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UNIT-I

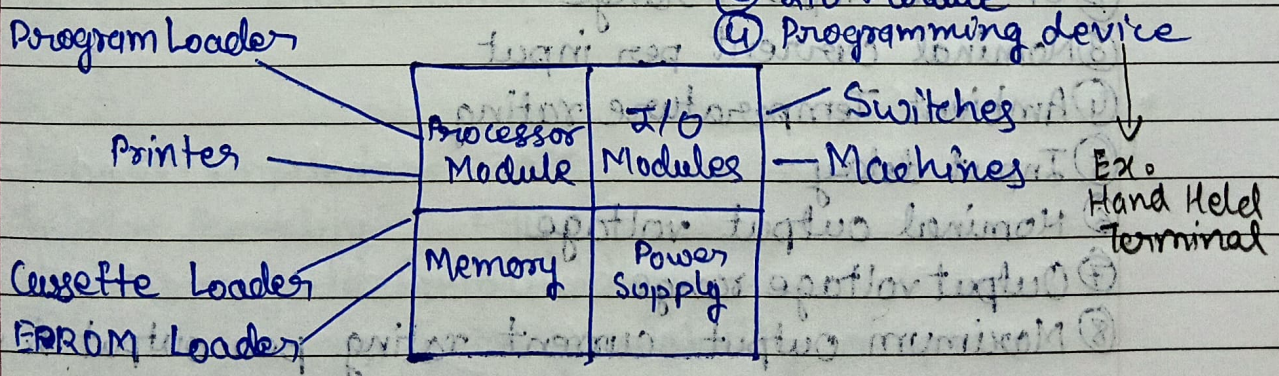
- PLC : Programmable Logic controller
A device which performs discrete or continuous logic in process plant or factory environment. It was developed originally to replace the relay.

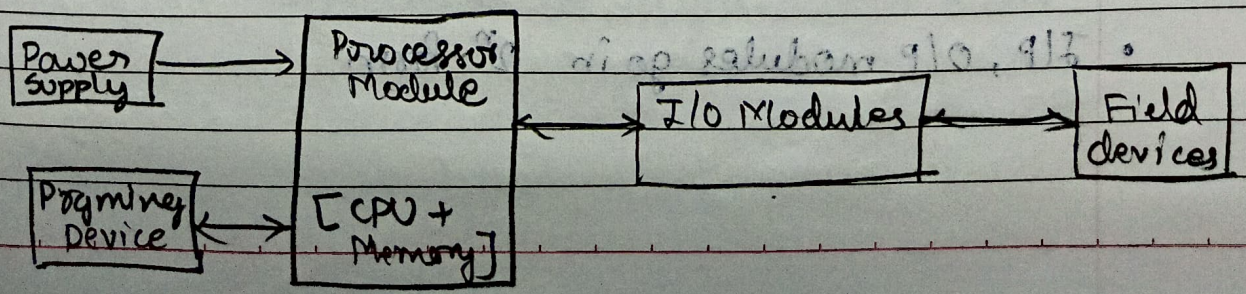
Advantages
- Economy
- Small Physical size
- Suitable modular design
- High reliability
- Ease of Programming
- Rugged construction
- Ability to communicate with computer

These are used in area requiring micro-controller and PC both. Ground signal of sensor and ground signal to PLC are physically seperated.

- PLC Architecture

Basic Components :
1. CPU and Memory Module
2. Power supply
3. I/O Module
4. Programming device





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- PLC Components

① I/O
② Power Supply → 220 120V AC, 24V DC
③ Pheripheral → Handheld programmer, CRT programmer, Operator Console
④ Conveyor belt → Limit switches.

- Specs.

Max. of PLC operates ⇒ 24 Volts DC / 110 Volts AC, 150 Hz
Field Sensors. ⇒ 4 to 20 mA
0 to 5 V

Limitation of PLC is Programming [Ladder diagrams]

PLC → 24V DC or 110 VDC, 50 Hz
Field Sensors → 4 to 20 mA, 0 to 5 V

- I/O Specifications

① Nominal input Voltage.
② On-state input V range
③ Nominal current per input
④ Ambient Temperature rating.
⑤ Input delay
⑥ Nominal output voltage
⑦ Output voltage range
⑧ Maximum output current rating per output & module

- I/P, O/P modules go in 2^n form

Types of Control:-

1. Temporal → control based in time
2. State → control based in state level
3. Hybrid → both temporal and state

- Typical specifications

No. of digital inputs = 120 [Generally 2^n]
— " — outputs = 64
No. of timers = 40
— " — auxiliary relays = 100

Memory, Backup Storage
I/O Modules : 8 channels
Input devices to accept data [limit switches, relay contacts, push button, selector switches],

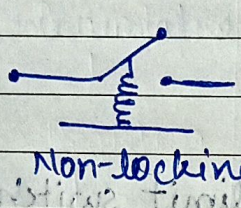
- SCADA : Supervisory Control and Data Acquistion system
  1. Self diagnostic Function
  2. Space available [700 mm X 500 mm]
  3. PLC programming software.

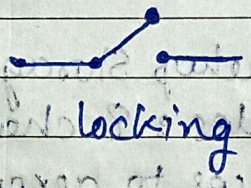
MODBUS, HARBT, CAN Protocols are used for communication in PLC to accept input data
→ Used in Industrial Sectors.
IN protocol are used in automobiles
TCP/IP serial communication.

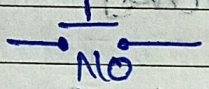
PLC ⇒
Ambient Temperature = 30°C
Relative Humidity = 90
Electro-magnetic Compatibility
Warranty : 2 yrs with availability of spares guaranteed for 10 yrs.

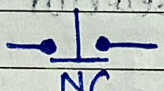
- switches → Has a spring
  push button → only one state; used for emergency start/stop

- switches : Output is Binary [0/1]

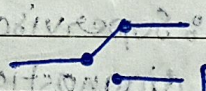








SPDT - Single pole double throw



DPST - Double pole single throw

Types: Basic, push-button, slide, thumbwheel, limit, proximity, photoelectric

Rating: Current and Voltage depends on configuration of switch.

- Input Module

① Input Module sense when a signal is received from a sensor on machine.

② Input Module converts input signal to correct voltage level for particular PLC.

③ Input Module isolates PLC from fluctuations in the input signal's voltage and current.

④ Input Module send a signal to PLC indicating which sensor originated the signal.

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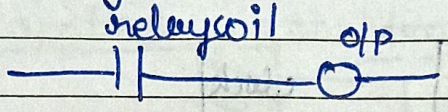
- Relays : switches whose operation is activated by an electromagnet is called a relay.



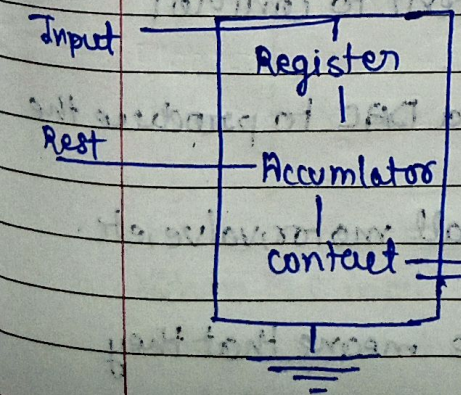
Can be used only for on/off control

PWM → Pulse with modulation
Square wave ~~with~~ of same frequency with variable duty cycle.

- Actuators
  1. Solenoid values
  2. Lights
  3. Motor Starters
  4. Servo Motor

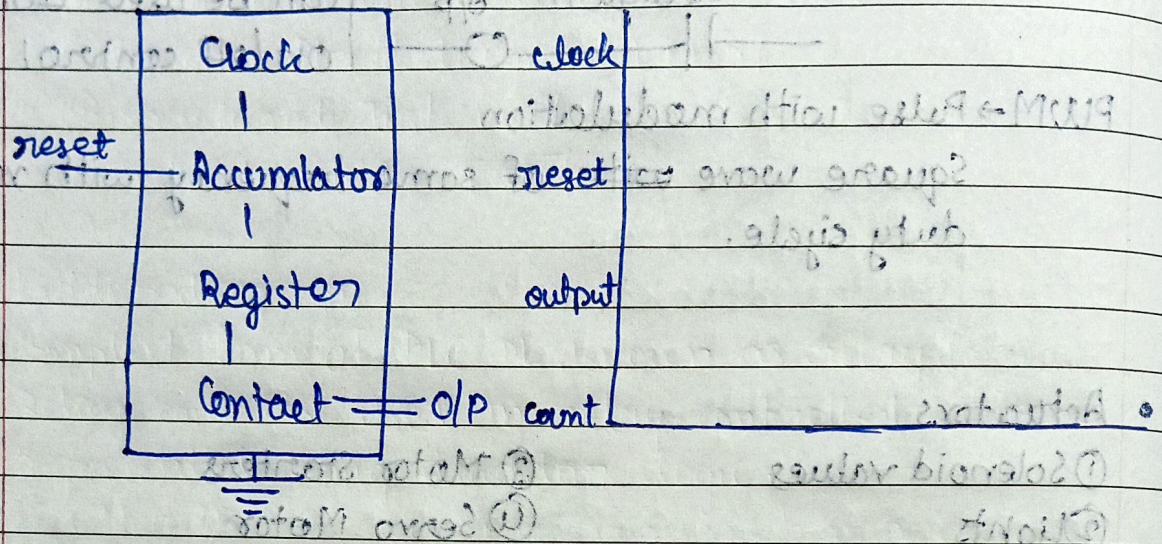
- Output Module
  1. It acts as a switch to supply power from the user power supply to operate the output
  2. Output switching devices mostly often used to switch power to load in PLC.
  3. Relay for AC or DC load.
  4. Triac for AC loads only
  5. Transistors for DC loads only.

- Counter : Digital counter output in form of a relay contact when a preassigned count value is reached.



Input
Reset
Output
Count

- Timer: A timer consists of an internal clock, a count value register and an accumulator.



- Analog Interface.

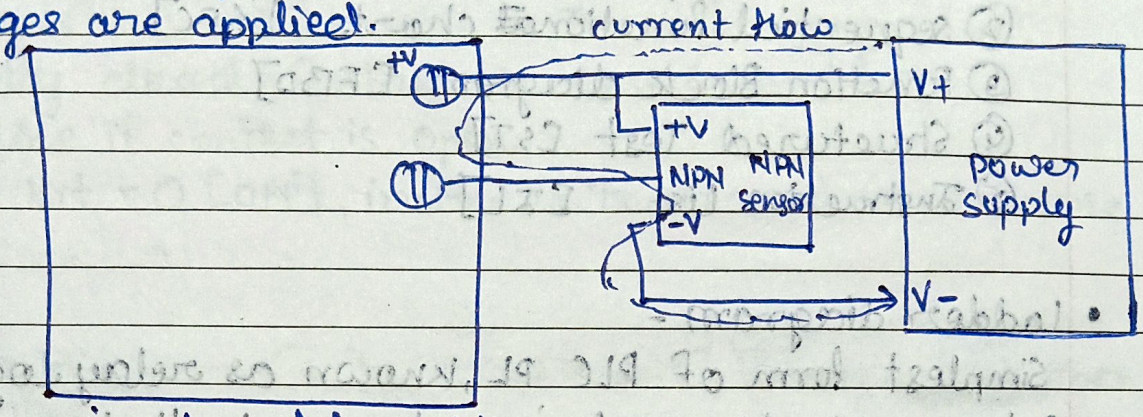
① Analog Input Interface Module:
- It containing circuitry necessary to accept analog voltage and currents from analog field devices.
- These signals are converted into digital value by ADC
- Analog input sensing devices include temperature, light, speed, position transducer, etc.

② Analog Output Interface Module:
- Receives digital data from processor that is converted into proportional voltage or current to control an analog field devices.
- Digital data is passed through a DAC to produce the necessary analog form.
- Analog output devices include small motor, valve, etc.

- Inputs are normally high impedance means that they will use very less current.

(NPN)

- Sinking - When active the output allows current to flow to a common ground. This is best selected when different voltages are applied.



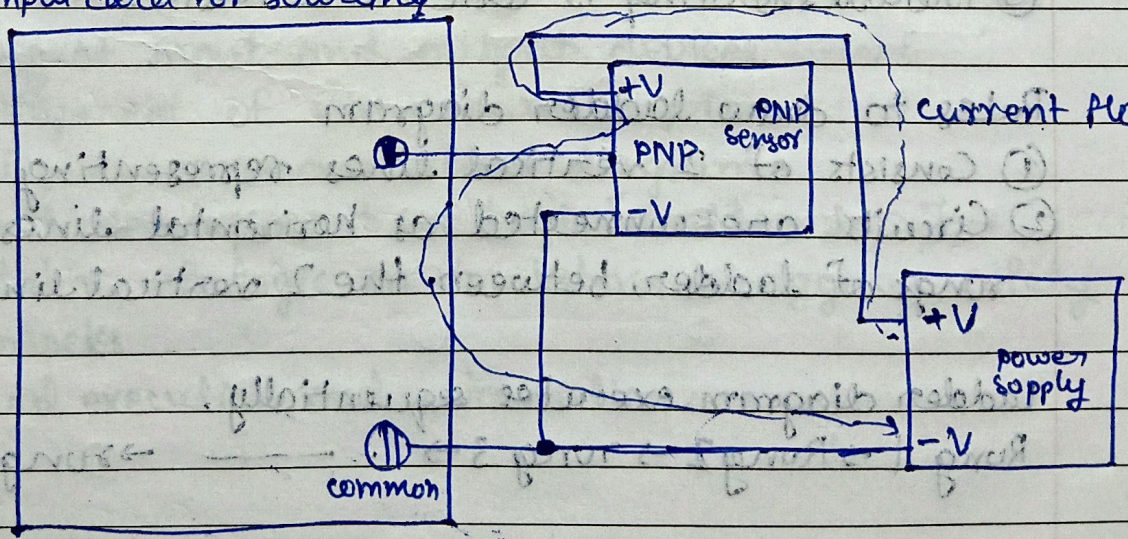
= input card for sinking sensors.

When a PLC input card does not have a common but it has V+ instead, it can be used for NPN sensors. The current will flow out of card and we must switch to ground.

(PNP) → More popular than NPN

- Sourcing - When active, current flows from a supply, through output device and to ground. This method is best when all devices use a single voltage supply.

PLC input card for sourcing



When PLC input card have common then we can use PNP sensors. Current will flow into the card and then ~~through~~ out the common to power supply.

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- PLC Programming : 5 Most Famous are -
  1. ladder diagram [LD]
  2. sequential function charts [SFC]
  3. Function Block diagram [FBD]
  4. Structured Text [ST]
  5. Instruction List [IL]

- ladder diagram -
  Simplest form of PLC PL, known as relay logic.
  Relay contacts used in relay-controlled systems are represented using ladder logic.

  Function Block diagram is simple and graphical method to program multiple functions in PLC.

  Advantages of LD:
  1. Easily programmed, easily understood PL.
  2. Flexibility in programming and reprogramming.
  3. Troubleshooting is easier and faster.

- Rules to draw ladder diagram
  1. Consists of 2 vertical lines representing power rails.
  2. Circuits are connected as horizontal lines, i.e. the rungs of ladder, between the 2 vertical lines.

- Ladder diagram executes sequentially.
  Rung 1 → Rung 2 → rung 3 → ——— → rung n

- LDP - Basically symbolic set of instructions used to create controller.

3 fundamental symbols that are used to translate relay control logic to contact symbolic logic are:

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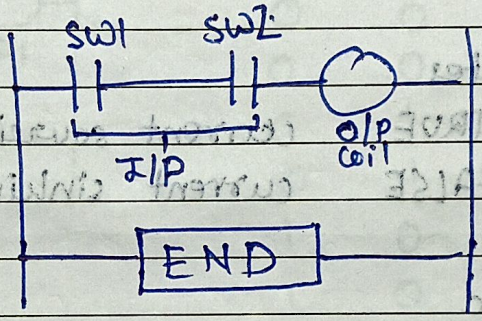
① EXAMINE IF CLOSED
② EXAMINE IF OPEN
③ OUTPUT ENERGIZE

- Normally open: Contact is open ⊣ ⊢ Examine if contact is closed.
  Status bit = 1 [ON], instr. is True. & vice versa.
- Normally closed: Contact is closed ⊣/⊢ Examine if contact is open.
  Status bit = 0 [OFF], instr. is True and vice versa
- Relay Coil —( )— [Output] if rung is TRUE, then ON
- Example



- Seven Steps for development and implementation of logic
  ① Development of Block diagram or P&ID [Piping and instrumentation diagram]
  ② Listing of input and output devices.
  ③ Development of Flow chart of process.
  ④ Developing cause and effect diagram
  ⑤ Actual development of logic [ladder logic]
  ⑥ Validation of logic on simulators; debugging, safety interlocks
  ⑦ Actual execution and optimization.

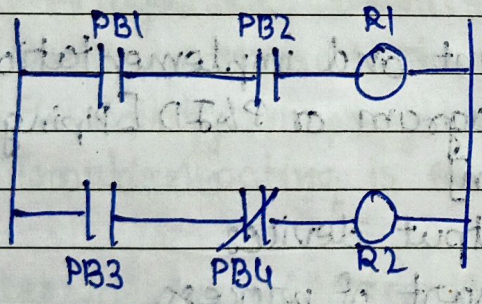
- PLC instructions
  1. Relay
  2. Timer and Counter
  3. Program Control
  4. Arithmetic [Also logical]
  5. Data Manipulation
  6. Data Transfer
  7. Other, such as sequencers.

wave ppty:
① duty cycle
② Frequency

encoder O/P are pulses proportional to speed of motor

- Logic states
  ON - TRUE
  OFF - FALSE
  current sourcing: 1-high, 0-low
  current sinking: 1-low, 0-high

- AND logic



R1 = PB1 AND PB2

R2 = PB3 ∧ ¬PB4

PB1	PB2	R1	PB3	PB4	R2
0	0	0	0	0	0
0	1	0	0	1	0
1	0	0	1	0	1
1	1	1	1	1	0

Switch - NO → 1 , NC → 0

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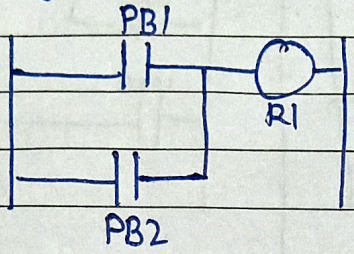
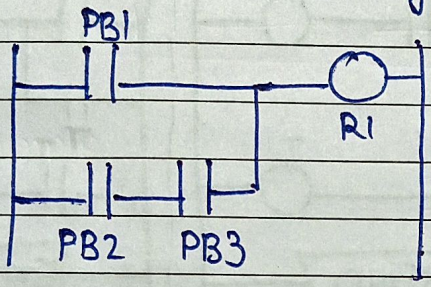
- OR logic



R1 = PB1 V PB2

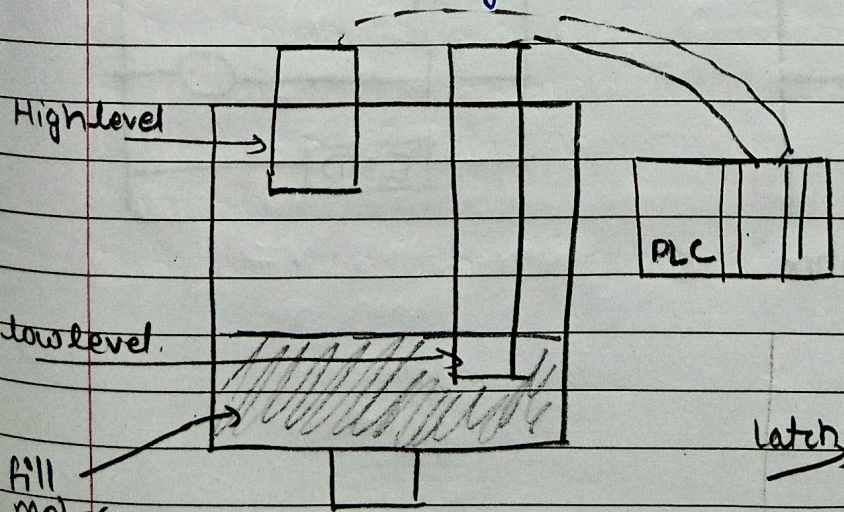
PB1	PB2	R1
0	0	0
0	1	1
1	0	1
1	1	1

- Combined AND & OR logic



PB1	PB2	PB3	R1
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

- Example - Oil is consumed randomly. The task needs to be refilled by turning on a pump. 2 Hydrostatic switches are used to detect a high & low level.

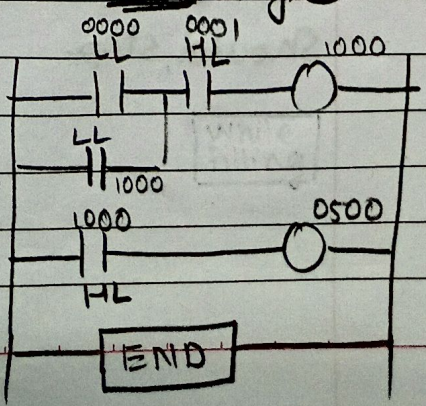


Drain dispensing oil from a tank

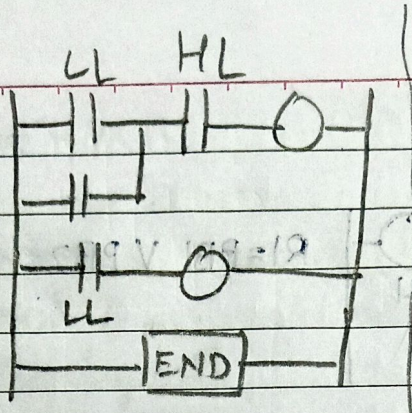
Task → No liquid around sensor, motor to start

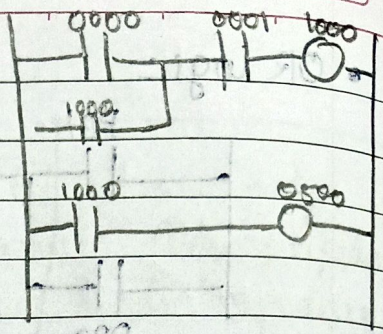
HL	LL	
1	1	→ stop
0	1	→ fill
0	0	→ fill

AND logic

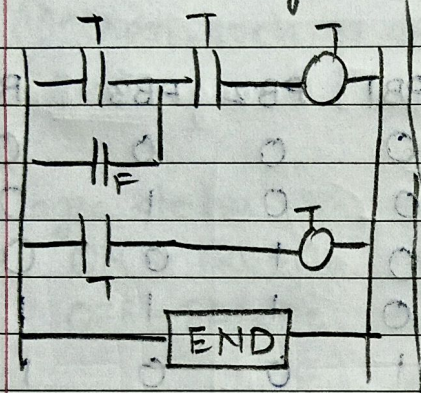


When draining

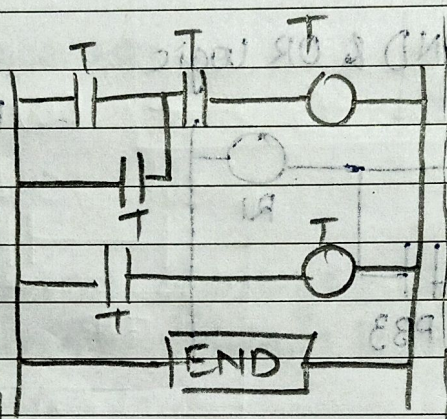




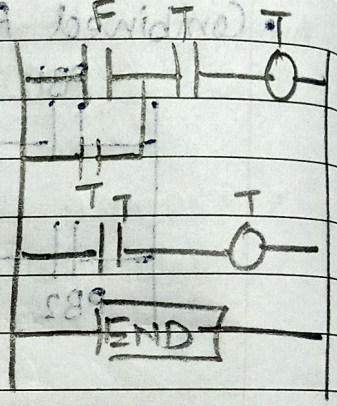
- While Filling

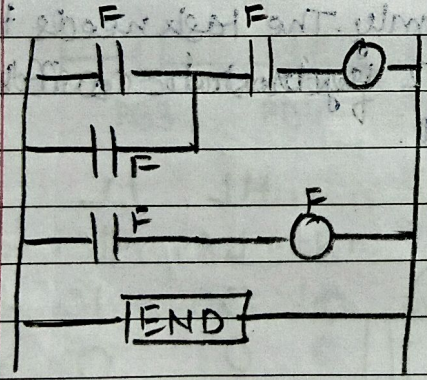


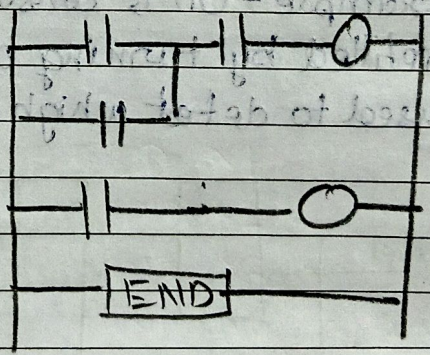
Tank is empty, motor is off.
[LL switch is off]



Tank reaching high level.







Tank is filled motor should stop.

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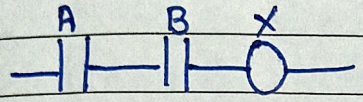
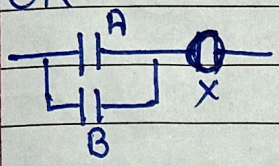
- Logic

① AND



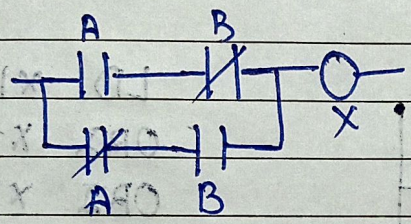

```
LD  A
AND B
OUT X
```

② OR

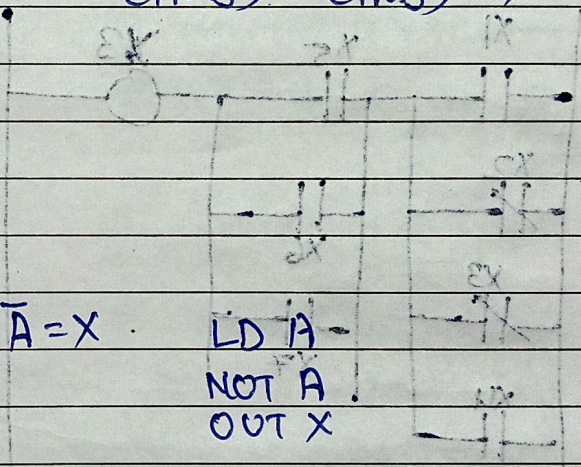



```
LD  A
OR  B
OUT X
```

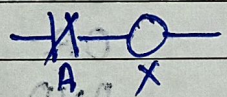
③ XOR



$(A.\bar{B}) + (\bar{A}.B) = X$



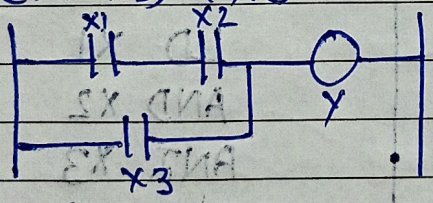
④ NOT



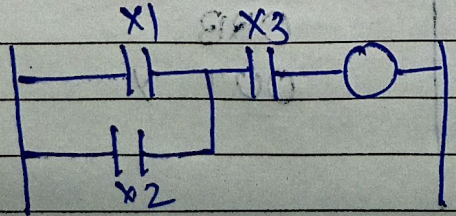
$\bar{A} = X$

```
LD  A
NOT A
OUT X
```

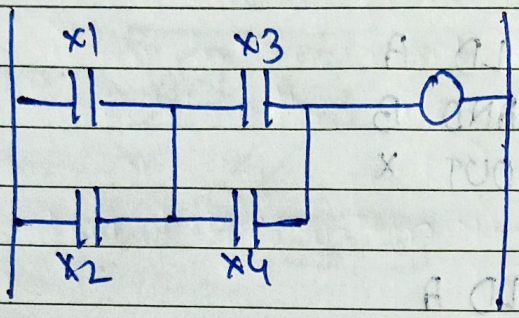
- $Y = (X1 \cdot X2) + X3$



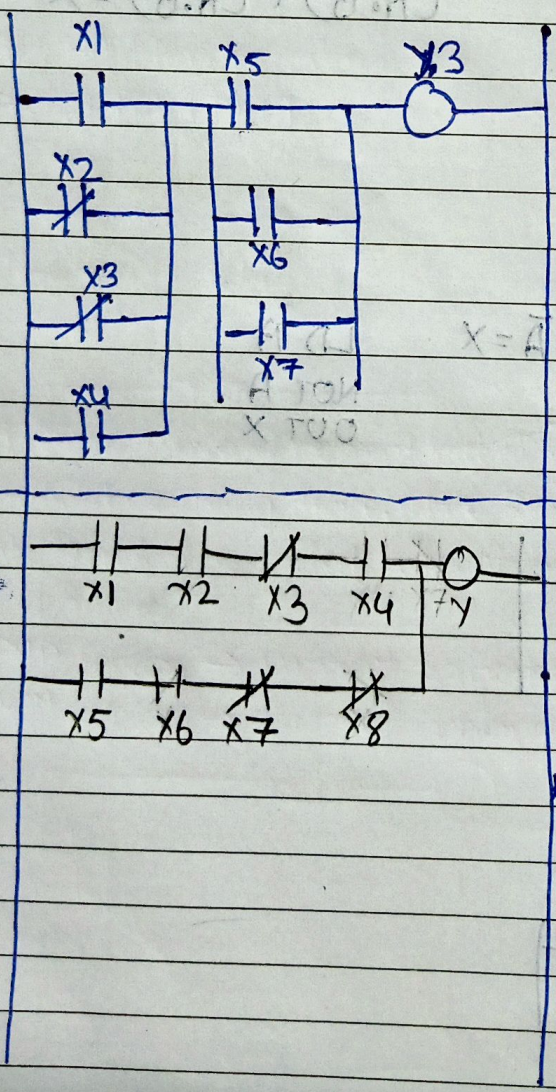
- $Y = (X1 + X2) \cdot X3$



- $Y=(X1+X2)(X3+X4)$




```
LD   X1
ORI  X2
ORI  X3
OR   X4
LDI  X5
OR   X6
OR   X7
AND
OUT  Y2
```

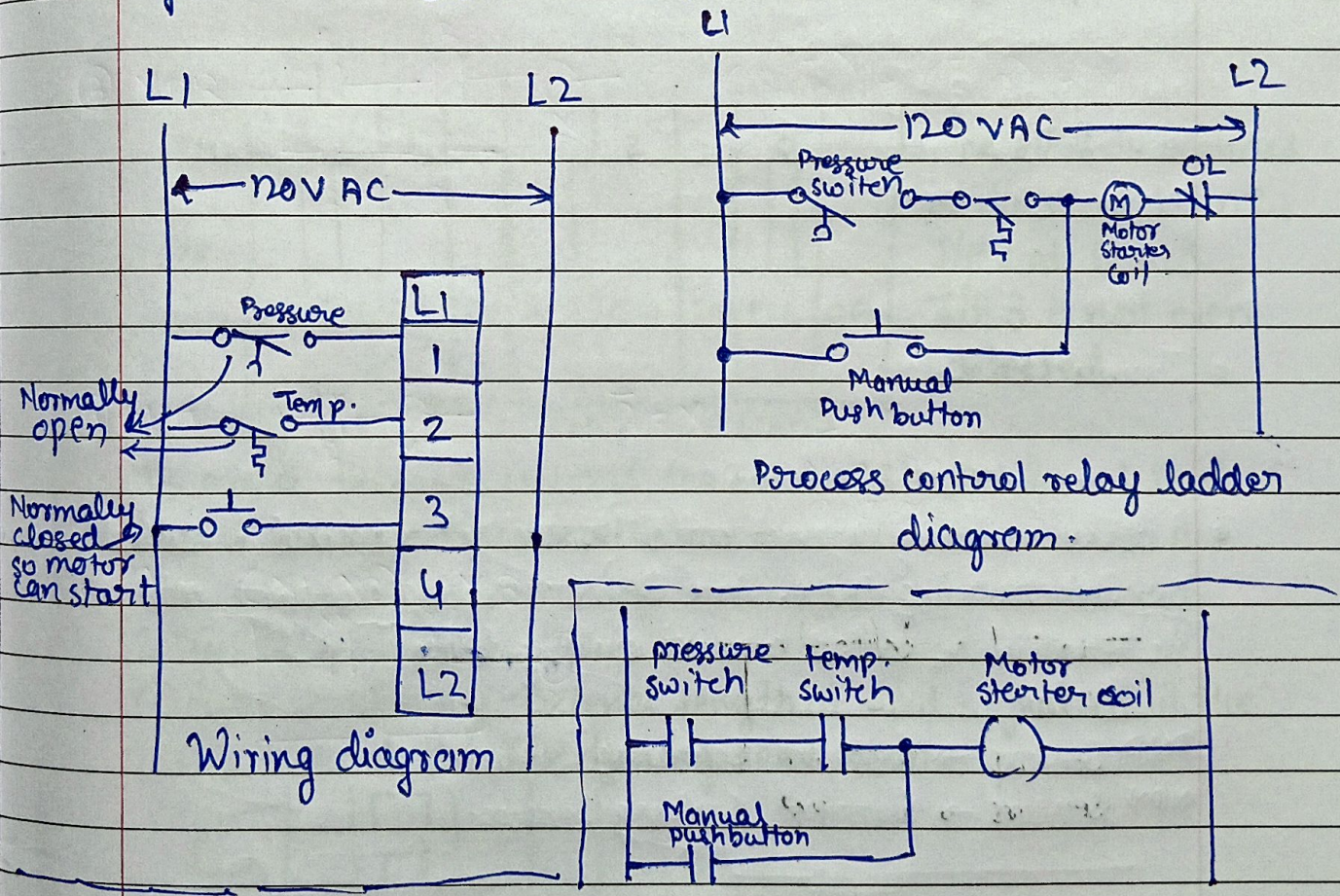



```
LD   X1
AND  X2
ANI  X3
AND  X4
LD   X5
ANI  X6
AND  X7
AND  X8
ORB
OUT  Y
```

- PLC Mixer Process Controller Problem

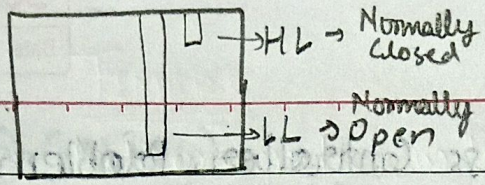
X1: Temperature Sensor
X2: Pressure Sensor
X3: Manual Switch / Push button

Manual Switch ON → Motor ON
Scan I/P from Temp, Pressure sensors:
if both High → stop the motor.
Again manual switch → Motor OFF



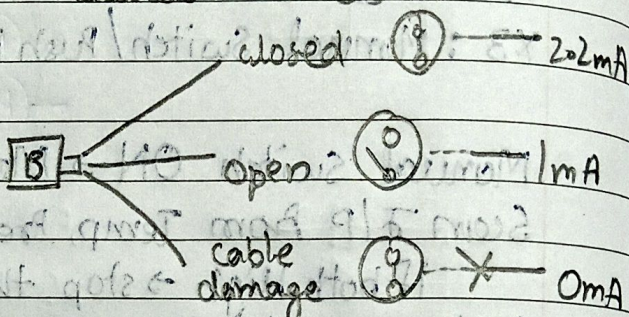
Process control relay ladder diagram.

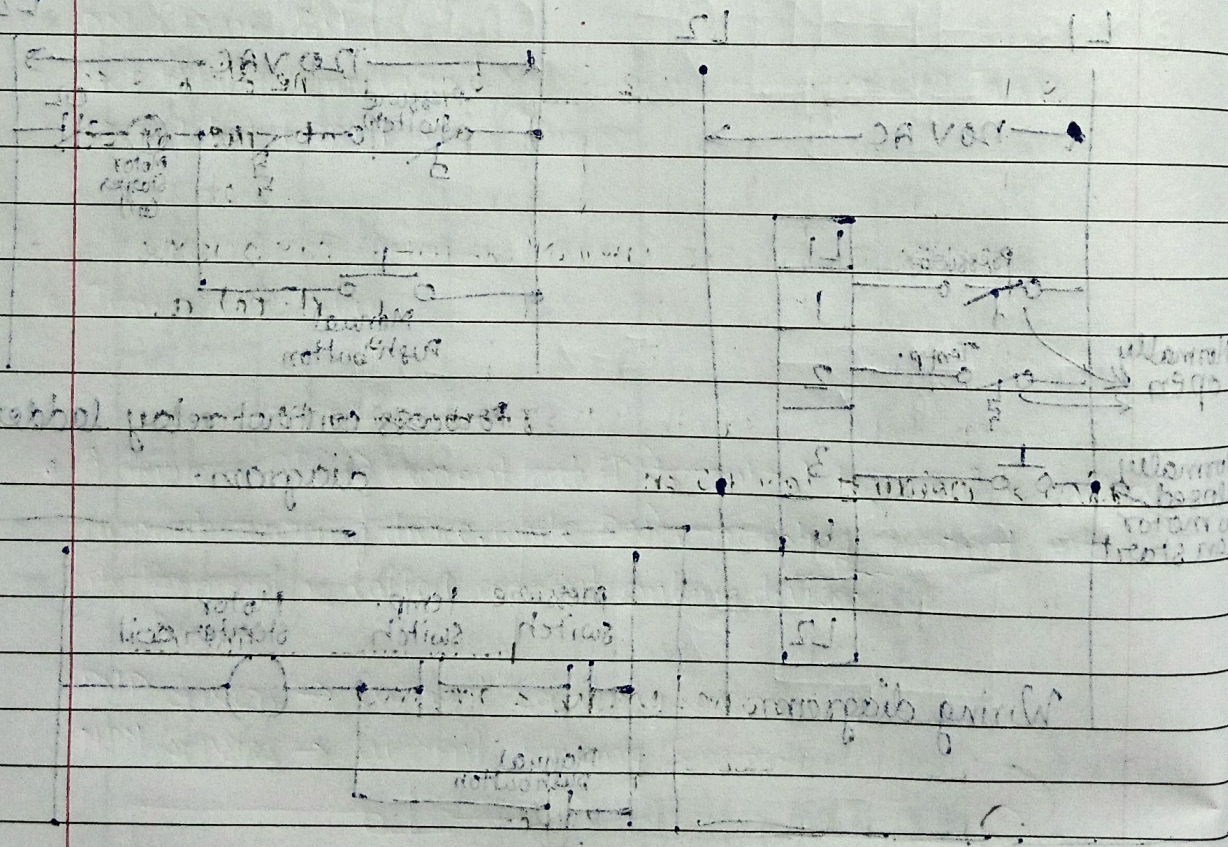
Wiring diagram



STOP → Always Considered NC

NAMUR switches used in Hazardous areas

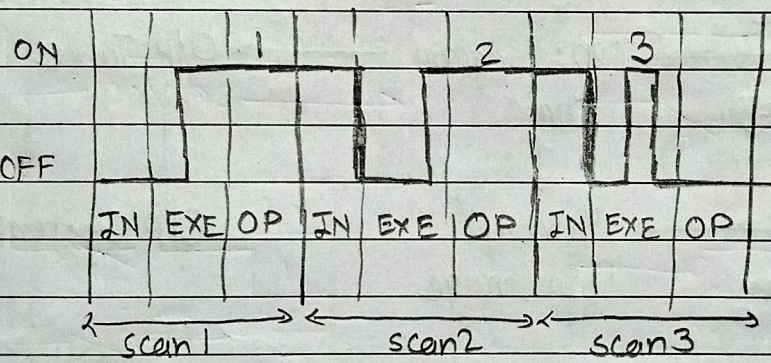




- How does PLC work? [PLC Scan]

PLC works by continuously scanning a program.

① Check input status → I/P response time +
② Execute Program → Pgm. execution time +
③ Update Output Status → Output response time =
Total response time

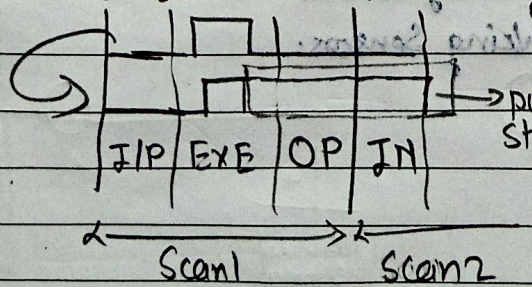


The I/P 1 is scanned at time of Scan2. I/P 2 at Scan3. I/P 3 is not even detected.

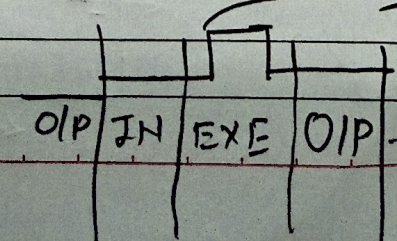
To avoid this we say that the I/P should be ON for at least 1 input delay time + 1 Scan.

In Techniques:-

① Pulse stretching - Extend length of input signal until the PLC looks at the I/P during next scan.



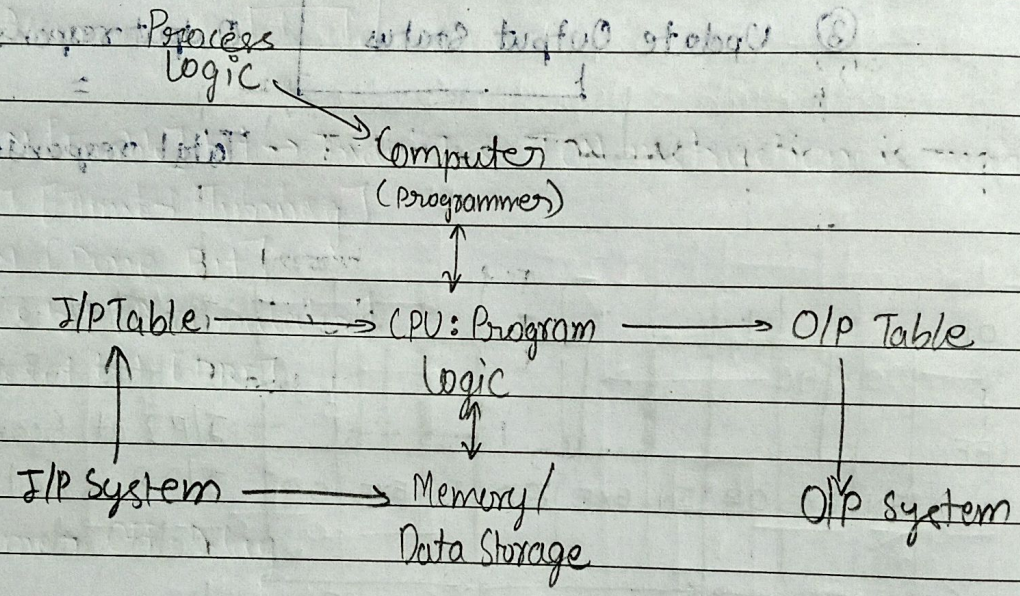
② Interrupt



Interrupt: Control flow transfers to special routine and once I/P is OFF comes back to prev state.

- Relays [as electromagnetic switch]
Uses an electromagnet ; an electric signal to control an electromagnet which in turns connect or disconnects another circuit.

- Operation of PLC System



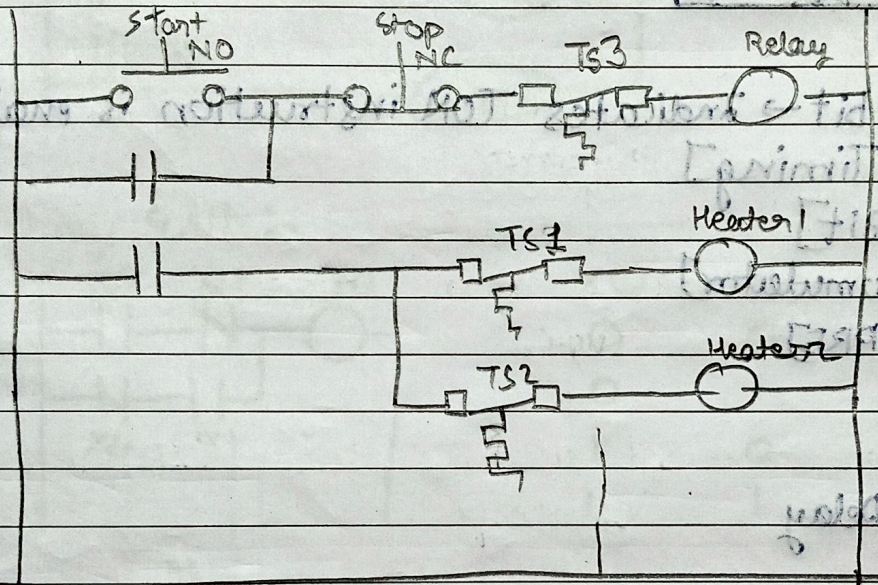
- A device sending current out of its control terminal is called current sourcing device, while device accepting current into its terminal is called current sinking device.

PNP Sensors → Current Sourcing Sensors.
NPN Sensors → Current Sinking Sensors.

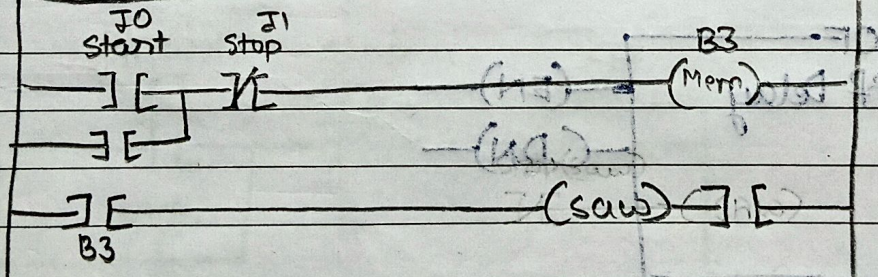
LADDER DIAGRAMS

① To develop a ladder diagram for ON/OFF temperature controller for continuous process of heating of mixture

Temp < 55 → H1, H2, H3 ON
55 ≤ Temp < 60 → H2, H3 ON
60 ≤ Temp < 65 → H3 ON
Temp ≥ 65 → All OFF

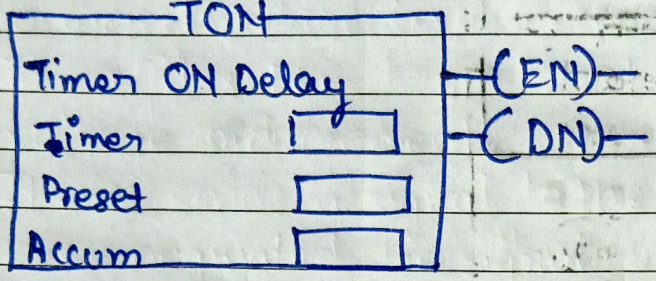


②



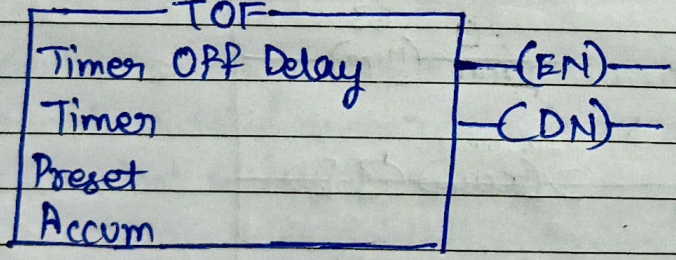
TIMERS

- Timer On-Delay



EN [Enable] bit → Indicates TON instruction is enabled.
TT [Timer Timing]
DN [Done Bit]
ACC bit [Accumulator]
Preset bit [PRE]

- Timer OFF-Delay



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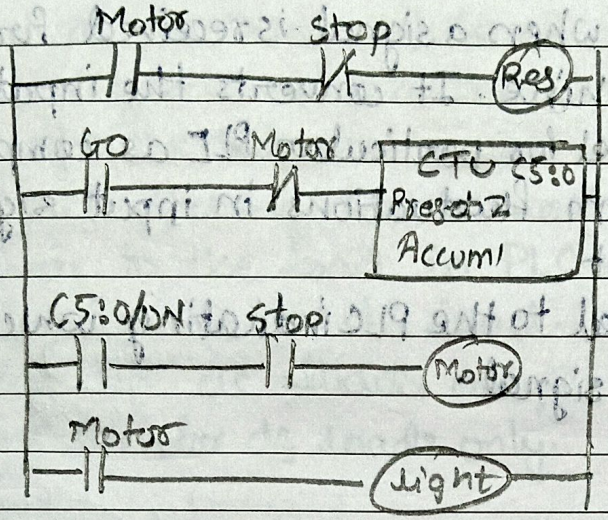
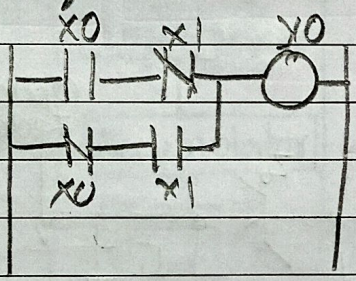
- Deadman Switch

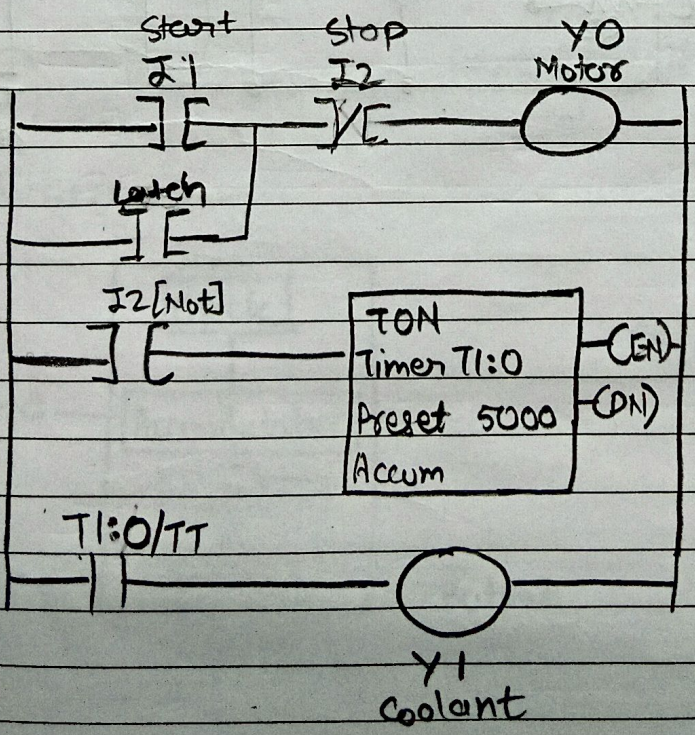


- 2-Way Switch



X0	X1	Y0
0	0	0
0	1	1
1	0	1
1	1	0

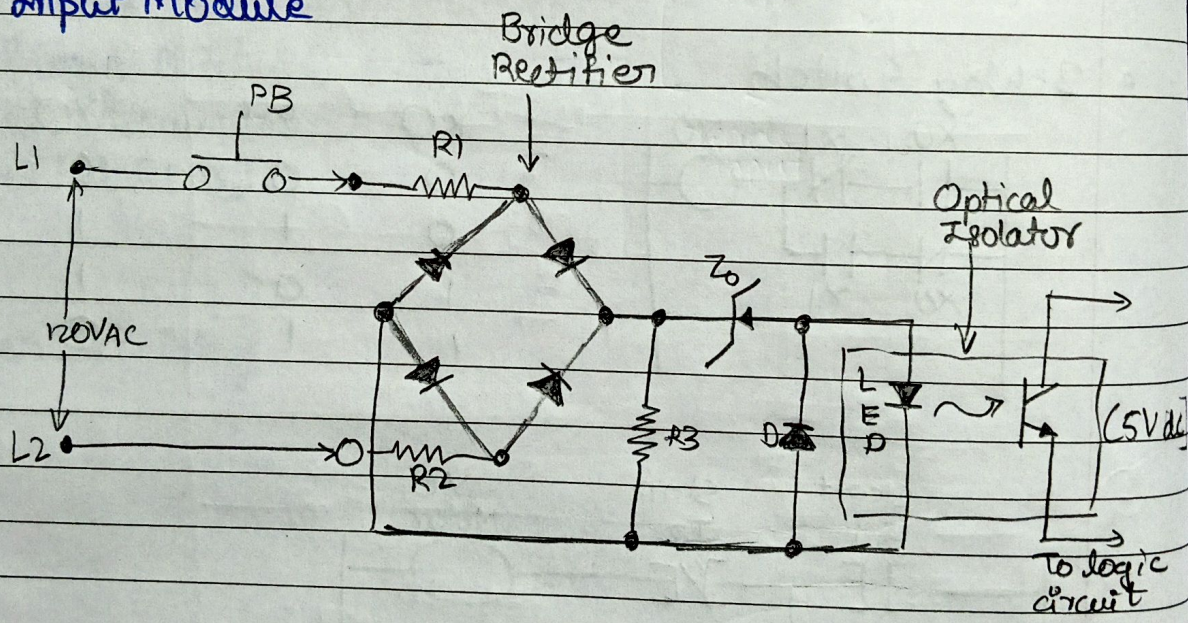
-



- **Input Module**

Input Module sense when a signal is received from a sensor on the machine. It converts the input signal to correct voltage level for particular PLC as compatible. It isolates PLC from fluctuations in input signal's voltage and current.
It also sends a signal to the PLC indicating which sensor originated the signal.

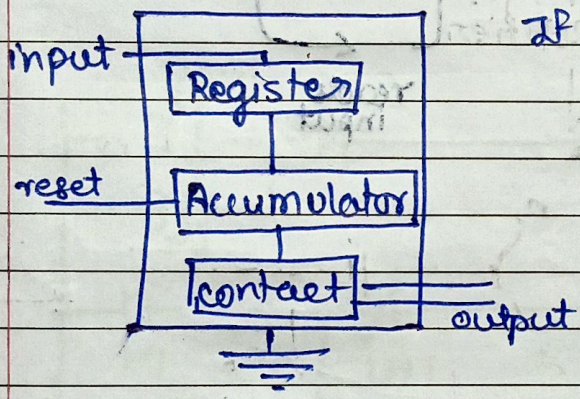
AC Input Module

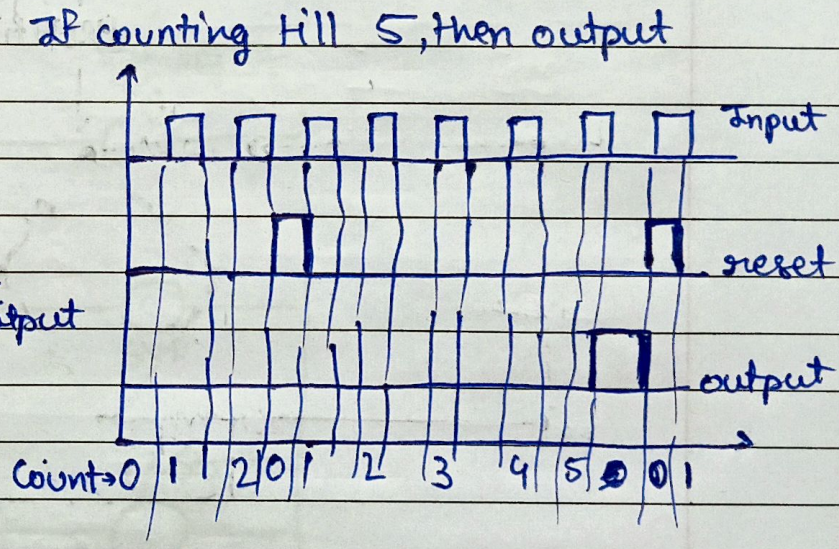


- Output Module

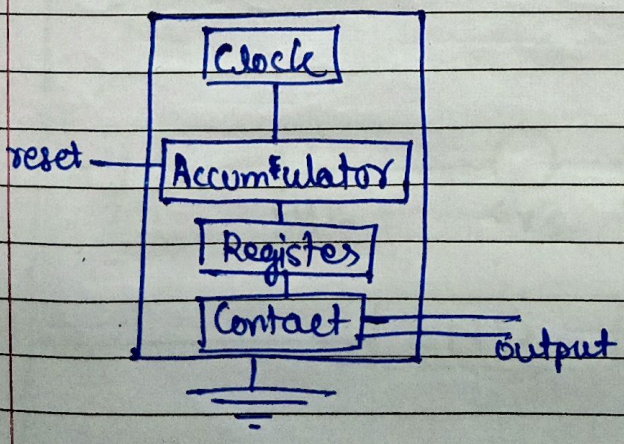
Output interface module of a PLC acts as a switch to supply power from the user power supply to operate the output.
Output switching devices most often used to switch power to the load in PLC.
Relay for ac or dc load.
Triac for ac loads only.
Transistors for dc loads only.

- Counter





- Timer



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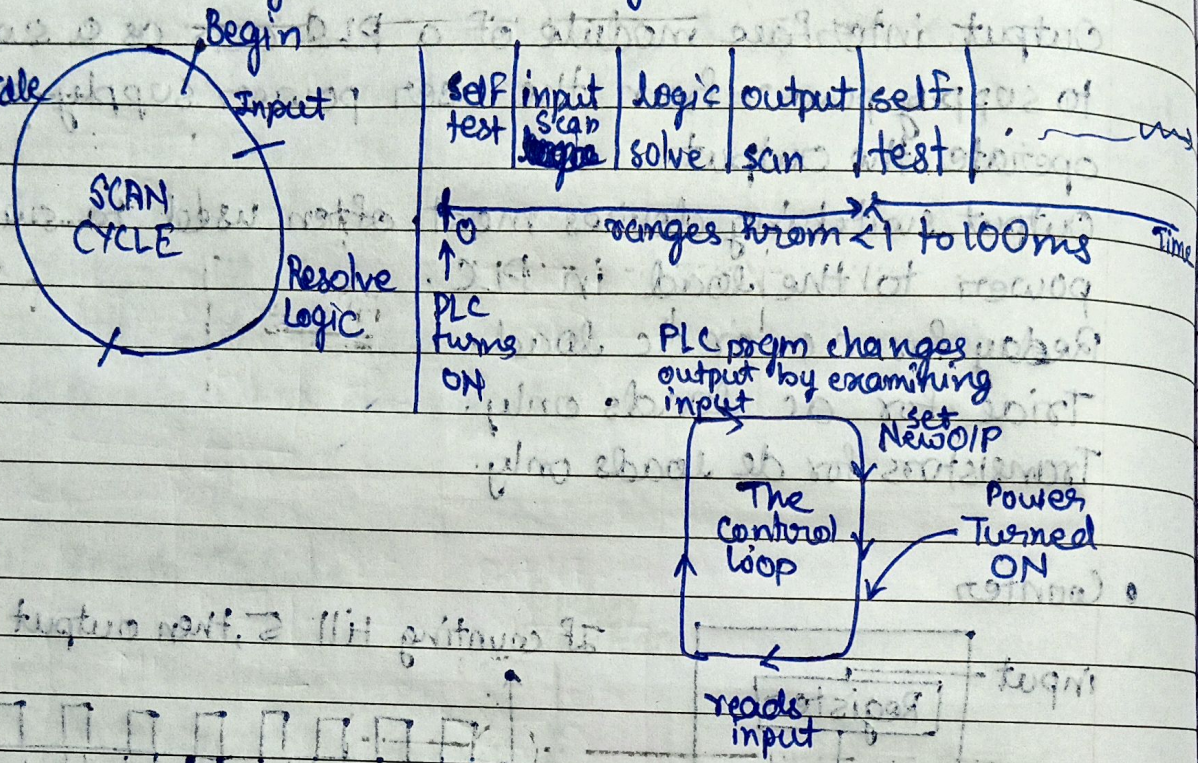
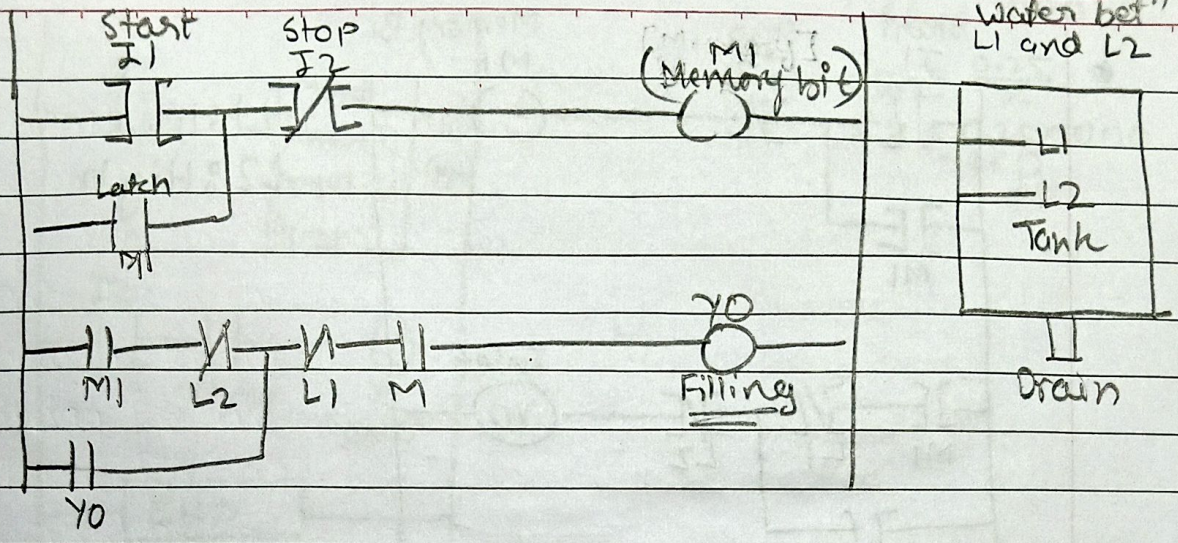
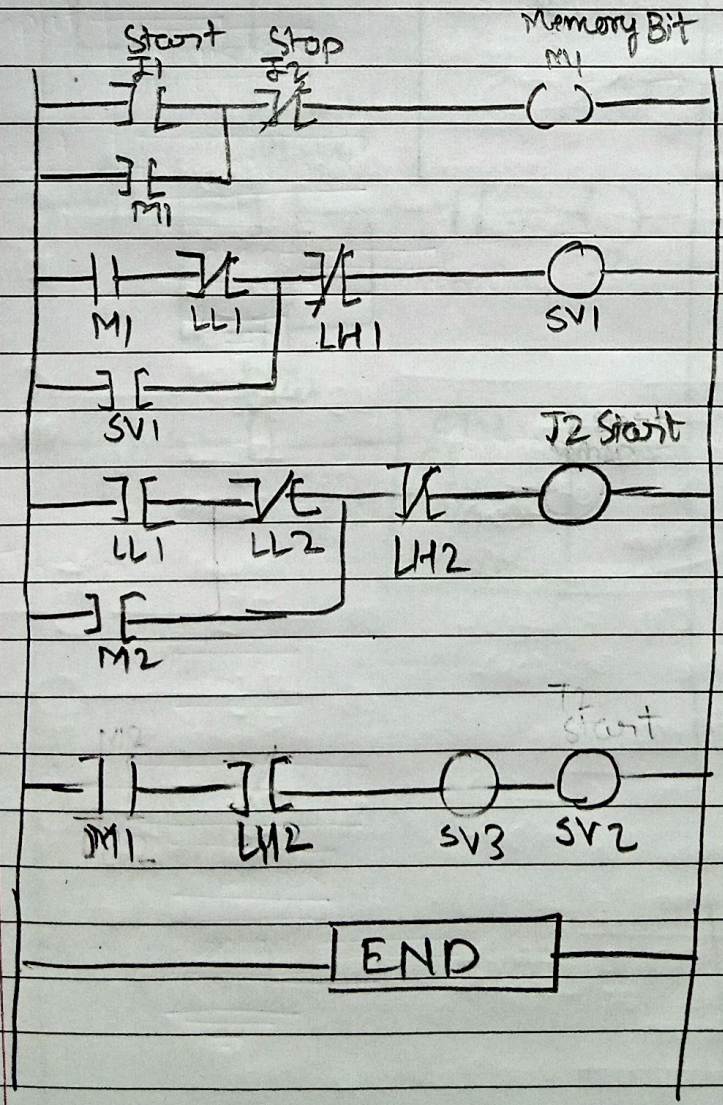
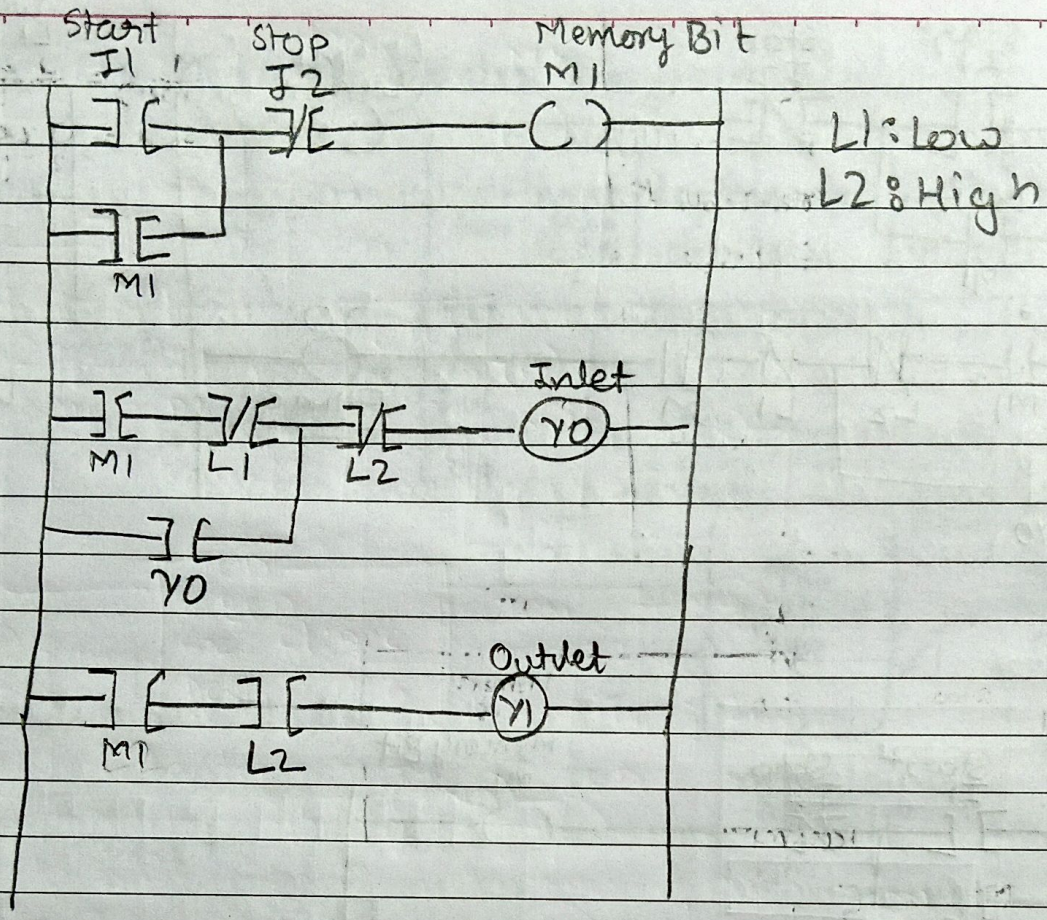
- PLC Scanning of Ladder Program




Start
I1
Stop
I2
M1
(Memory bit)
Latch
M1
M1
L2
L1
M
Y0
Filling
Y0
Water betn
L1 and L2
L1
L2
Tank
Drain


Start
I1
Stop
I2
Memory Bit
M1
M1
M1
LL1
LH1
SV1
SV1
T2 Start
LL1
LL2
LH2
M2
M1
LH2
SV3
SV2
END

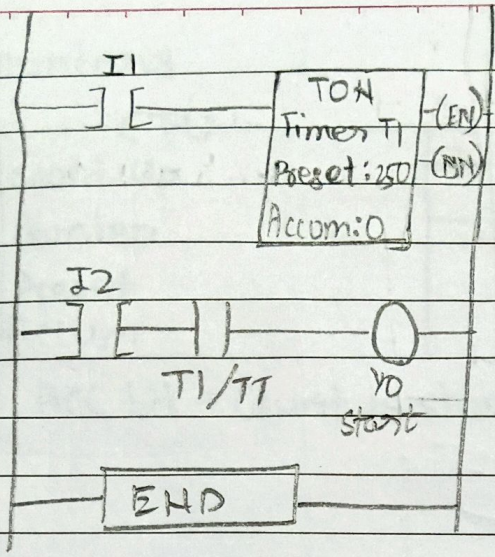


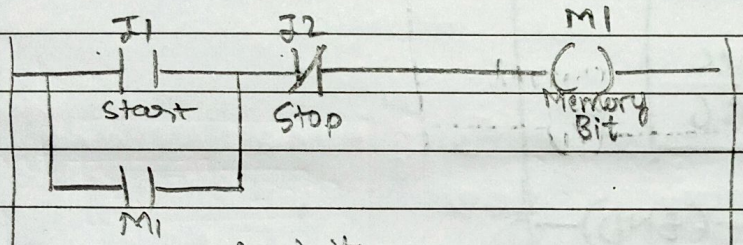
1 sec = 1000

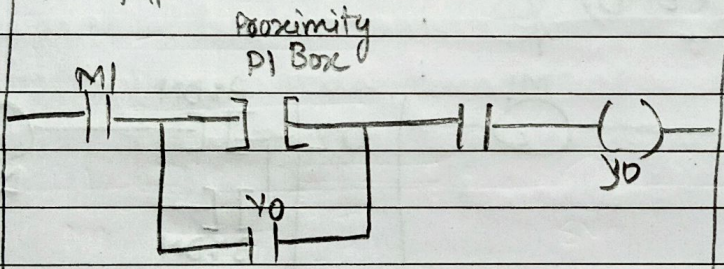
$\frac{1}{1000} = \frac{0.25}{x}$,

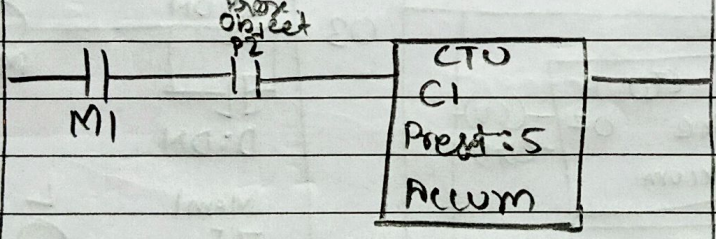
$\therefore x = 0.25 \times 1000$

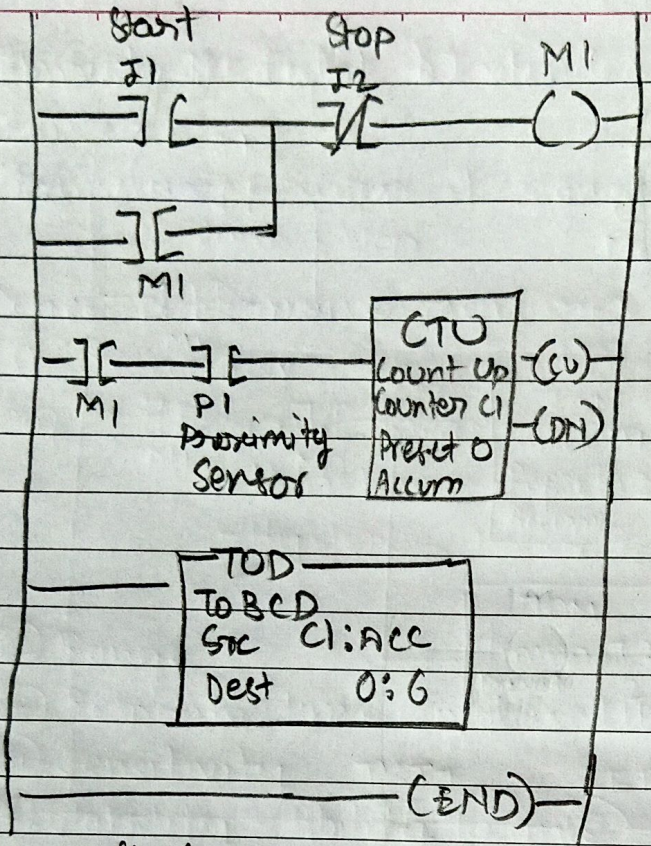
$= 250$

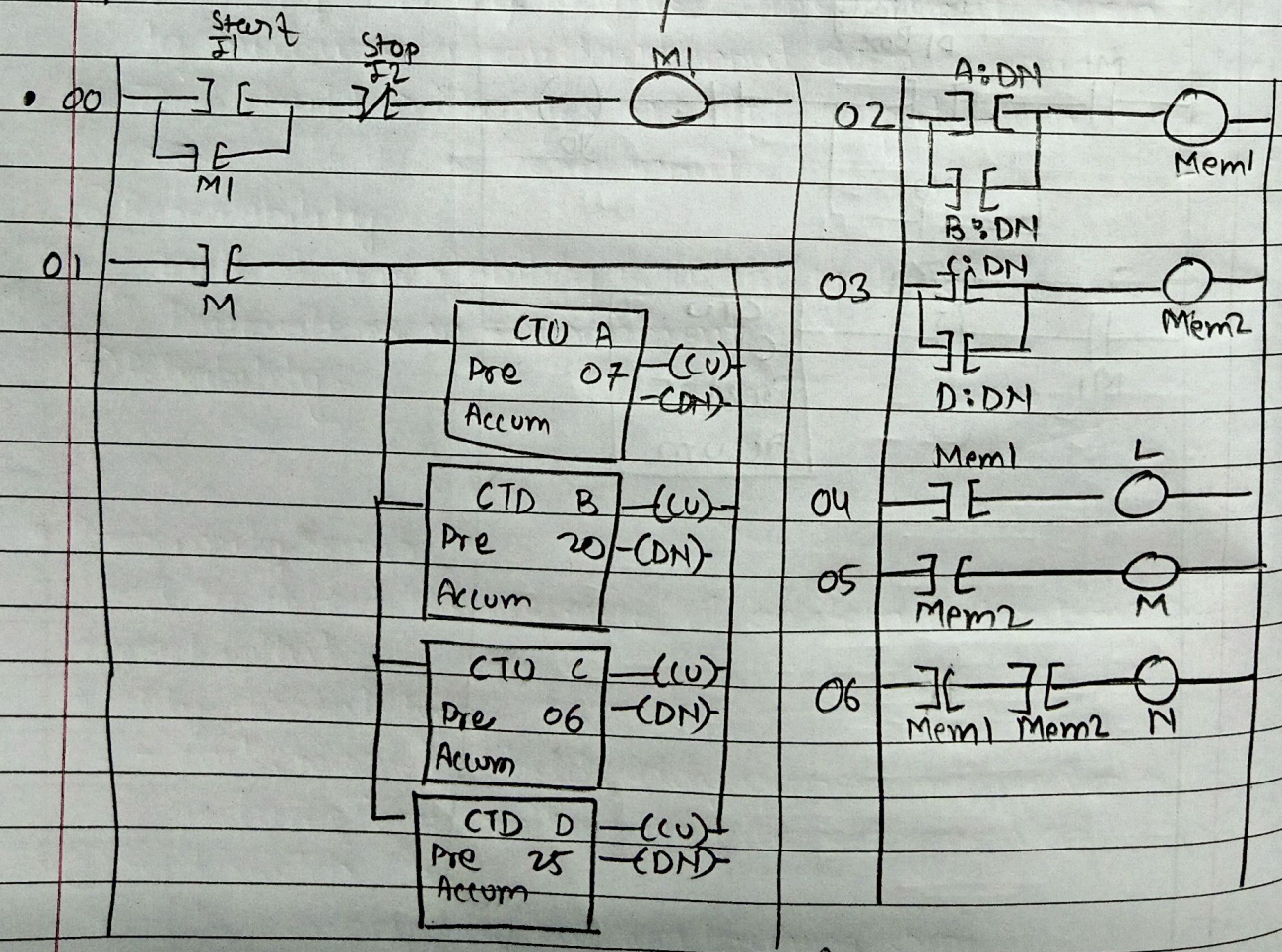









Start
I1
Stop
I2
M1
M1
M1
P1
Proximity
Sensor
CTU
Count Up
Counter C1
Preset 0
Accum
(CU)
(DN)
TOD
To BCD
Src C1:ACC
Dest 0:6
(END)


Start
I1
Stop
I2
M1
00
M1
01
M
CTU A
Pre 07
Accum
(CU)
(DN)
CTD B
Pre 20
Accum
CTU C
Pre 06
Accum
CTD D
Pre 25
Accum
02
A:DN
B:DN
Mem1
03
C:DN
D:DN
Mem2
04
Mem1
L
05
Mem2
M
06
Mem1
Mem2
N

continued

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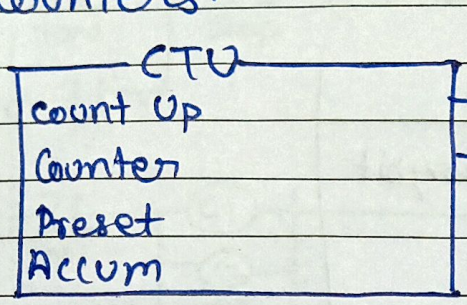
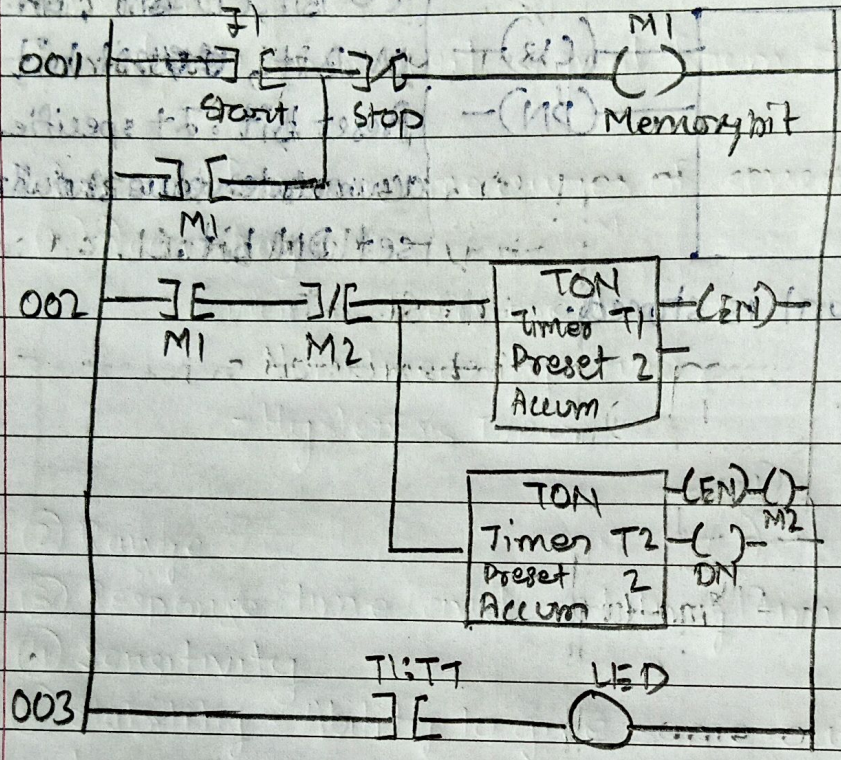
- Counters.

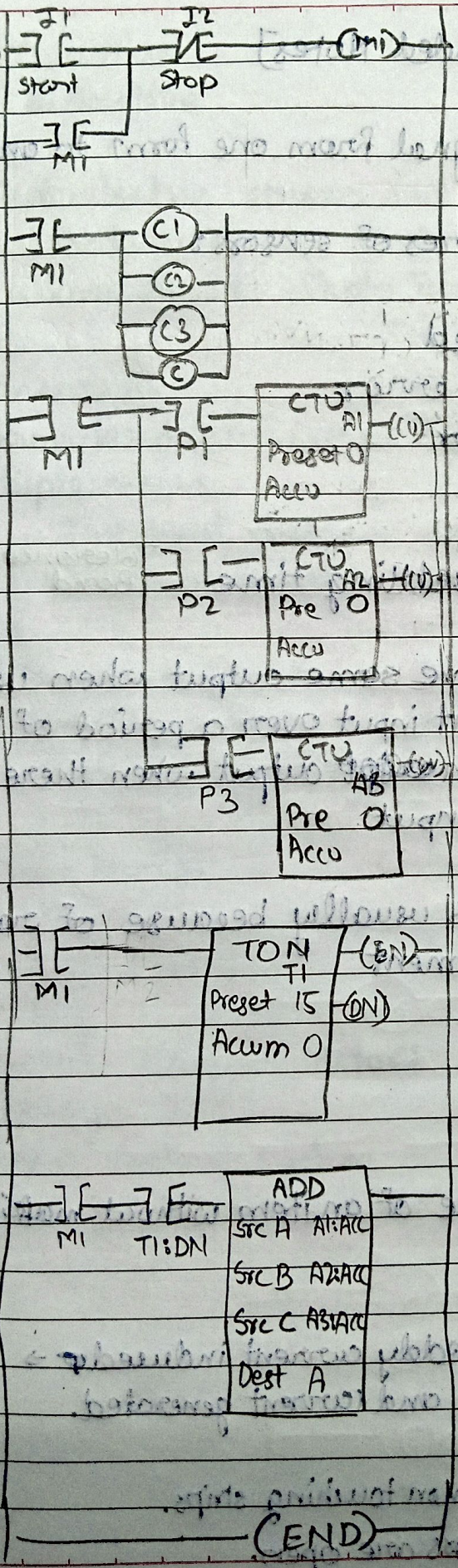


CU Bit, CD bit, DN bit
OV Bit, UN bit
Preset bit: It specifies val. that accumulate value should reach to set DN bit.

ACC bit → Count is stored.

- Blinking of light → 2 secs





C1, C2, C3 → Conveyors
C → Main conveyor
P1, P2, P3 → Proximity sensors
A1, A2, A3 → counters
A → Main ADDition
M1 → Start timer
M2 → Acts as reset for TON: T1

⊙ Input Modules [Extended Notes]

Sensor.

Transducer → Convert signal from one form to another.

Define performance measures of sensors:

① Accuracy
- Error is measured
  - Non-linearity error
  - Hysteresis Error

② Range

③ Response time and settling time — Tolerance Band

④ Sensitivity

⑤ Stability - Ability to give same output when used to measure a constant input over a period of time.
Zero drift → Changes in output when there is zero input.

⑥ Repeatability
Lack of repeatability is usually because of random fluctuations in environment

⑦ Reliability.

• Proximity Sensor

Used to detect the presence of an item without making contact with it.

① Eddy current type
- coil, magnetic field, eddy current induced → induces emf, voltage and current generated.

② Reed switch
- two overlapping but non touching strips.

In alarms to detect doors are open.

③ Capacitive
④ Inductive

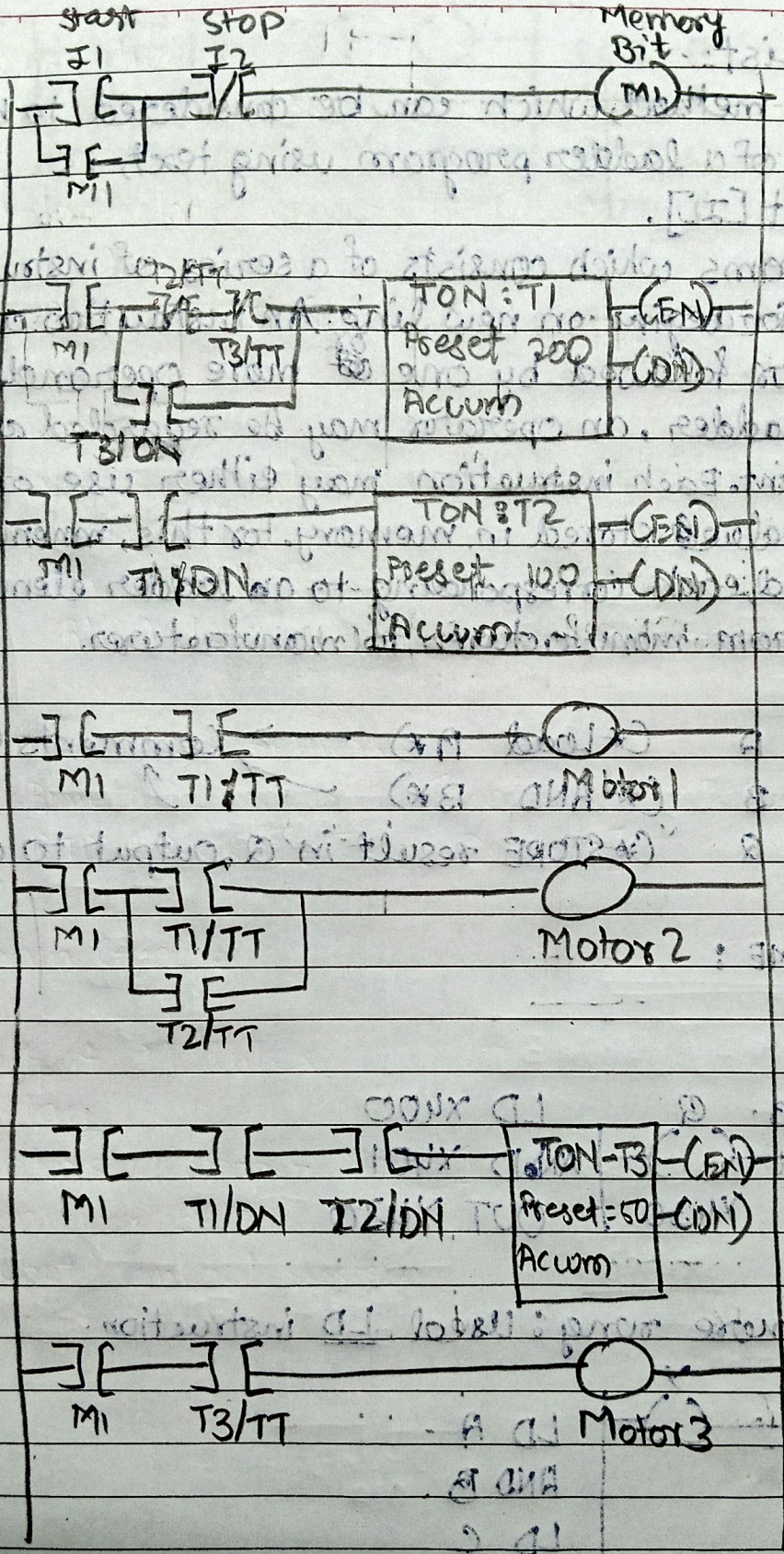
- Photoelectric sensors and switches
  Photo conductive Diode [cell]
  Photodiode, Photo Transistor.

- Encoders
  Provides digital O/P as a result of angular/linear displacement.
  Increment Encoder - angular/linear displacement
  Absolute Encoder - angular/linear position

- Temperature Sensors
  Bimetallic Strip [Coefficient of Expansion]
  RTD [Resistive Temp. Detector]

- Strain Guage

◉ Output Modules
- Relay
- Motors [Stepper Motor]
- Conveyor Belt
- Robot Control system


Start
I1
Stop
I2
Memory Bit
M1
M1
T3/TT
T3/DN
TON : T1
Preset 200
Accum
(EN)
(DN)
M1
T1/DN
TON : T2
Preset 100
Accum
(EN)
(DN)
M1
T1/TT
Motor1
M1
T1/TT
T2/TT
Motor2
M1
T1/DN
I2/DN
TON-T3
Preset=50
Accum
(EN)
(DN)
M1
T3/TT
Motor3

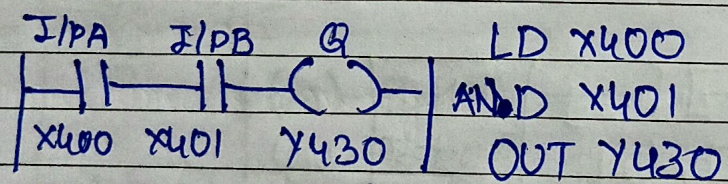
Instruction List

Programming method, which can be considered to be the entering of a ladder program using text, is Instruction List [IL].

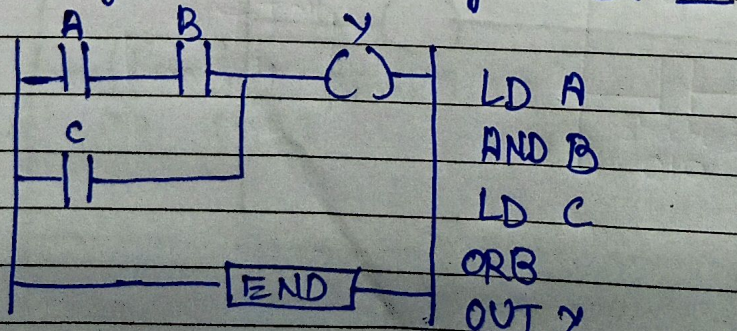
IL gives programs which consists of a series of instructions, each instruction begins on new line. An instruction consists of an operator followed by one or more operands. In terms of ladder, an operator may be regarded as ladder element. Each instruction may either use or change the values stored in memory. For this, mnemonic codes are used, each corresponding to a ladder element. It differs from manufacturer to manufacturer.

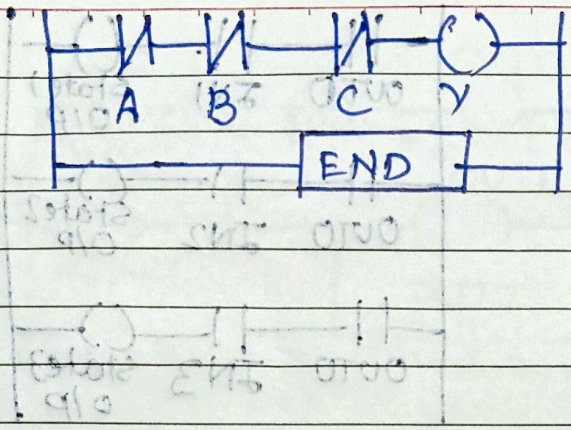
```
LD    A    (* Load A *)      ---> Comments (* *)
AND   B    (* AND B *)       ---> Comments (* *)
ST    Q    (* STORE result in Q, output to Q *)
```

```
LABEL NAME :  - - -
              - - -
```



Adding one more rung: Used LD instruction.

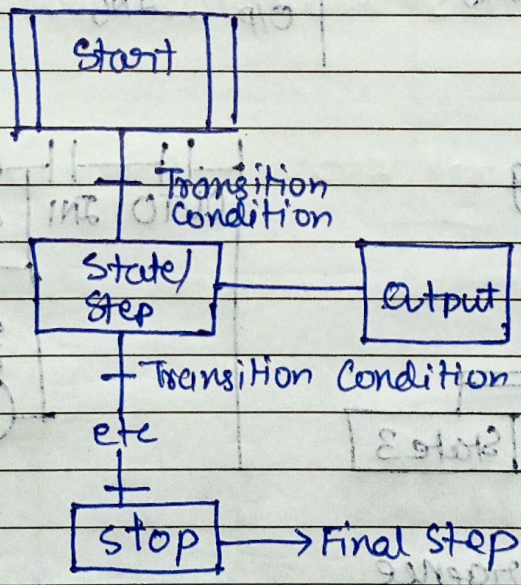


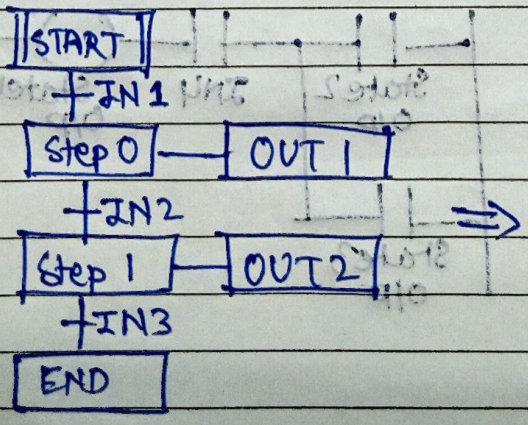


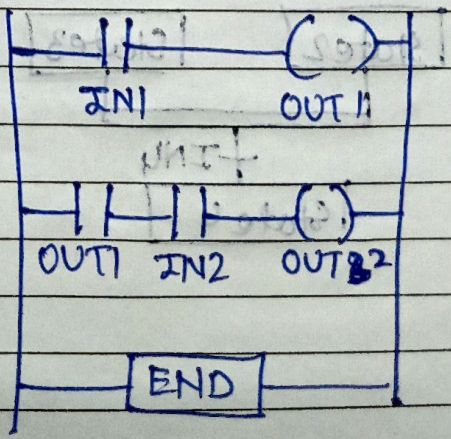

```
LDI A
ANI B
ANI C
OUT Y
END
```

⊙ Sequential Function Charts

It is used for pictorial representation of a system's operation to show the sequence of events in its operation.







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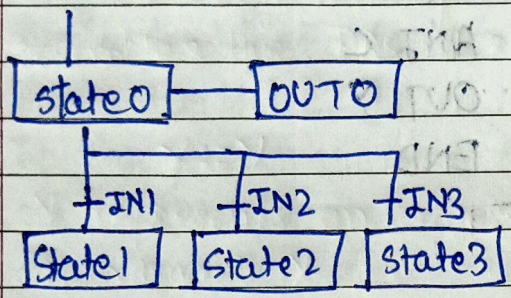
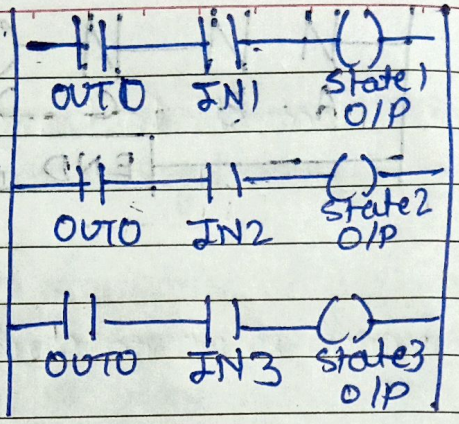
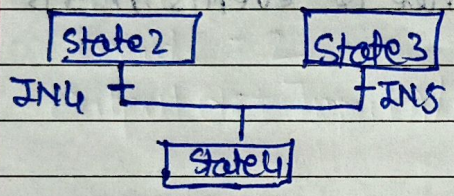
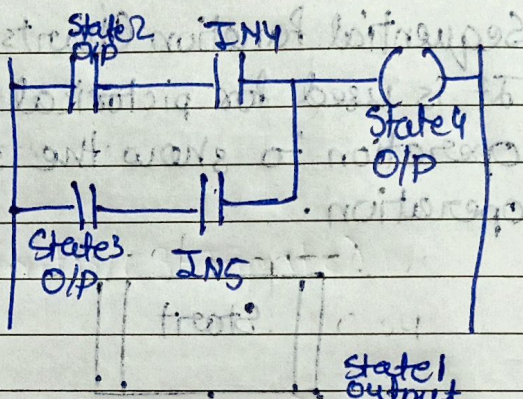
- Selective Branching



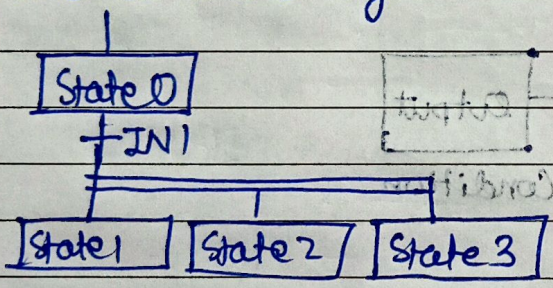


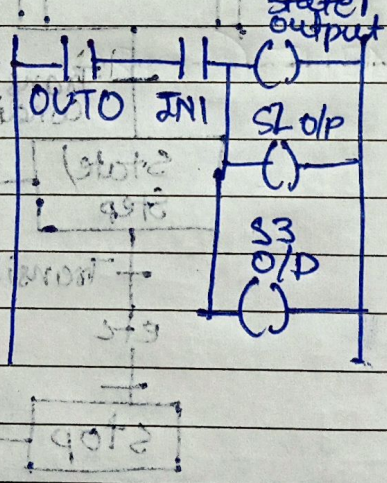
- Convergence



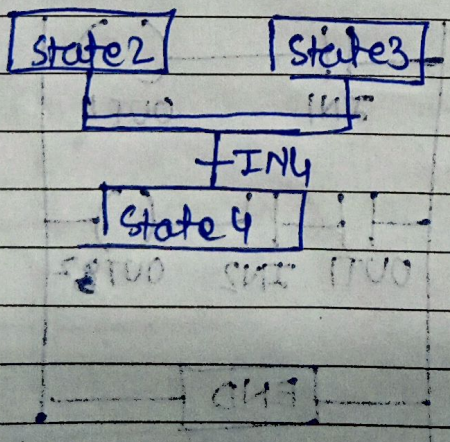


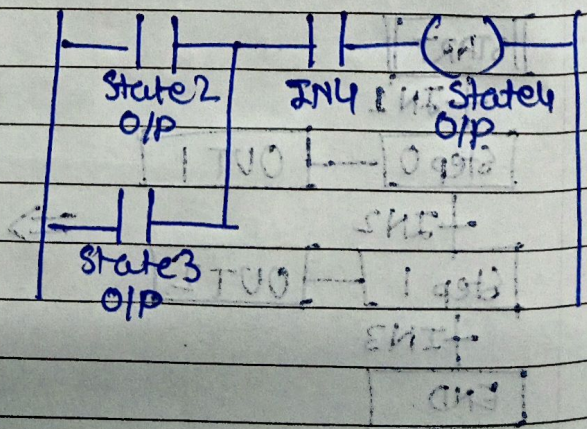
- Parallel Branching

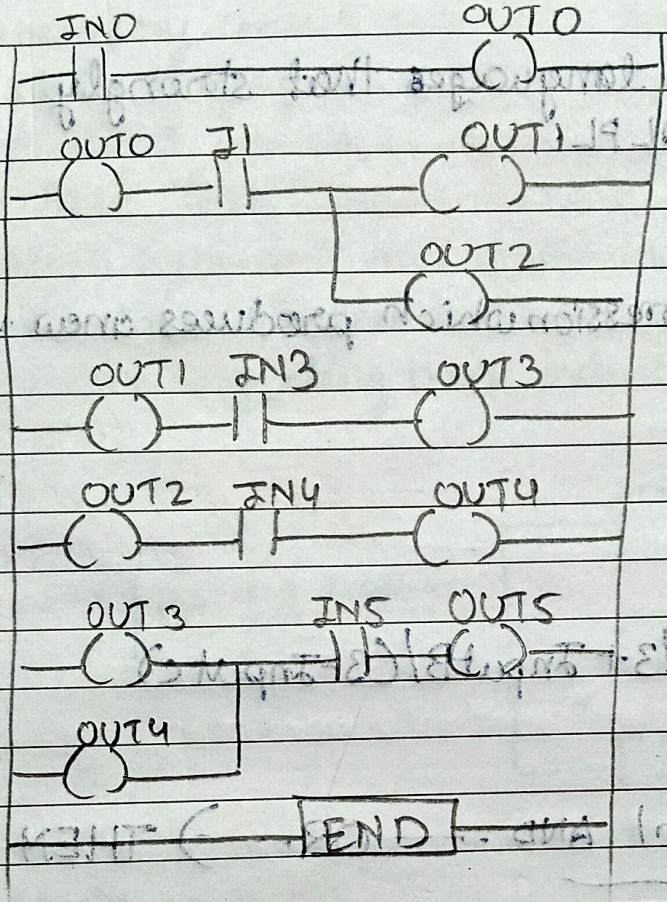




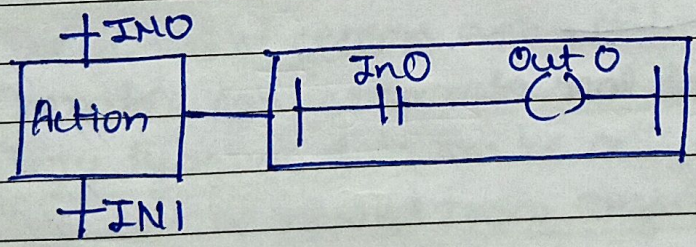
- Simultaneous Convergence






IN0
OUT0
OUT0
I1
OUT1
OUT2
OUT1
IN3
OUT3
OUT2
IN4
OUT4
OUT3
IN5
OUT5
OUT4
END

- Actions


IN0
Action
IN1
In0
Out0

- Structured Text

It is a programming languages that strongly resembles the PASCAL PL.

X:=Y

Y represents an expression which produces a new value for variable X.

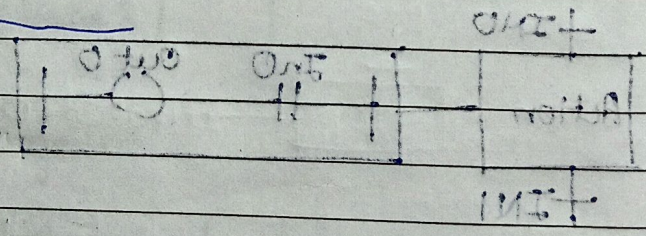
Input A = 6
Input B = 4
Input C = 2
Output Q:= InputA/3 + InputB/(3-InputC)

Conditional:

IF (condition1 AND ... OR ...) THEN

ELSE

END_IF



Need
Obj.
Func.
Uses

Architecture

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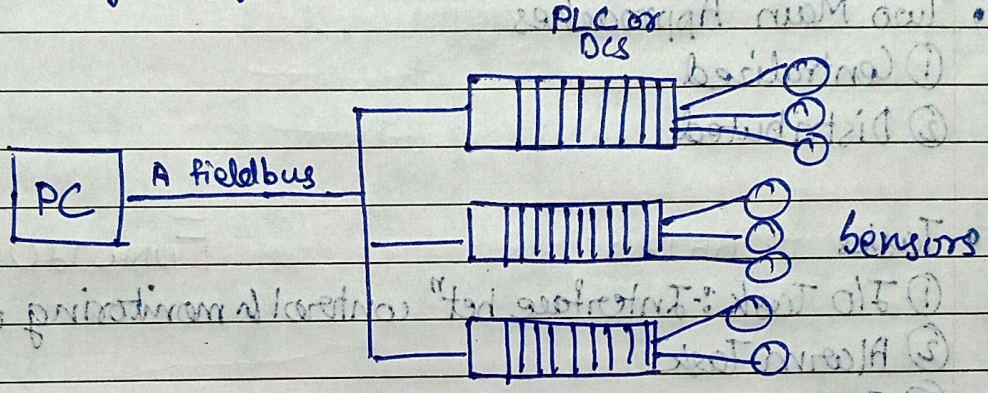
SCADA

Supervisory Control and Data Acquisition.
It is a category of software applications for controlling industrial processes, which is the gathering of data in Real Time from remote location in order to control equipment and conditions. SCADA provides organization with tools needed to make and deploy data-driven decisions regarding their industrial processes.

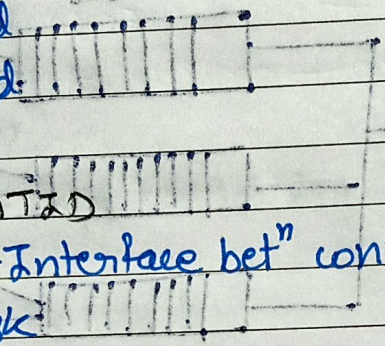


Advantages :-
① Computer can record and store a very large amount of data.
② Data can be used for analytics and provide better view.
③ Thousands of sensors over a wide area can be connected.
④ Operator can incorporate real data simulations.
⑤ Many types of data can be collected from RTUs
⑥ Data can be viewed from anywhere.

Disadvantages:-
① System is more complicated
② Different Operating skills are required.
③ With lots of sensors, a lots of wire to deal with.
④ Operator can see only as far as the PLC.

- SCADA Hardware
  1. Field level instrumentation and control devices.
  2. Marshalling terminals and RTUs (Remote Terminal Unit)
  3. Communication Systems
  4. Master station(s)
  5. Commercial data processing dept. computer system

- Two Main Approaches
  1. Centralized
  2. Distributed



- Tasks → RATID
  1. I/O Task :- Interface bet" control & monitoring sys. and plan
  2. Alarm Task
  3. Trends Task :- Collect data to be monitored over time.
  4. Reports Task :-
  5. Display Task :- Manages all data to be monitored and all control actions requested by operat

- Key features
  1. User Interface
  2. Graphics Display
  3. Alarms
  4. Trends
  5. RTU and PLC interface
  6. Scalability
  7. Access to data
  8. Database
  9. Networking
  10. Fault Tolerance and Redundancy
  11. Client/server distributed processing

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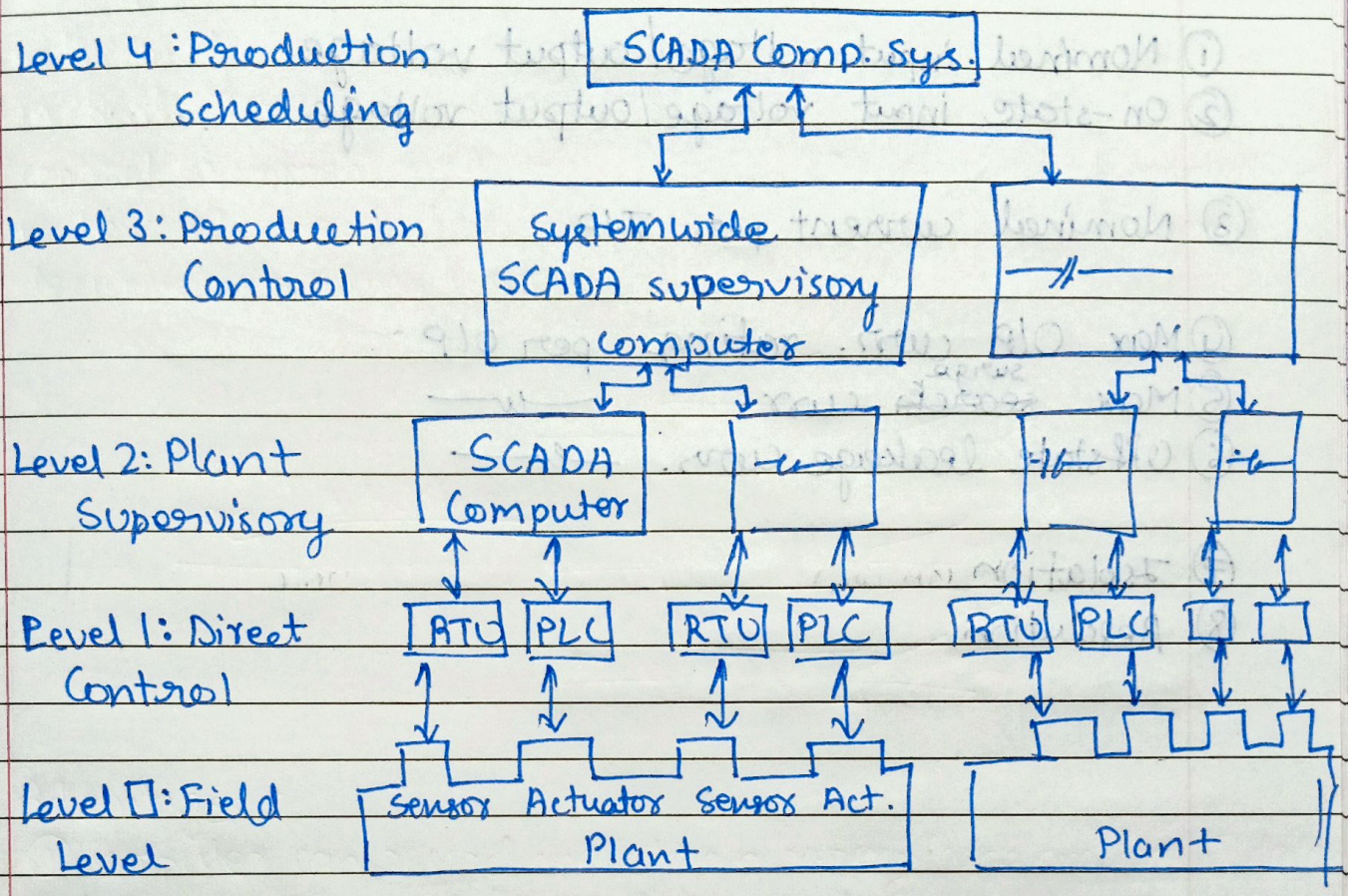
- Layers of SCADA System Architecture



- Applications
  1. Electricity generation & distribution
  2. Oil and Gas refining operation
  3. Telecommunication infrastructure
  4. Chemical Manufacturing