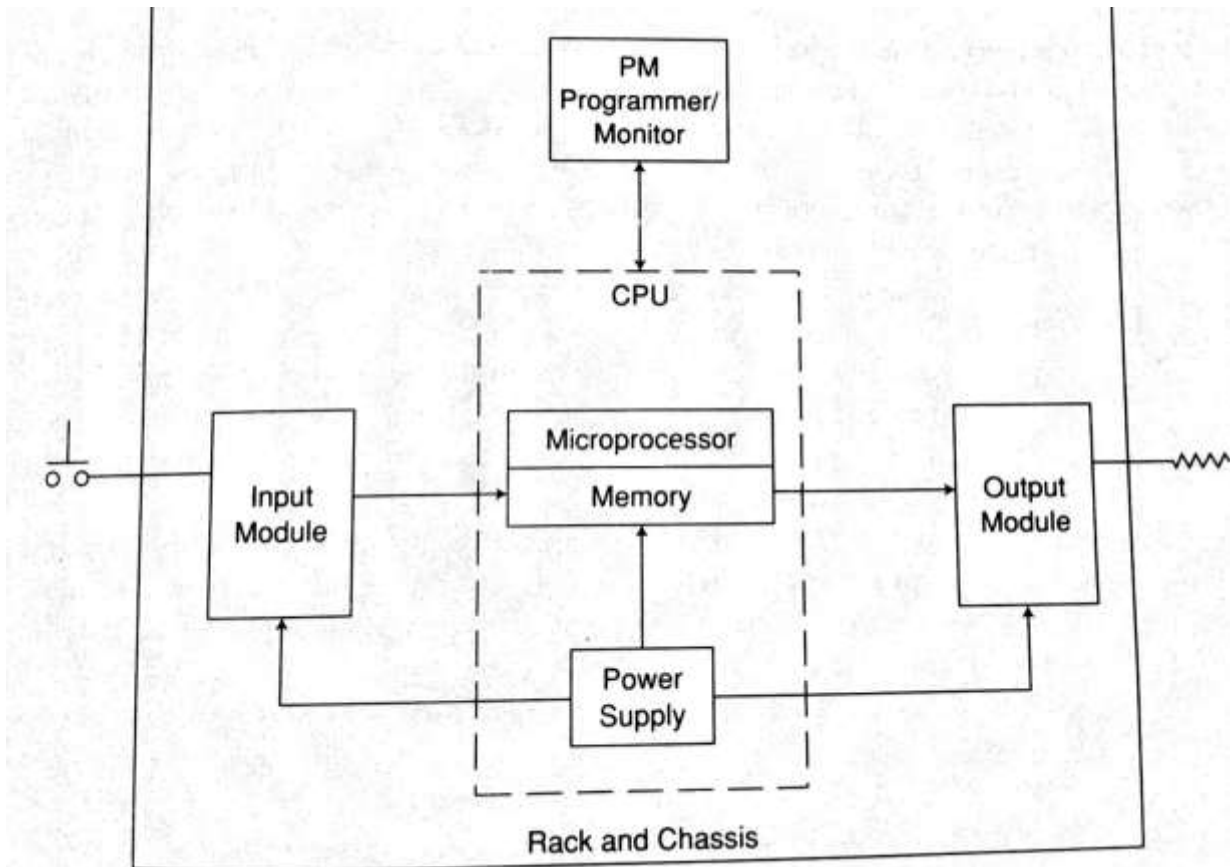
The main parts of a PLC are,

1) Central Processing Unit consisting of a microprocessor, and memory unit. A microprocessor is essentially a logic solver. Memory unit is used to store operating system of PLC, user program and temporary data.

2) Power supply: A switched mode power supply is used which generates the required dc levels to power the internal circuit

3) Programmer/ Monitor: Programmer/monitor is device used to load program into PLC from a hand held terminal or a PC

4) I/O modules: The IO modules are for connecting outside world digital/analog input output devices to PLC.
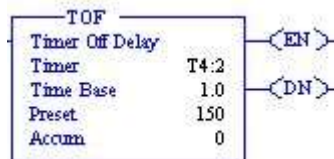
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(c) Explain the ON delay timer & OFF delay timer of PLC. (2+2 marks ON delay timer, 2+ 2 for OFF delay timer)	**8**

ON delay timer

```
    ──TON──────────
   │Timer On Delay      ─⟨EN⟩─
 ──┤Timer        T4:1
   │Time Base     1.0    ─⟨DN⟩─
   │Preset        100
   │Accum           0
```


The on-delay operation is an operation to give output when preset time expires after a predetermined input is given to the power supply circuit or input circuit.

OFF delay timer

```
    ──TOF──────────
   │Timer Off Delay     ─⟨EN⟩─
 ──┤Timer        T4:2
   │Time Base     1.0    ─⟨DN⟩─
   │Preset        150
   │Accum           0
```

The off-delay operation is an operation to turn OFF output when preset time expires after a predetermined input is given to the power supply circuit or input circuit, and at the same time output signal is given and predetermined input is turned OFF.

Example of power supply off-delay operation
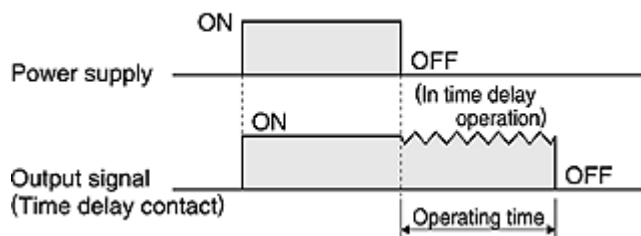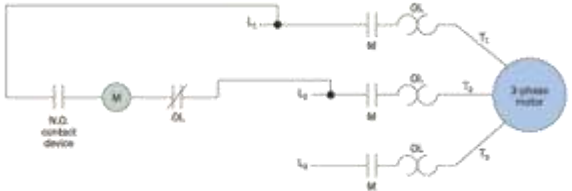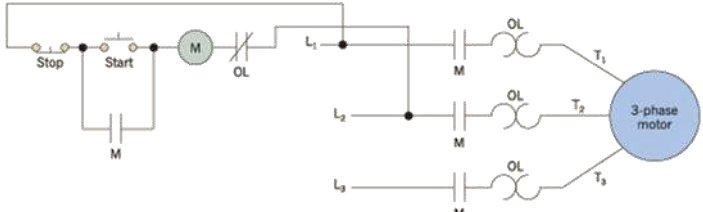
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|	16
Q3. Attempt any FOUR	
(a) Differentiate between two and three wire control (1 mark each)	**4**

Two wire control:	Three wire control
It provides low voltage release	It provides low voltage protection
IT will automatically start when power resumes	It will start when only start push button is pressed
It does not have sealing contact	It has sealing contact
It is not safe for operator	It is safe for operator
It is used for submersible pump motors which are located at remote locations	Its is used for industrial control panels where safety is important

4

(b) Draw and explain construction of AC Servo motor (2 marks diagram + 2 expln)

AC servo motors are is wound with two windings at 900 with respect to each other. One winding is called as reference winding(fixed voltage) and the other as control wdg (variable voltage). 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.
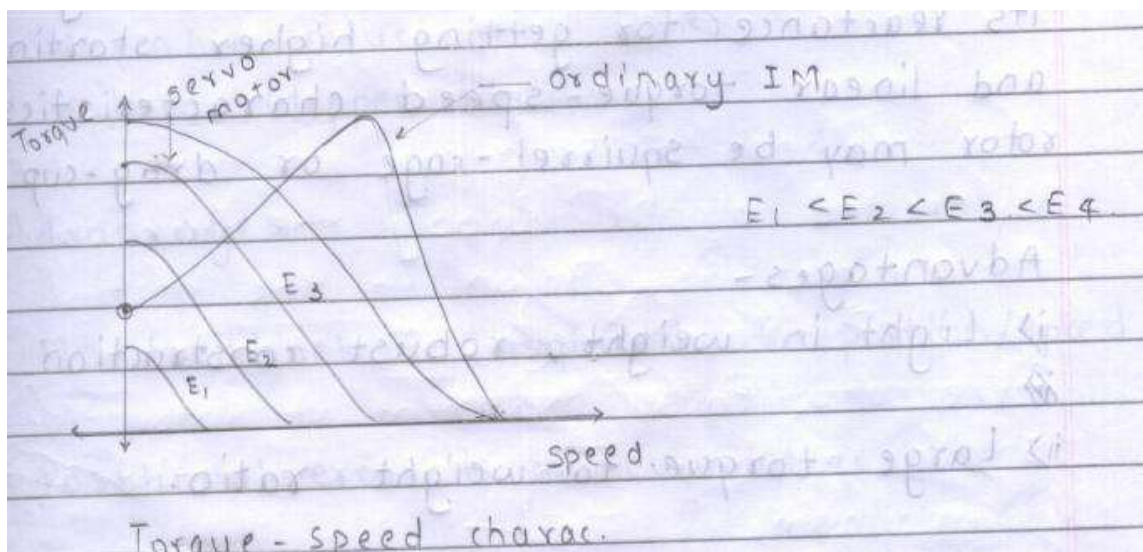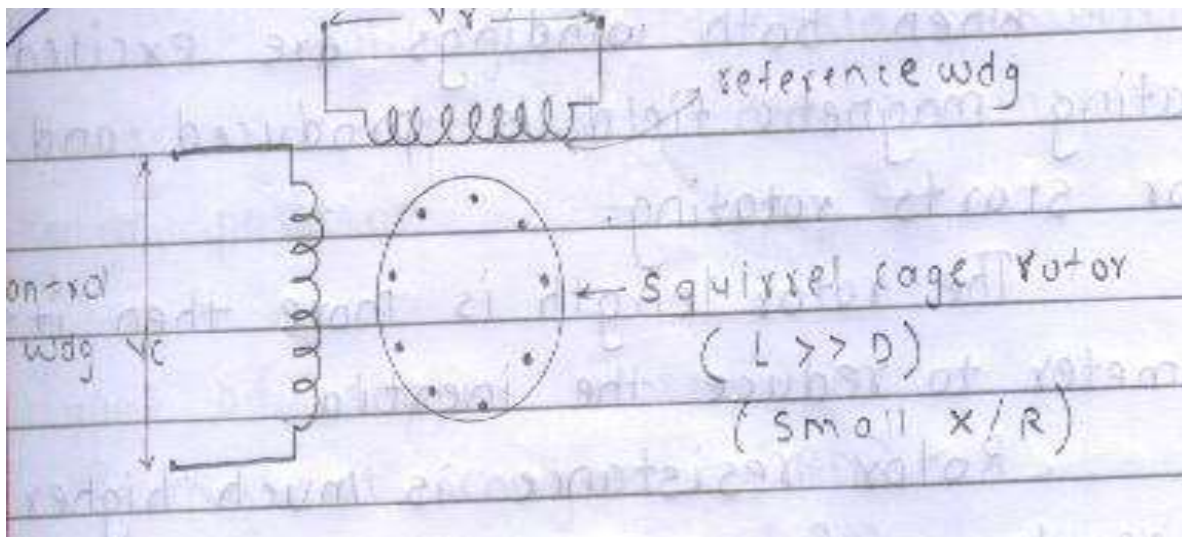
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|	
(c) What is proximity sensor ? State its four applications. (2 marks expln + 2 applications) Proximity sensors are input devices that detect presence of an object without physical contact. Inductive and capacitive proximity sensors are popularly used in industrial applications. Applications: 1) Gear teeth sensing 2) Sensing presence of object on conveyer e.g. bottle filling plant 3) Sensing position of a piston in pneumatic cyclinder 4) Sensing level of fluid in a bottle 5) Sensing moving object inside a pipe 6) RPM measurement	**4**

(d) Explain the function of ROM & RAM memory of PLC. (2 marks + 2 marks)
 	
    Read Only Memory (ROM) is used by PLC for storing operating system. The operating system is programmed by the manufacturer.
 	
    Random access memory (RAM) is a Read Write memory and used by PLC to store temporary data like status of I/O pins, temporary results of calculations, timer counter values etc.
	4

(e) Draw Ladder diagram to verify EXOR, NOT gate (2 marks + 2 marks) EXOR gate NOT gate	**4**
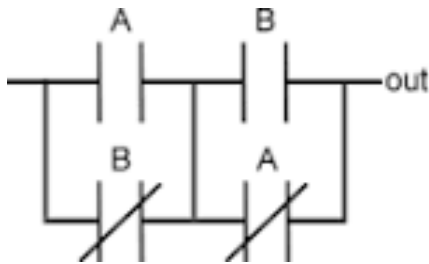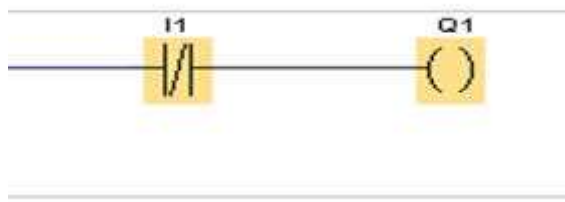
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(f) Draw and Explain working of PI controller (2 marks explntn + 2 characteristics)

The controller output for P+I controller is given by equation,

$$CO = K_p e(t) + K_I \int e(t) + CO(0)$$

P+I controller combines proportional and integral action. Proportional control provides one-to-one relationship between error and controller output. The output of integral controller is dependent on accumulation of error over a period of time. The integral term removes any offset error produced by proportional action. The P+I response in shown in following figure
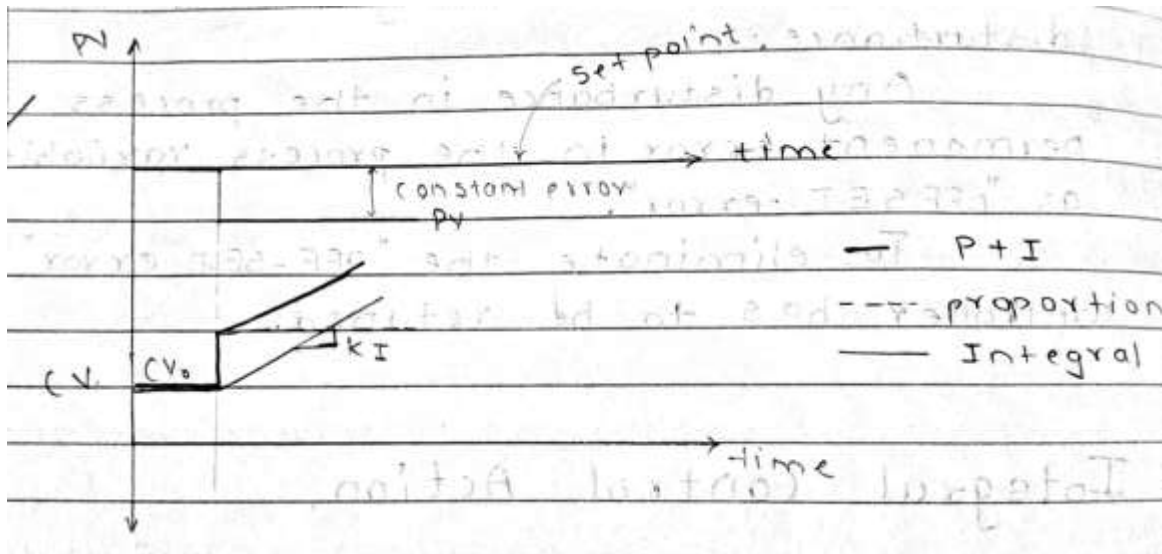
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Q4. Attempt any FOUR		**16**
(a) Differentiate between control wiring and power wiring (1 each four points).		**4**

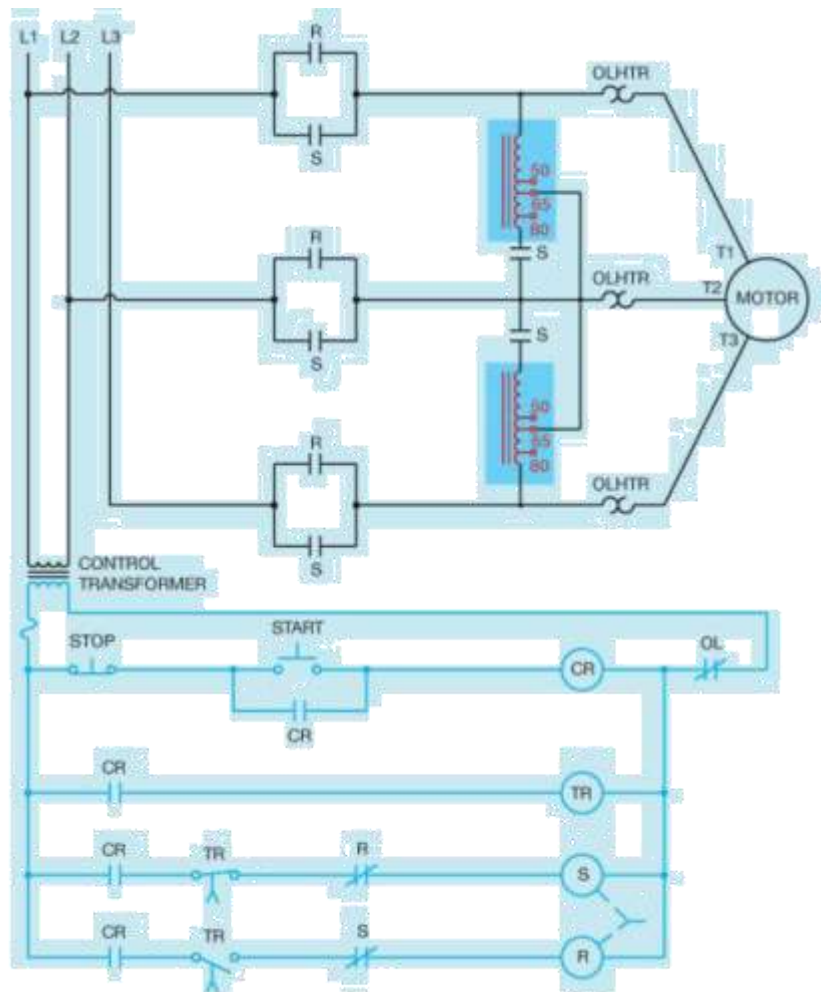| **Control Wiring**	**Power Wiring**
Used for connecting control circuit which consists of input devices such as push buttons, selector switches, proximity switches, indicating lamps etc.	Used for connecting load to main power supply through appropriate switchgear. and protecting devices such as overload relay contacts.
Control wiring is connected at the secondary of a control transformer	Power wiring is connected between main supply and load
It's a low voltage (e.g. 110VAC)	It is at main supply voltage level (e.g. 440V)
A conductor with small current capacity can be used for connecting control circuit as control circuit does not consume higher current	Conductor selections for power wiring is based on rating of load and overload capacity.

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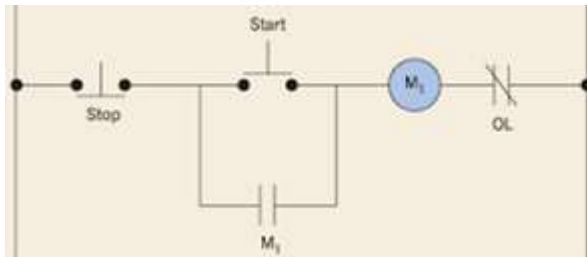|	
(b) Draw the power and control circuit for 3 phase induction motor using auto transformer type starter. (2 control circuit+ 2 power circuit)	**4**
(c) What is opto-ioslator ? Explain role of opto isolator in PLC (2 marks diagram + 2 expln) AN opto isolator is a device which consists of a light producing device such as LED and a light sensing element such as photo transistor. When a voltage is applied to LED, a light is produced which strikes the photo detector. The photo detector then changes its output. Optoisolator provides electrical isolation between input and output side. Opto isolator is an important part of IO module of PLC. Both input and output module have Optoisolator to achieve electrical isolation between outside electrical circuit and PLC circuit. 	**4**
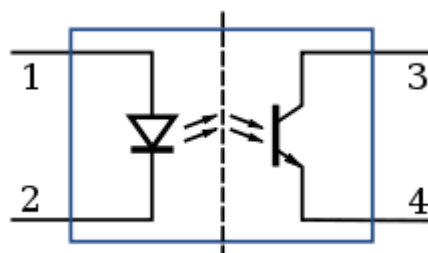
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(d) Develop ladder diagram for DOL starter (4 marks diagram**)** 	**4**
(e) Draw and explain analog input module of PLC (2 marks diagram + 2 expln) Analog input module are used for supplying analog input signal to PLC. Analog signals are generated by transducers, potentiometers. PLCs analog input module consists of analog-to-digital converter (ADC). ADC converts the analog voltage into binary equivalent number and stores it in RAM of PLC. PLC reads the binary number and takes further decision based on the required logic 	**4**
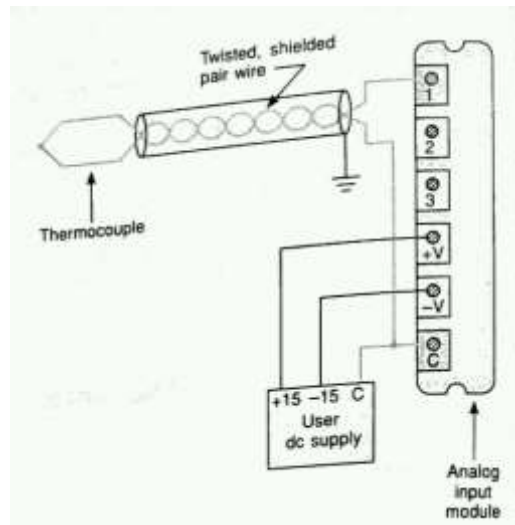
(g) Explain the integral control action. (2 marks explntn + 2 characteristics)

4

The integral controller produce output depending upon integral of error over a period of time. I controller can be expressed by following equation.

$$CO_I(t) = K_I \int e(t)dt \quad \text{where KI is integral gain in sec}^{-1}$$

The integral control output increases linearly when the error is constant and thus when added to proportional mode this can eliminate any offset error. Inegral action is slow responding and improves steady state behavior of control system.
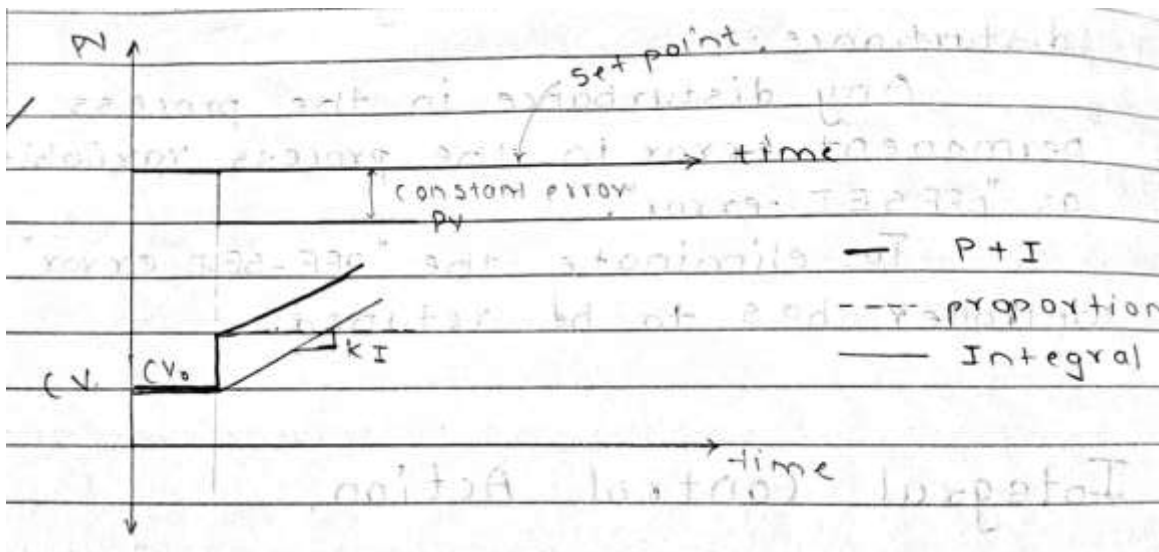
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Q5. Attempt any TWO :	**16**
(a) Draw and explain the control and power diagram for D.C. injection Braking. (3 marks for power circuit + 3 marks for control circuit + 2 expln)	**8**
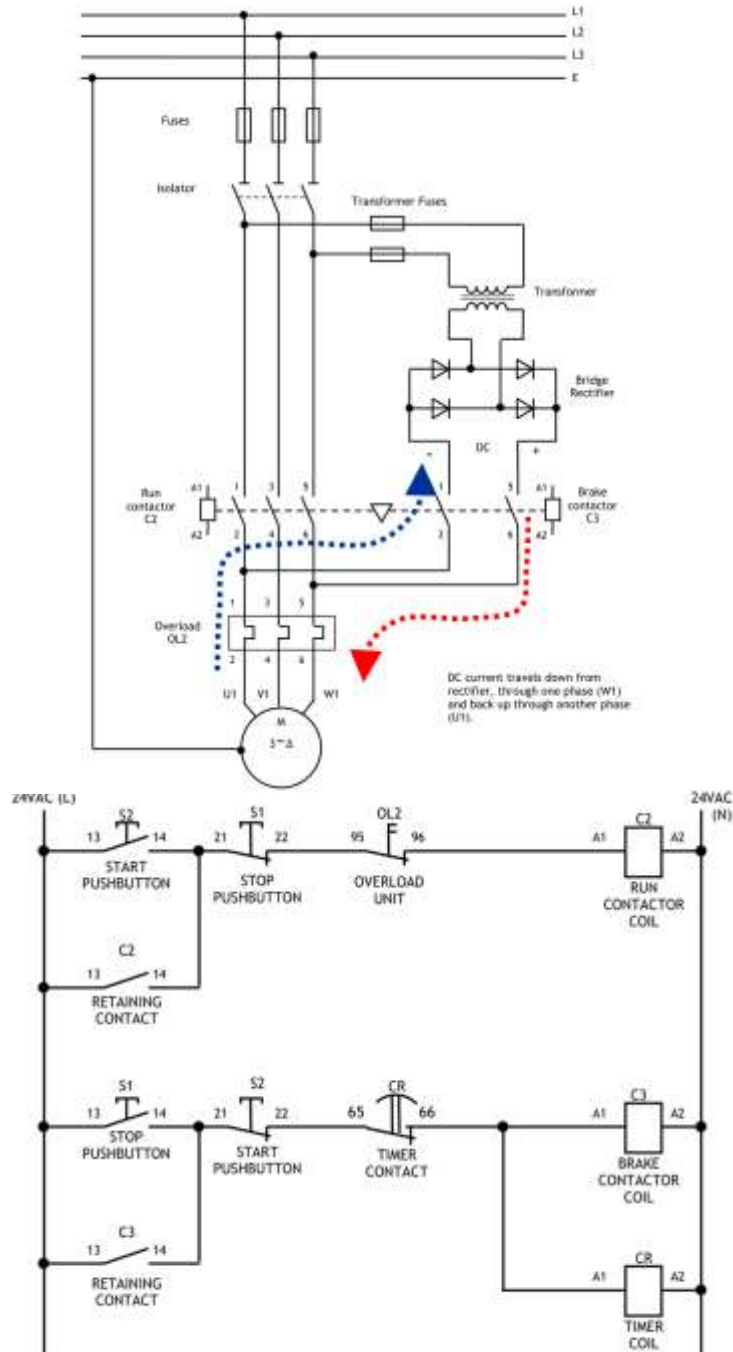
Circuit Operation

1) Starting & Running - Pressing the start button S2 will energise coil C2 provided the stop button S1 is not pressed and the overload OL2 has not tripped. The retaining contact of C2 will keep the contactor energised when the start button S2 is released. The motor then runs up to speed.

2) Stopping & Braking - Pressing the stop button S1 will de-energise contactor C2 and energise contactor C3 provided the start button S2 is not pressed. The retaining contact of C3 will keep the contactor energised when the stop button S1 is released. This causes the motor to stop due to the injection of DC. C3 will remain energised until the timer CR finishes timing. Then its normally closed contact will open de-energising C3 and removing DC from the stator. This in turn de-energises the timer coil.

(b)	**(i)**	**List and explain the types of ROM.** (4 marks + 4 marks, any four advantages)	**4+4**
	(ii)	**List any four advantages of PLC.**	

ROM types
1) PROM
2) EPROM
3) EEPROM

1) PROM: - (Programmable Read Only Memory): In this memory it may be programed once and once only, by the user/programmer. The user than programs the chip to his/her requirements. No erasures are possible. To change program in a programmed PROM, you may throw it away and replace it with a new un-programmed PROM. The PROM is rarely used because it requires special programming circuits .It does however the advantages of being an unalterable backup to a ROM

2) EPROM: (Erasable Programmable Read Only Memory): It is a PROM that can be erased. The EPROM is erased by subjecting a window in its top to ultraviolet light for a few minutes. It is also called as Ultra Violet RAM. When exposed to UV light the chips memory bits are reset to 0 the chips window is covered during normal use to prevent unwanted eraser. When the EPROM is exposed to ultraviolet light all of memory locations are erased. This can be reused.

3) EEPROM: (Electrically Erasable Programmable read only memory): It is similar to EPROM instead of UV light exposer for eraser through an electrical signal is applied to the chip. The EEPROM advantages over the EPROM is the easy and speed with which it is reset & erased. The EEPROM is used in place of RAM when they want to fast eraser without using time for individual reprogramming of each part of the chips memory. EEPROM is the memory of choice for storing, backing up and transferring PLC programs.

(ii) List any four advantages of PLC

1) Flexibility.

2) Implementing changes & correcting errors.

3) Speed of operation.

4) Reliability & maintainability.

5) PLCS are smaller in size & can operate Number of devices at a time.

6) Logic change can be very easily done by just adjusting the ladder logic.

7) Operation of PLC can be displayed on CRT or LCD screen.

8) Error occurred in operation can be very easily observed.

9) PLC can keep records of status of Input & Output signals.

10) PLC can provide security for ladder programming.

11) Speed of PLC is in milliseconds.

|	
(c) List and explain the different counters of PLC in detail. (2 marks digram + 4 marks timing diagram+ 2marks explntn)	**8**

A counter in PLC is an instruction equivalent to mechanical counter. A counter block of PLC has two control inputs, Count line and Reset line. When count line makes FALSE-to-TRUE transition, the counter increments/decrements its accumulated value by 1. FALSE-to-TRUE transition on reset line resets the accumulated count to zero. The common format of counter instruction of PLC is shown in following figure.
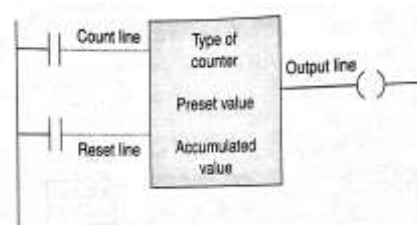
Commonly used counters used in PLC are

1)   UP Counter
2)   DOWN counter
3)   UP-DOWN Counter

The counter operation is shown with the help of timing diagram of an up-down counter which is combination of up and down counter. The up-down counter has three inputs, count up, count down and reset.


FALSE-to-TRUE transitions on count-up, down line
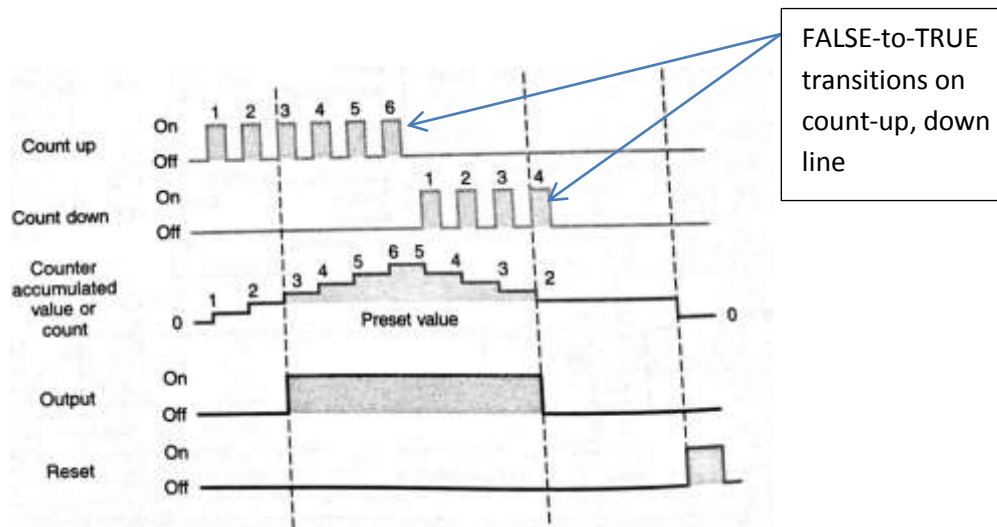
|	
Q6. Attempt any FOUR	**16**
(a) Explain the construction and working of electronic overload relay. (2 marks + 2 marks)	**4**

Electronic overload relay consists of a solid state circuit that operates the electromagnetic switching device to protect the load from overload. The load current is sensed by using a current transducer such as current transformer. The output of current transformer is converted to voltage signal as required by the electronic circuit. The electronic circuit consists of RMS-to-DC conversion, threshold detection, time setting and relay driver sections. The output of relay driver section sends trip signal to electromagnetic switching device.
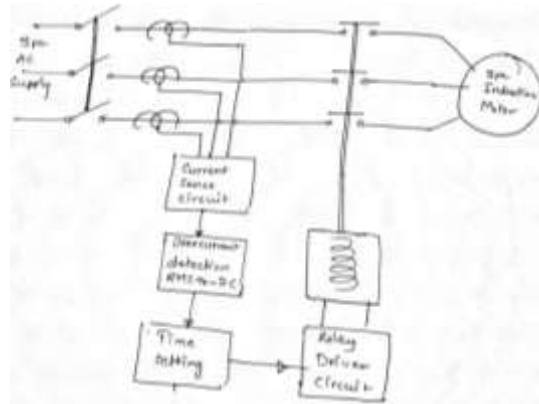
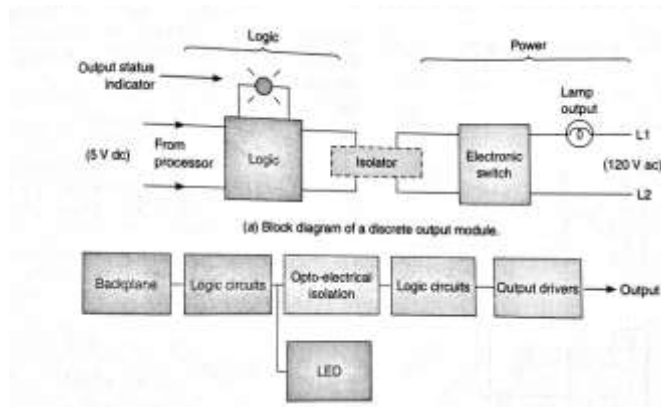|	
(b) Develop power and control diagram to control forward & reverse motion of 3-phase induction motor. (2control circuit + 2 power circuit)	**4**
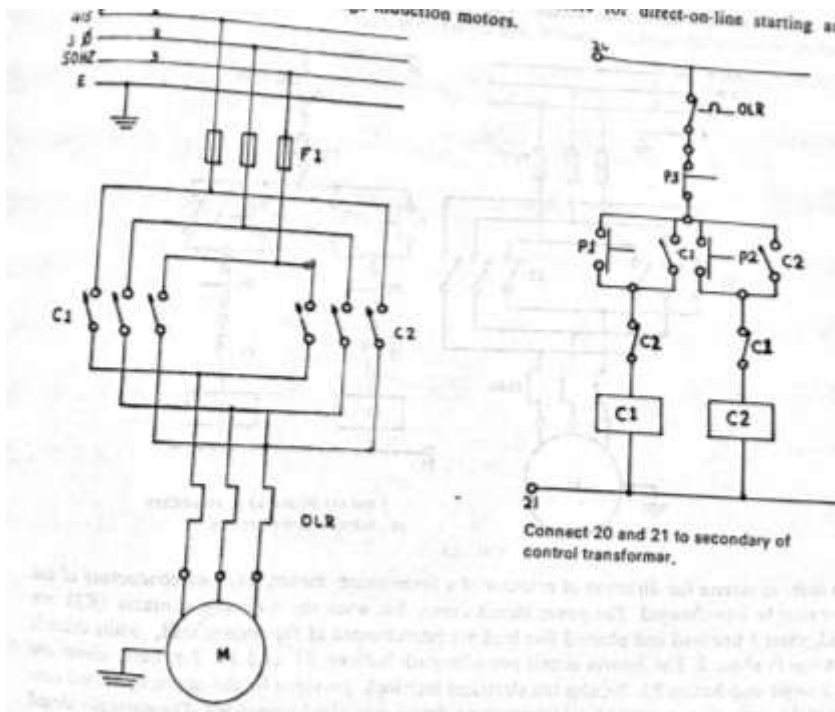
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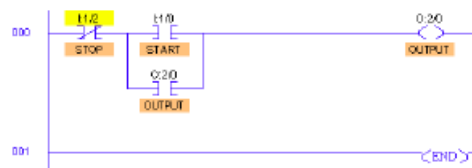|	
(c) Draw digital output-module and give its rating. (2marks for diagram + 2 rating)	**4**

(a) Block diagram of a discrete output module.

Commonly used ratings for Output modules are:

1) 24VDC
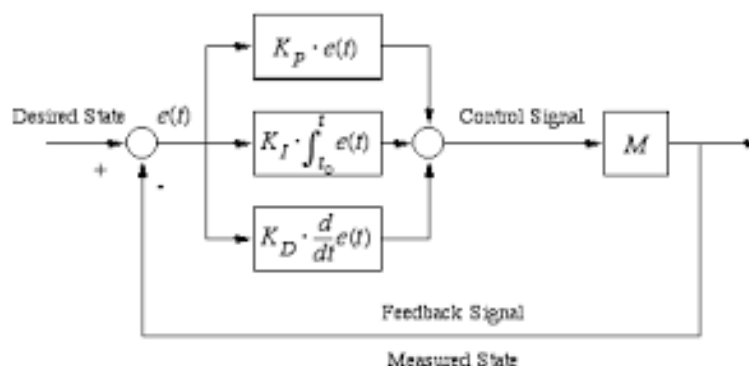2) 120V AC/DC
3) 230V AC/DC
4) 12-48V DC
5) 5V DC (TTL)

(d)Using ladder diagram develop standard stat-stop-seal circuit. (4marks)	**4**

|	
(e) Draw the block diagram of PID controller and explain its working. (2 marks for block diagram + 2 explntn)	**4**

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PID controller output equation is expressed as

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

Proportional controller action produces one-to-one relationship between error and controller output within proportional band. K_P is the proportional gain and proportional band PB = $100/K_p$. Proportional band is the range of error for which controller output is directly proportional to error.

Integral action produces output depending upon time accumulation of error. Integral control action removes any steady state error or offset error in the controlled variable

Derivative action responds to rate of change of error. Derivative action is effective in case of sudden disturbances in the setpoint or process load. The effect of PID action is shown in following diagram.
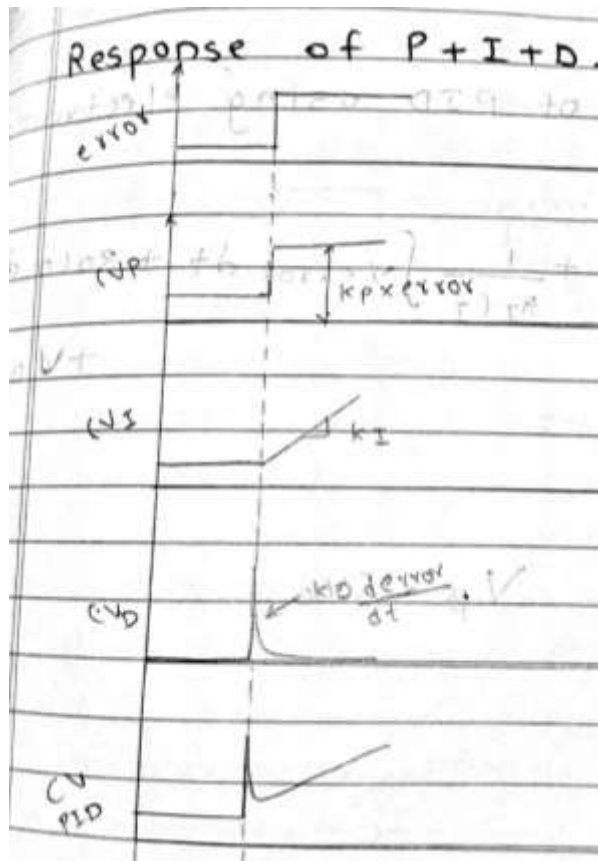
(f) Compare Integral controller with derivative controller. (1 each for any four)

Sr. no.	Integral controller	Derivative controller
1.	Output of integral controller is proportional to integration of error signal	Output of Derivative controller is proportional to time derivative of error signal
2.	For constant error integral output increases with time	For constant error derivative output is zero
3	It improves steady state performance	Improves dynamic performance.
4	Sudden disturbance will not cause any integral action	Sudden disturbance saturates derivative output
5	Noise insensitive	Noise sensitive and may cause unnecessary control action.