PROGRAMMABLE LOGIC CONTROLLER

INTRODUCTION

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Evaluation Scheme: Credits: - 02

- Test 1 – 20 Marks (Online)
- Test 2 – 20 Marks (Online)
- ESE – 60 Marks (Offline)

Readings:

- Textbook: - Introduction to Programmable Controller by Garry Dunning,
- Ref. Book:- Programmable Logic Controllers: Principles and Application by John W. Webb, Ronald A. Reis,

Learning Objectives:

- Understand PLC architecture and its use for different types of control applications
- Understanding of various kinds of Instrumentation used for PLC based control
- Overview of Ladder Diagram Programming
- Development of industrial control applications using PLC

EXERCISE

What are some common examples of control?

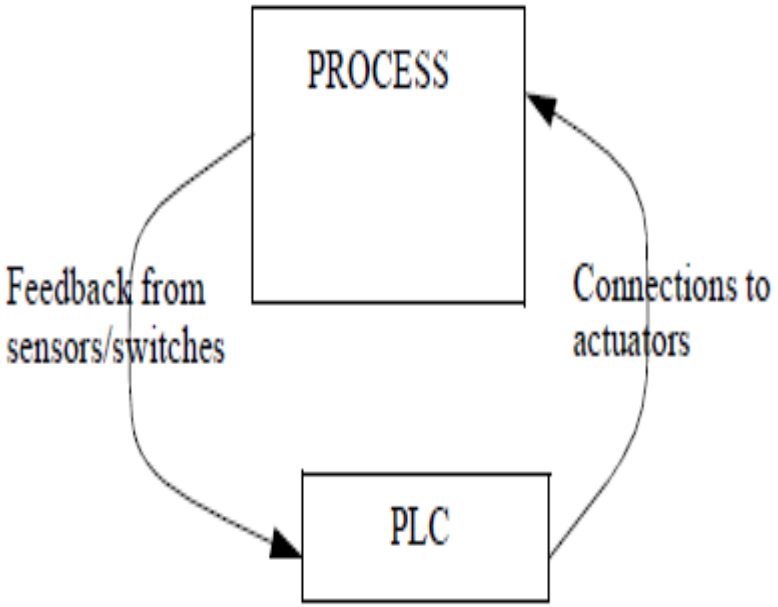
Washing machine, sump pump, microwave, conveyor belt, automation, etc……..

Others?

TYPES OF CONTROL

- Temporal -- control based in time
- State -- control based in state level
- Hybrid – both temporal and state

Controller and Process



PURPOSE OF PROGRAMMABLE LOGIC CONTROLLERS (PLCS)

- Initially designed to replace relay logic boards
  - Sequence device actuation
  - Coordinate activities
- Accepts input from a series of switches
- Sends output to devices or relays

FUNCTIONS OF CONTROLLERS

- On-off control,
- Sequential control,
- Feedback control, and
- Motion control.

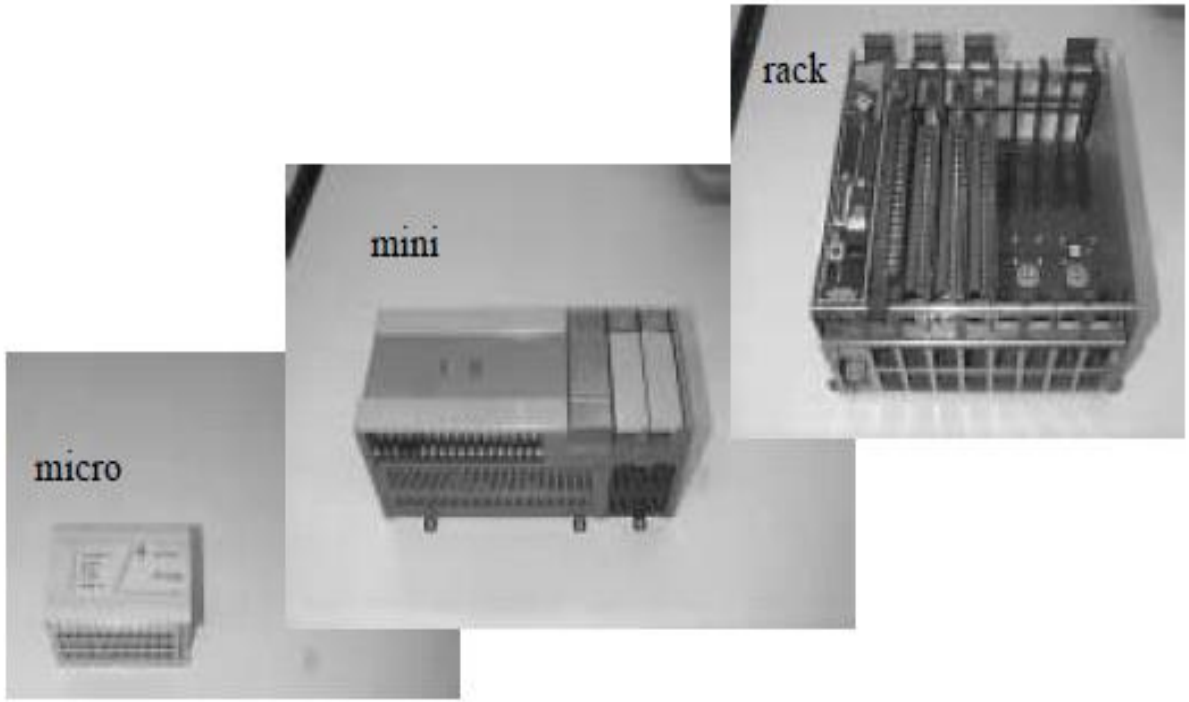
PROGRAMMABLE LOGIC CONTROLLER (PLC)

Invented in 1968 as a substitute for hardwired relay panels.

"A digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions such as logic sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machines or processes. The digital computer which is used to perform the functions of a programmable controller is considered to be within this scope."

National Electrical Manufacturing Association (NEMA)

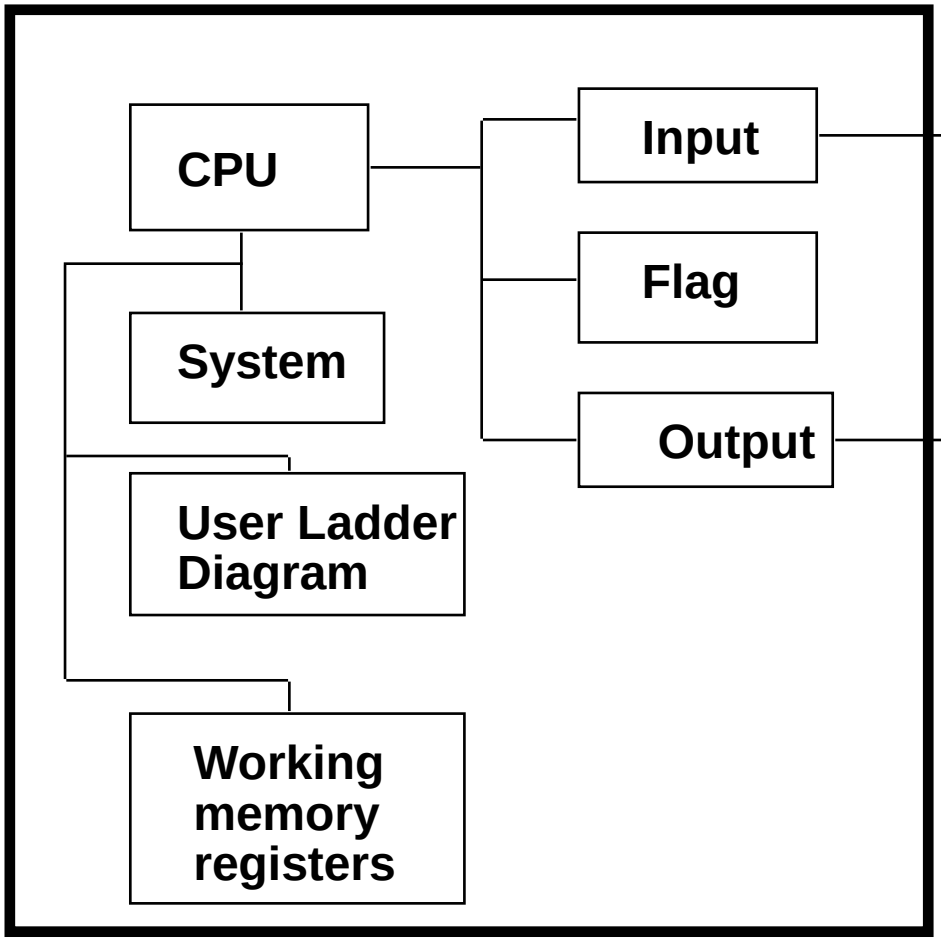
Typical Configurations for PLC

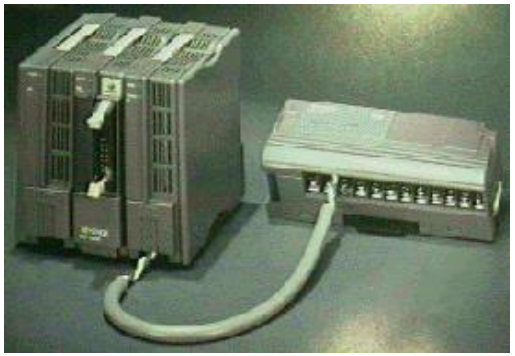


VENDORS

- Rockwell
- Allen-Bradley
- GE/Fanuc
- Schneider
- Siemens
- Mitsubishi
- etc.

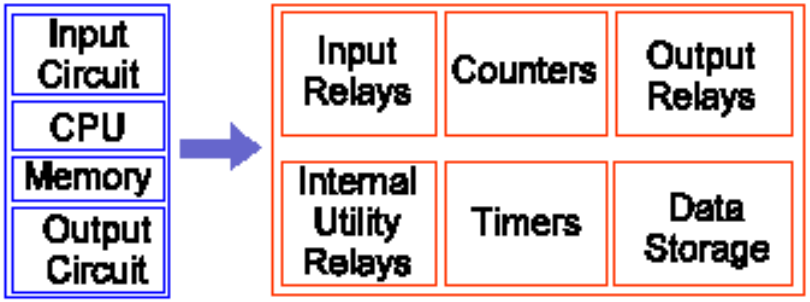
PLC


CPU
System
User Ladder Diagram
Working memory registers
Input
Flag
Output
Input Module
Output Module



PLC Components

- **Power Supply** - This can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24Vdc, 120Vac, 220Vac.
- **CPU (Central Processing Unit)** - This is a computational unit where ladder logic is stored and processed.
- **I/O (Input/Output)** - A number of input/output terminals must be provided so that the PLC can monitor the process and initiate actions.
- **Indicator lights** - These indicate the status of the PLC including power on, program running, and a fault. These are essential when diagnosing problems.



WHAT DEVICES DOES A PLC INTERACT WITH?

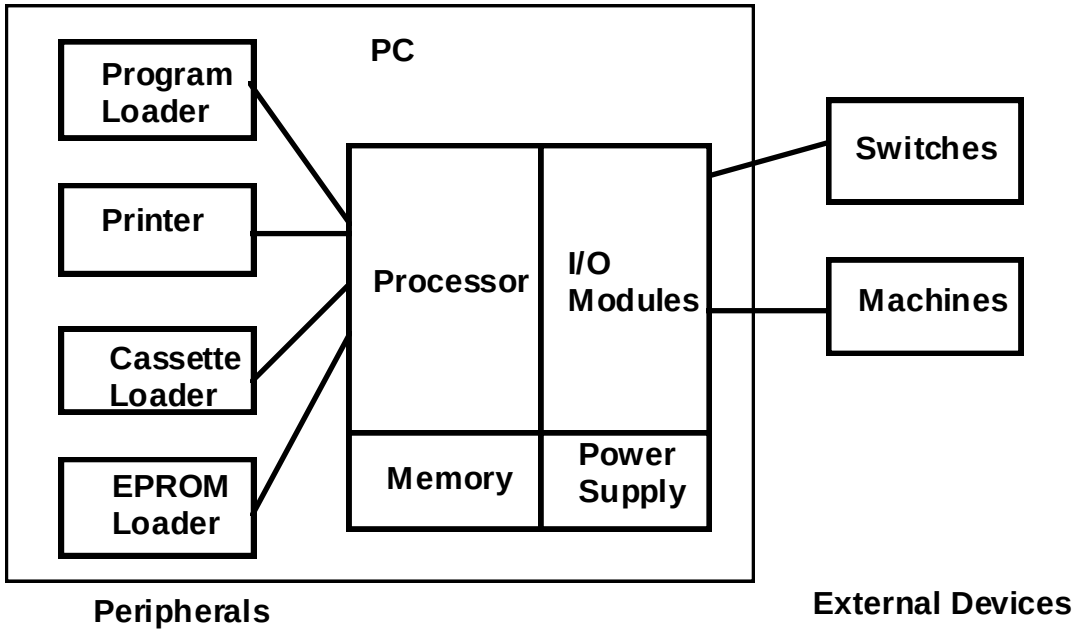
- **INPUT RELAYS-**(contacts)These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc.
- **INTERNAL UTILITY RELAYS-**(contacts) These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays.
- **COUNTERS**-These again do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down. Since they are simulated they are limited in their counting speed.

WHAT DEVICES DOES A PLC INTERACT WITH?

- **TIMERS**-These also do not physically exist. They come in many varieties and increments. The most common type is an on-delay type.
- **OUTPUT RELAYS-**(coils)These are connected to the outside world. They physically exist and send on/off signals to solenoids, lights, etc. They can be transistors, relays, or triacs depending upon the model chosen.
- **DATA STORAGE**-Typically there are registers assigned to simply store data. They are usually used as temporary storage for math or data manipulation. They can also typically be used to store data when power is removed from the PLC. Upon power-up they will still have the same contents as before power was removed.

PLC ARCHITECTURE

Programmable controllers replace most of the relay panel wiring by software programming.



A typical PLC

PLC COMPONENTS

1. **Processor** Microprocessor based, may allow arithmetic operations, logic operators, block memory moves, computer interface, local area network, functions, etc.

2. **Memory** Measured in words.

ROM (Read Only Memory),

RAM (Random Access Memory),

PROM (Programmable Read Only Memory),

EEPROM (Electronically Erasable Programmable ROM),

EPROM (Erasable Programmable Read Only Memory),

EAPROM (Electronically Alterable Programmable

PLC COMPONENTS

3. I/O Modular plug-in periphery,
AC voltage input and output,
DC voltage input and output,
Low level analog input,
High level analog input and output,
Special purpose modules, e.g.., high speed timers,
Stepping motor controllers, etc. PID, Motion

4. Power supply AC power, DC Power

5. Peripheral Handheld programmer (loader),
CRT programmer,
Operator console,
Network communication interface. MAP, LAN

I/O Specifications

- Nominal Input Voltage
- On-State Input Voltage Range
- Nominal Current per Input
- Ambient Temperature Rating
- Input Delay
- Nominal Output Voltage
- Output Voltage range
- Maximum Output Current Rating per Output and Module

I/O Specifications

- Maximum Surge Current per Output
- Off-State Leakage Current per Output
- Electrical Isolation
- Number of Inputs and Outputs per Card
- Backplane Current Draw
- Resolution
- Input Impedance and Capacitance
- Common Mode Rejection Ratio

TYPICAL SPECIFICATIONS OF PLC

- **System Configuration**
  No of digital inputs: 120
  No of digital outputs : 64
  No of timers : 40
  No of auxiliary relays : 100

- **Memory**
  The memory shall be sufficient to run the ladder program attached here with. Also, the memory shall be expandable if necessary

- **Backup Storage**
  Removable memory sub module (EEPROM) which is sufficient to store the ladder program attached herewith shall be provided to back up the program

TYPICAL SPECIFICATIONS OF PLC

- **Input/output modules**

  Input /output modules of existing PLC are 8 channel. Hence 8 channel input/output modules are preferred so that existing wiring could be used . All input /output channels shall have status indicators
- **Input devices**
  - Limit switches
  - Relay contacts
  - Push button switches
  - Selector switches
  - Analog Sensors
- **Output devices**
  - Relays 110 V, 50 Hz
  - Lamp indicators 110 V

- **The PLC shall be modular type and expandable if necessary. Also, the modules shall be easily removable from the bases. All input/output modules shall be hot pluggable.**

TYPICAL SPECIFICATIONS OF PLC

- **Supervisory Control And Data Acquisition system (SCADA) compatible.**
- PLC programming soft ware and any additional hardware such as interface cards, cables required to connect the PLC to the PC should be provided by the supplier
- Self diagnostic function Self diagnostic program shall be run continuously to monitor the system hardware and software
- Space available Space available is 700 mm X 500 mm. The space required for the new system shall be compatible with the space available.
- **Power supply:** +24Vdc or 110 V, 50 Hz.

TYPICAL SPECIFICATIONS OF PLC

- **Ambient conditions**

  Ambient température : 30 degreeC, Relative humidity : 90

- **Electro Magnetic Compatibility**

  The system shall comply with Generic Emission Standard EN 50081 part II and Generic Immunity Standard EN 50082 part II.

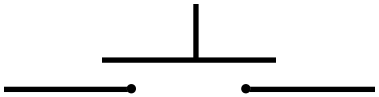
- **Warranty:**

  System
  warranty for a period of 2 years from the date of commissioning shall be provided.15.2 Availability of spares shall be guaranteed for next ten years p eriod

SWITCHES

Non-locking

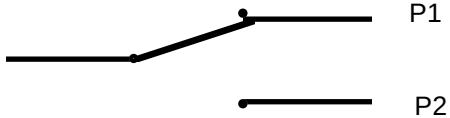
Locking



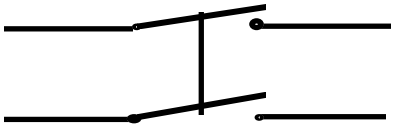
Normally Open

Normally Closed

SPDT

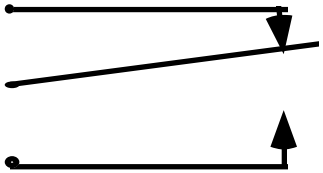


Multiple Throw



Multiple Pole

DPST



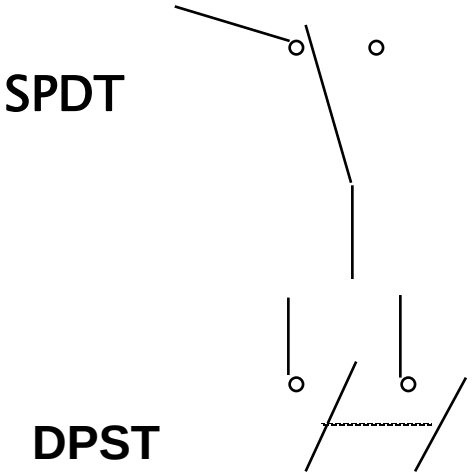
Break-before-make

Make-before-break

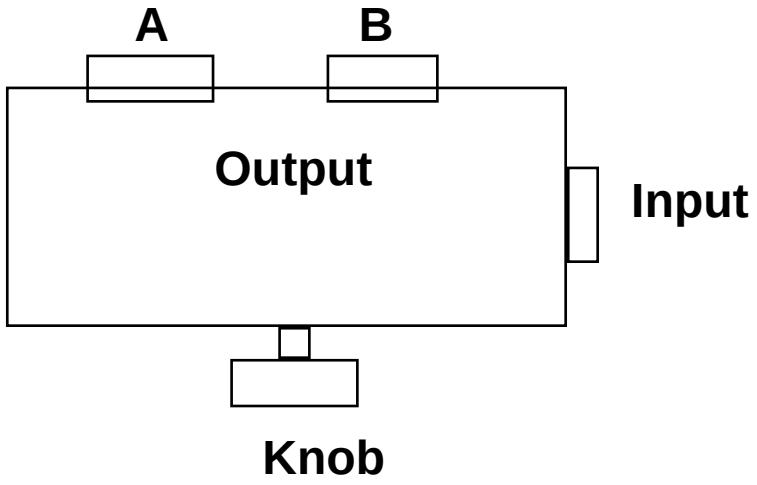
SWITCHES

Throw - number of states

Pole - number of connecting moving parts (number of individual circuits).



A serial switch box (A-B box) has two 25 pin serial ports to switch from.



How is this switch classified?

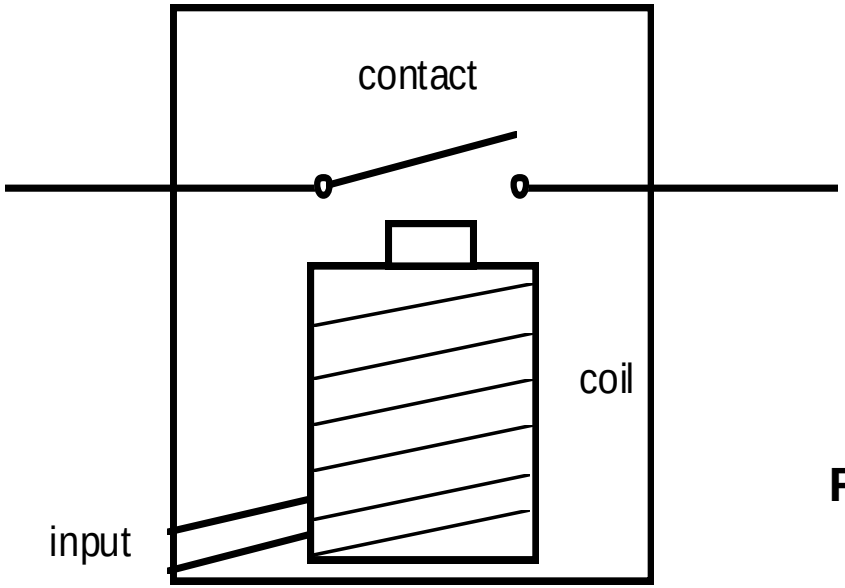
TYPES OF SWITCHES

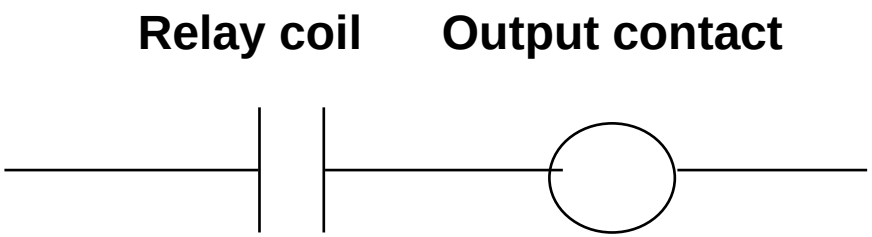
1. Basic switch, operated by a mechanical level,
2. Push-button switch,
3. Slide switch,
4. Thumbwheel switch,
5. Limit switch,
6. Proximity switch, and
7. Photoelectric switch.

RATING: voltage, current

RELAYS

A switch whose operation is activated by an electromagnet is called a "relay"





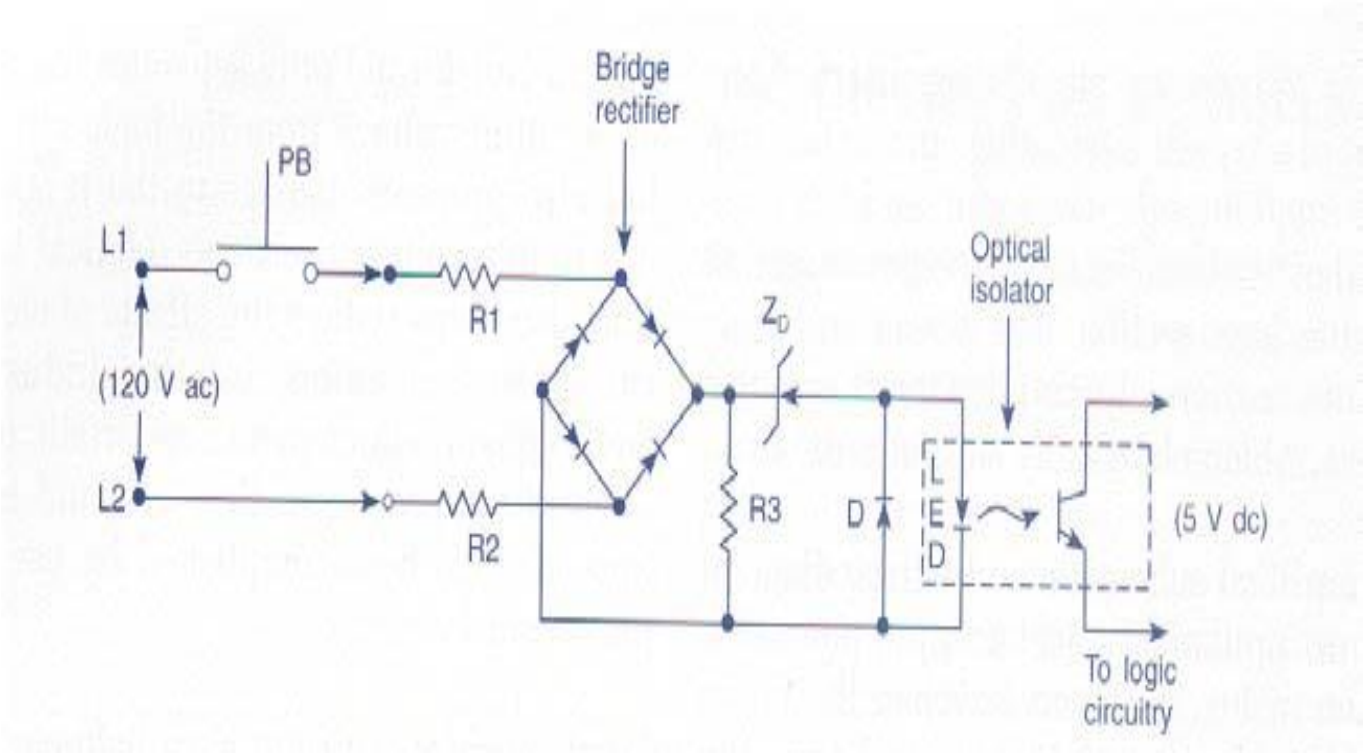
Actuators

- **Solenoid Valves** - logical outputs that can switch a hydraulic or pneumatic flow.
- **Lights** - logical outputs that can often be powered directly from PLC output boards.
- **Motor Starters** - motors often draw a large amount of current when started, so they require motor starters, which are basically large relays.
- **Servo Motors** - a continuous output from the PLC can command a variable speed or position.

Input Module

- Input Module sense when a signal is received from a sensor on the machine
- Input Module convert the input signal to the correct voltage level for the particular PLC as compatible
- Input Module isolate the PLC from fluctuations in the input signal's voltage and current
- Input Module send a signal to the PLC indicating which sensor originated the signal

AC Input Module

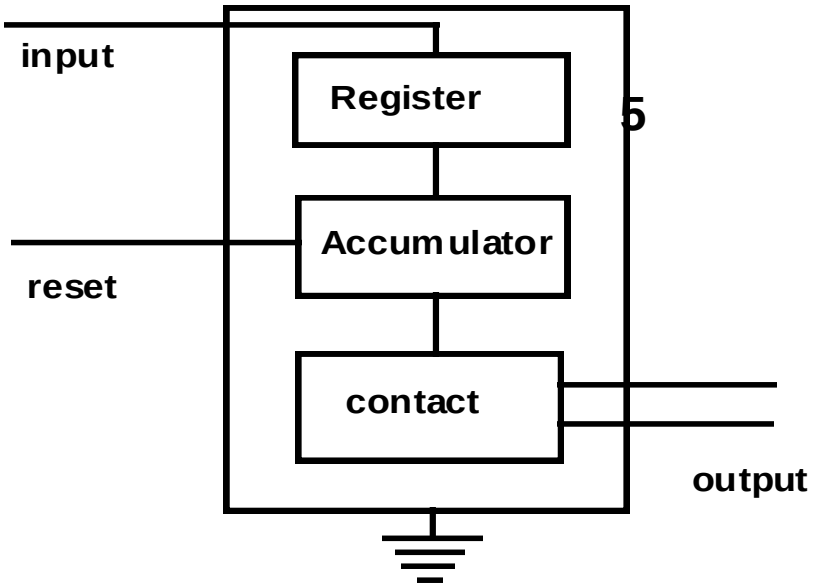


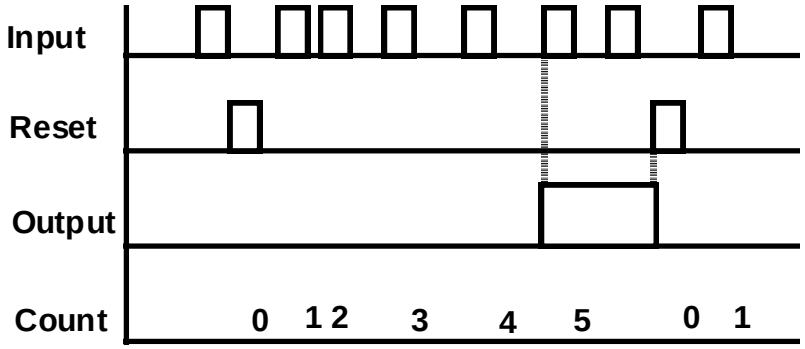
Output Module

- 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

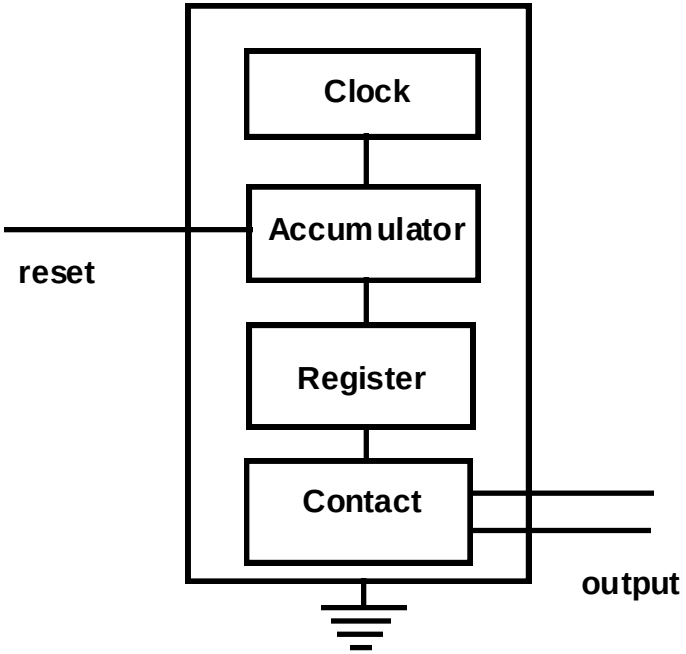
Digital counters output in the form of a relay contact when a preassigned count value is reached.

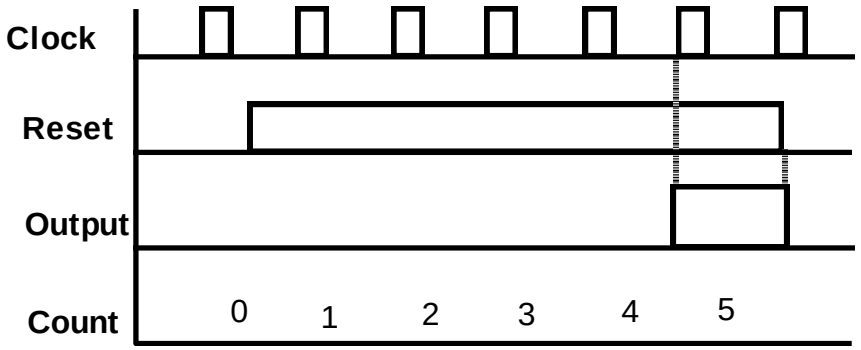




TIMER

A timer consists of an internal clock, a count value register, and an accumulator. It is used for or some timing purpose.

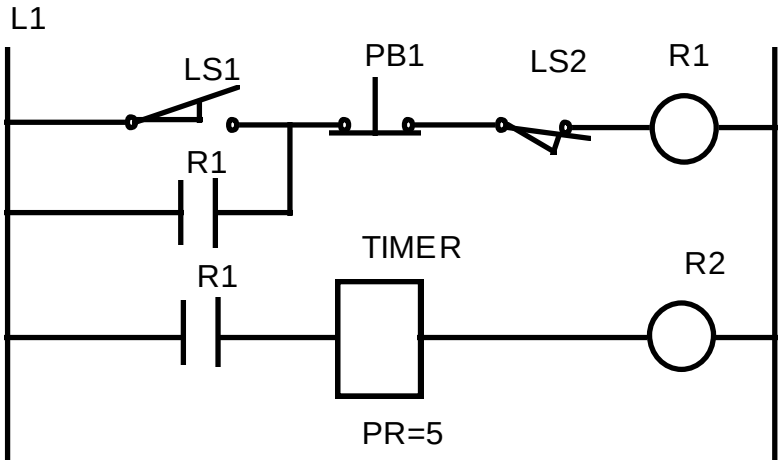


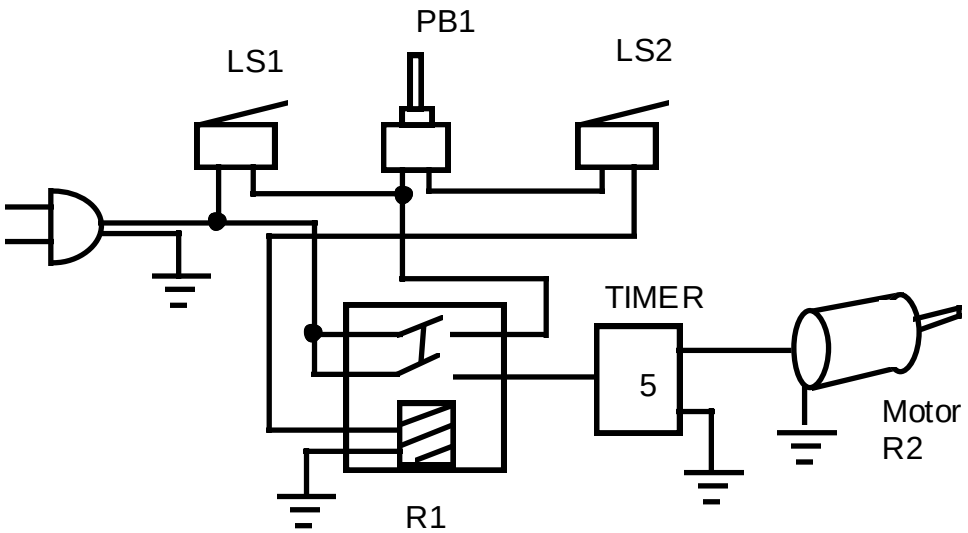


Time 5 seconds.

AN EXAMPLE OF RELAY LOGIC

For process control, it is desired to have the process start (by turning on a motor) five seconds after a part touches a limit switch. The process is terminated automatically when the finished part touches a second limit switch. An emergency switch will stop the process any time when it is pushed.

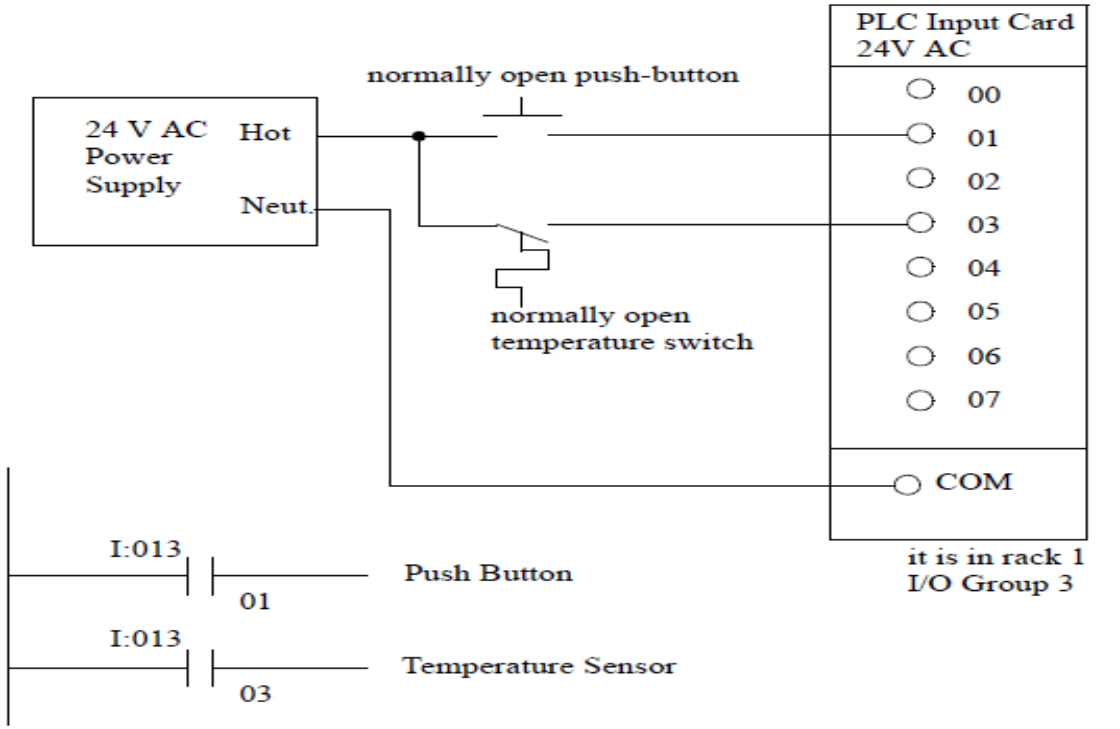




Special I/O Modules

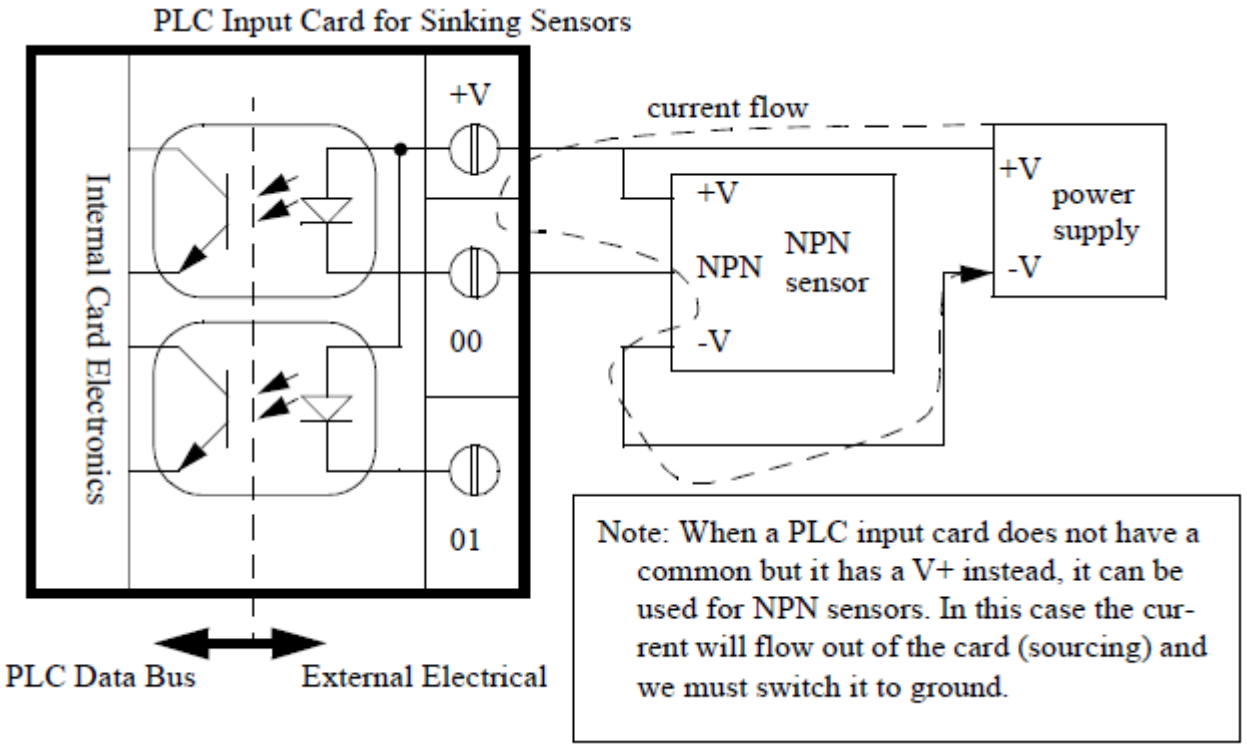
- High-Speed Counter Module
- Thumb-Wheel Module
- TTL Module
- Encoder-Counter Module
- BASIC or ASCII Module
- Stepper-Motor Module
- BCD-Output Module
- PID Module
- Servo Module
- Communications Module
- Language Module
- Speech Module

Typical Configurations for PLC

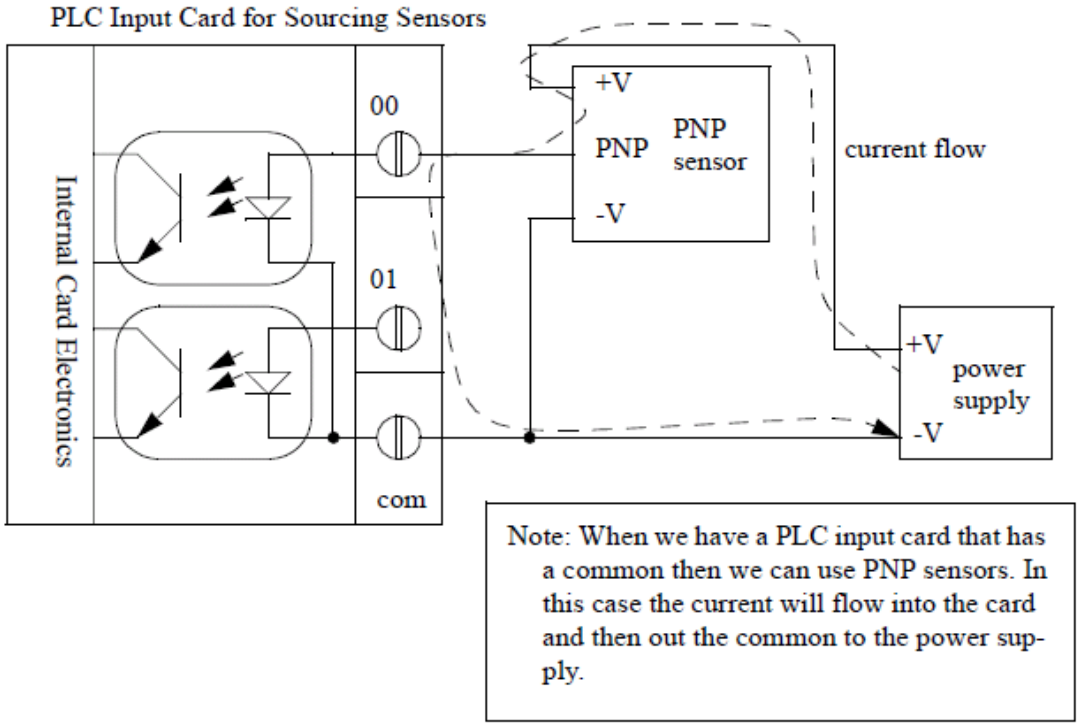


Note: inputs are normally high impedance. This means that they will use very little current.

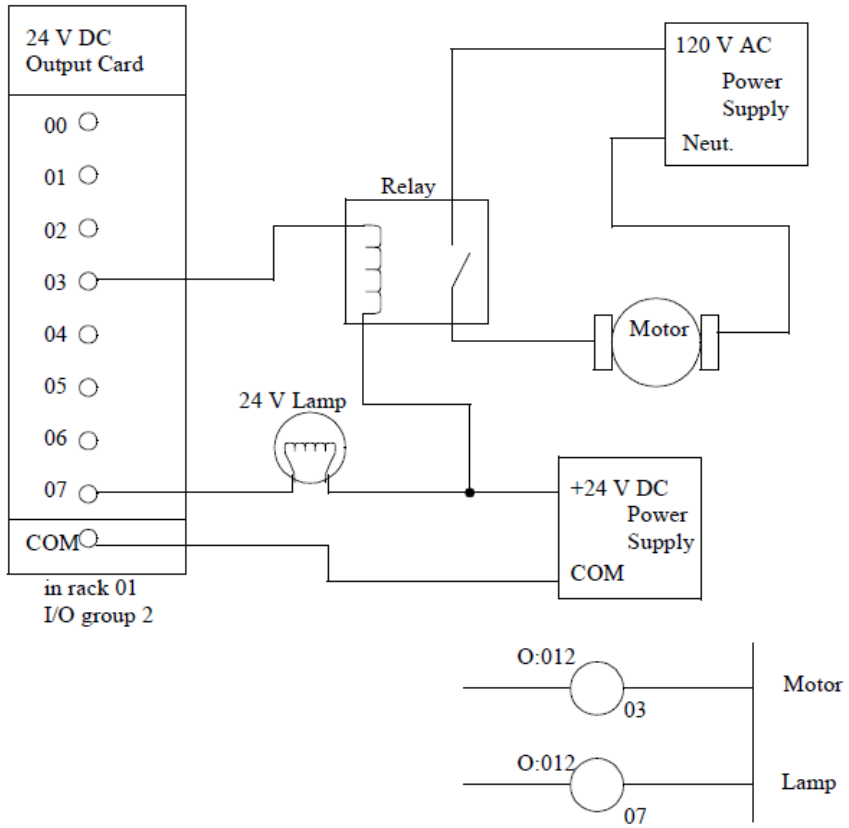
A PLC Input Card for Sinking Sensors



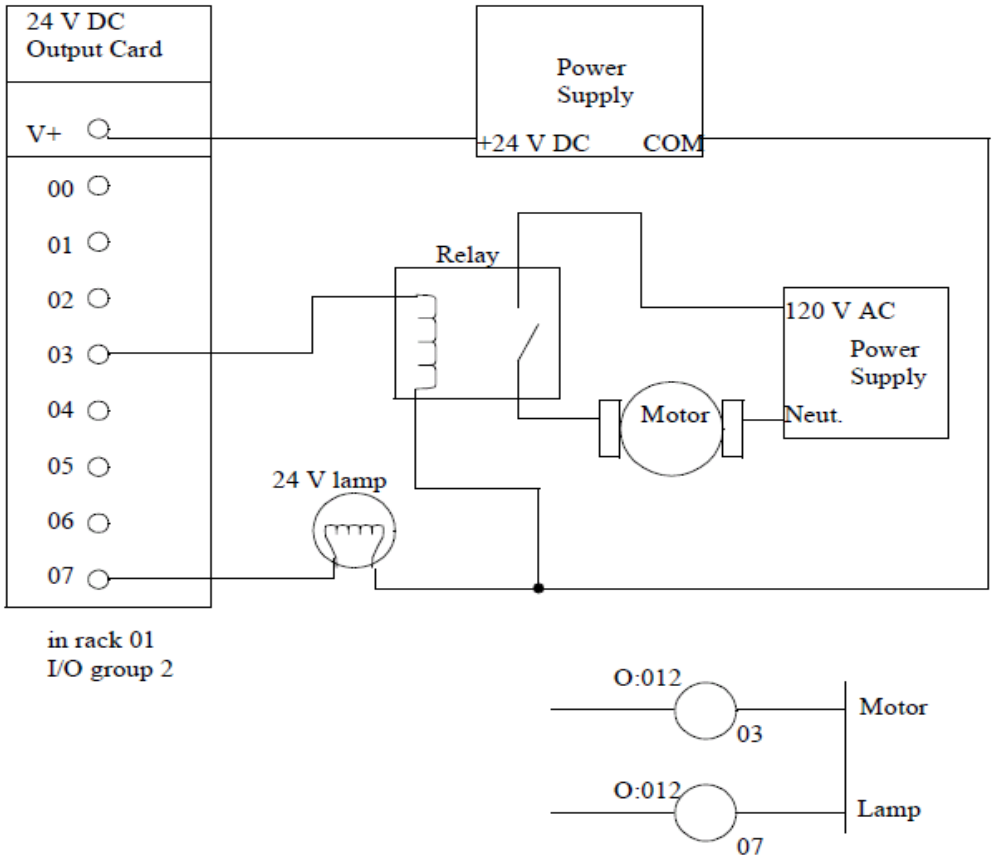
PLC Input Card for Sourcing Sensors



A 24Vdc Output Card (Sinking)



24Vdc Output Card With a Voltage Input (Sourcing)



PLC PROGRAMMING

The 5 most popular types of PLC Programming Languages are:

1. Ladder Diagram (LD)
2. Sequential Function Charts (SFC)
3. Function Block Diagram (FBD)
4. Structured Text (ST)
5. Instruction List (IL)

PLC PROGRAMMING- LADDER DIAGRAM

Ladder Diagram (LD)

- Ladder logic is the simplest form of PLC programming.
- It is also known as “relay logic”. The relay contacts used in relay- controlled systems are represented using ladder logic.
- Functional Block Diagram (FBD) is a simple and graphical method to program multiple functions in PLC

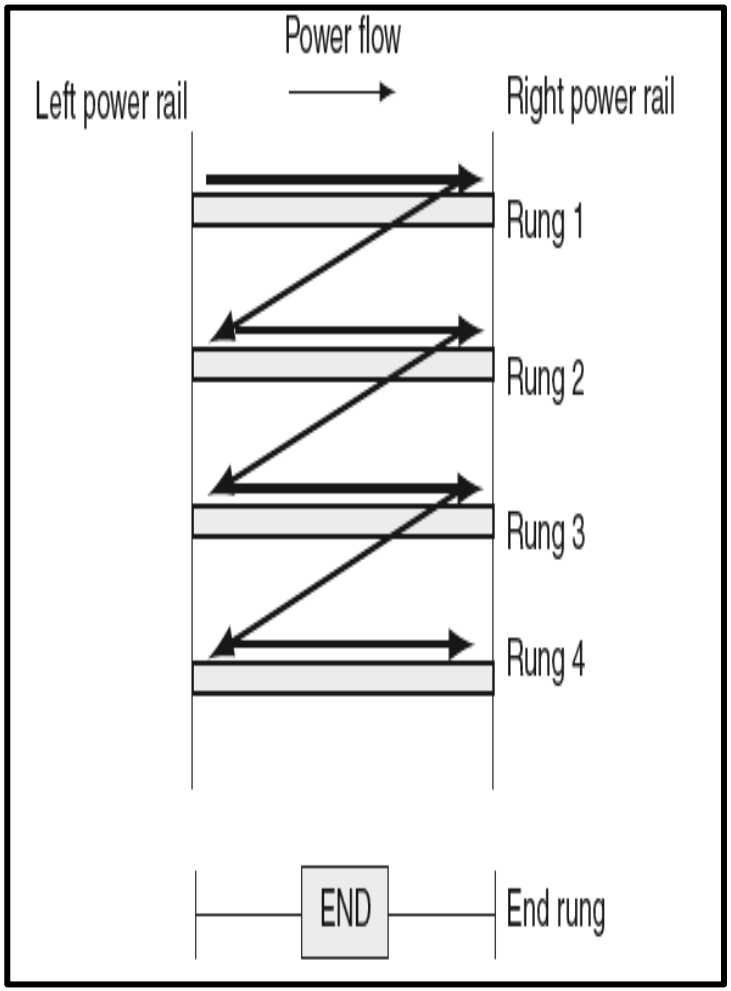
Advantages of the Ladder Diagram (LD)

- It is easily programmed and has an easily understood programming language.
- It has flexibility in programming and reprogramming.
- Troubleshooting is easier and faster

PLC PROGRAMMING- LADDER DIAGRAM

Rules to draw the ladder logic diagram

- The ladder diagram consists of two vertical lines representing the power rails.
- Circuits are connected as horizontal lines, i.e., the rungs of the ladder, between these two verticals.



PLC PROGRAMMING

Ladder Diagram Programming: The ladder diagram language is basically a *symbolic set of instructions used to create the con*troller program.

The three fundamental symbols that are used to translate relay control logic to contact symbolic logic are (RELAY TYPE INSTRUCTIONS)

EXAMINE IF CLOSED,

EXAMINE IF OPEN, and

OUTPUT ENERGIZE

PLC PROGRAMMING

Normally Open

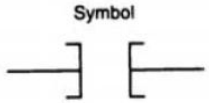
- Analogous to the normally open relay contact. For this instruction.
- We ask the processor to EXAMINE IF (the contact is) CLOSED.
- The status bit will be either1(ON) or 0 (OFF)
- The status bit is examined for an ON condition.
- If the status bit, is 1 (ON). Then the instruction is TRUE.

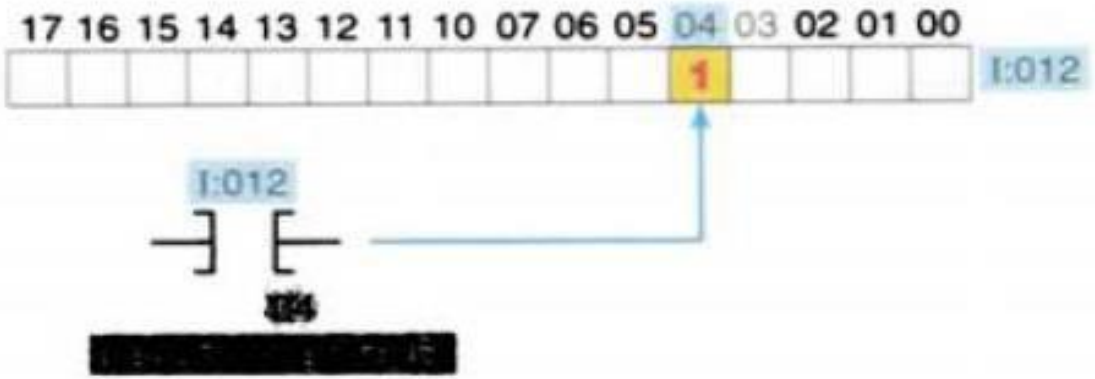
If the status bit is 0 (OFF). Then the instruction is FALSE.

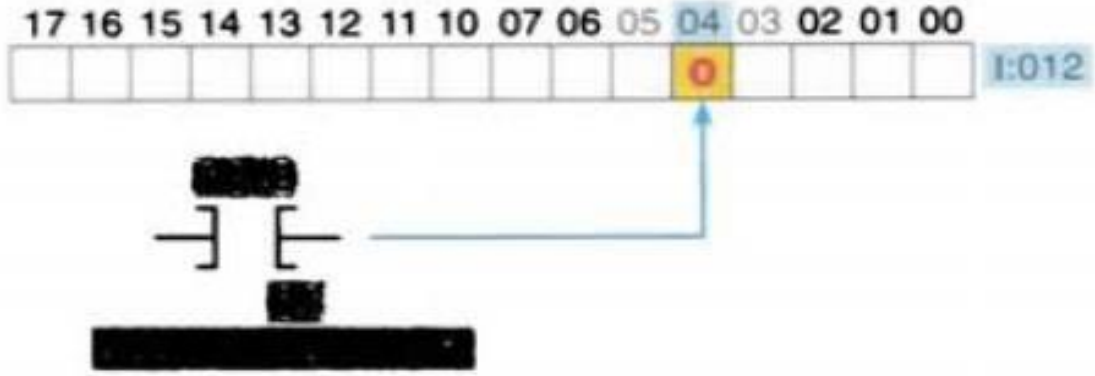
Symbol

PLC PROGRAMMING

If the status bit is 0 (OFF). Then the instruction is FALSE.





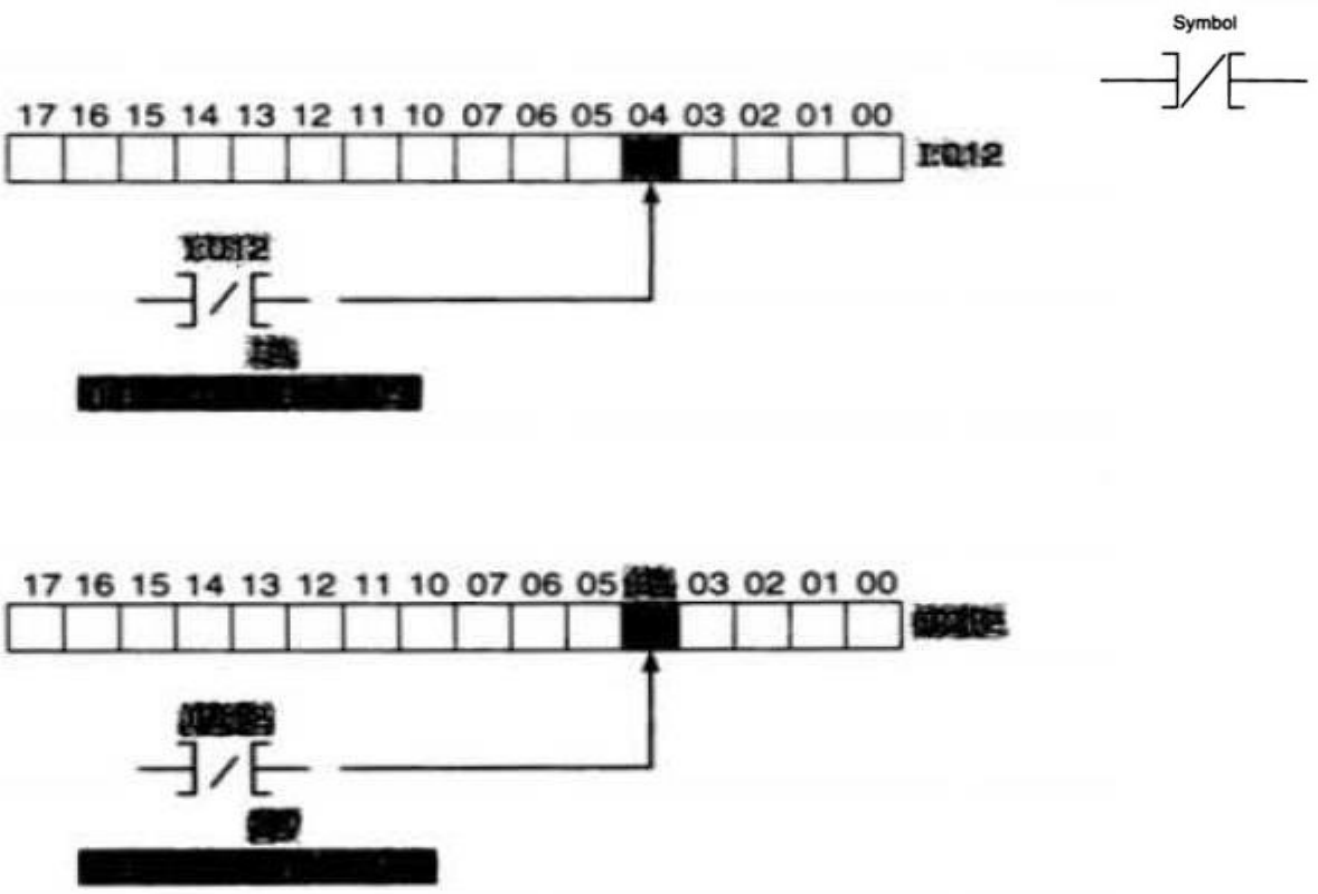


PLC PROGRAMMING

Normally Closed

- Instruction, we ask the processor to EXAMINE IF (the contact is) OPEN.
- The status bit will be either 1 (ON) or 0 (OFF).
- The status bit is examined for an OFF condition.
- If the status bit is 0 (OFF), then the instruction is TRUE.
- It the status bit is 1 (ON), then the Instruction is FALSE.

PLC PROGRAMMING



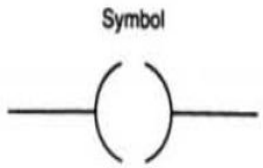
PLC PROGRAMMING

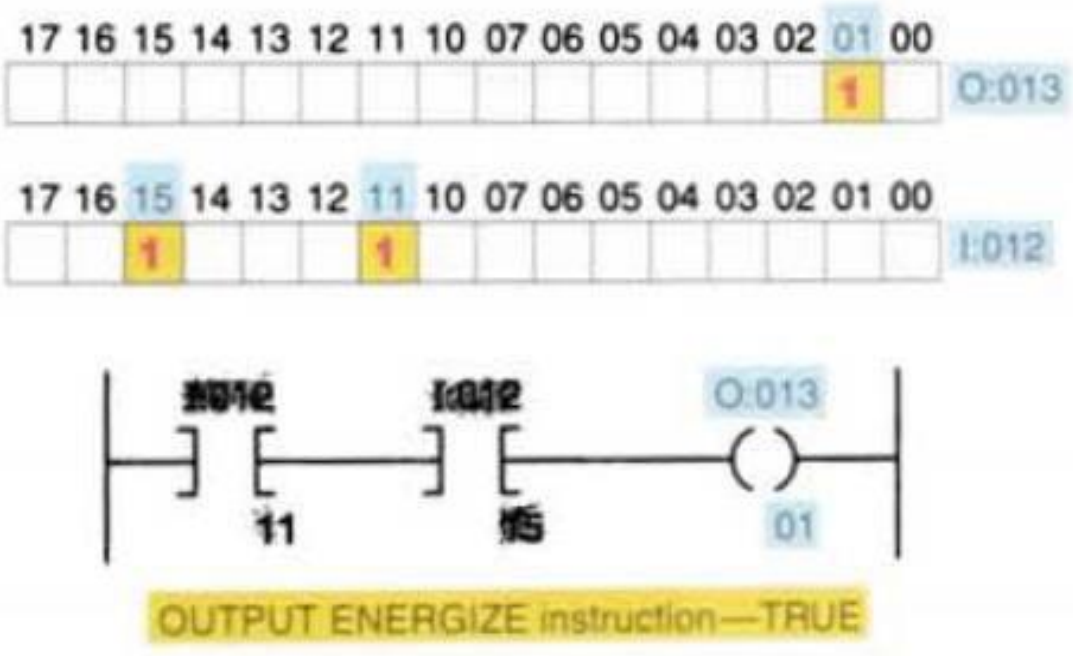
Relay Coil

- The processor (makes it is Instruction true (analogous to energizing a coil) when
- there is a path 01 true XIC and XIO instructions in the rung.
- If any left to right path of input conditions is TRUE. the output is energized (turned ON).
- The status bit 01 the addressed OUTPUT Energize instruction is set to 1 (ON) when
- the rung is TRUE.

PLC PROGRAMMING

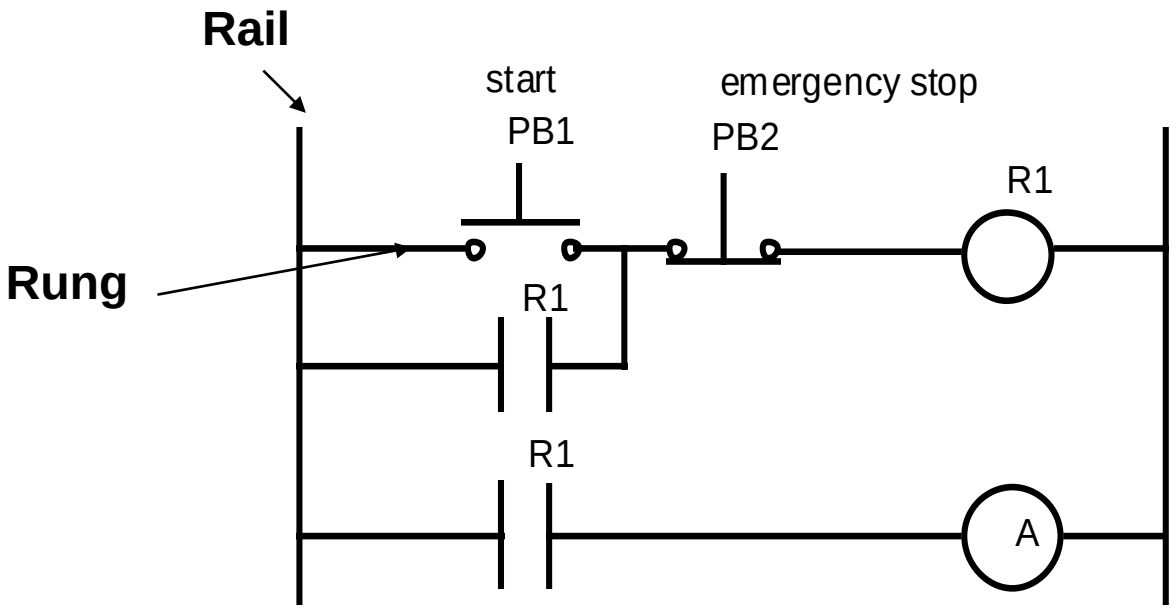
The status bit 01 the addressed OUTPUT Energize instruction is reset 10 0 (OFF) when the rung is FALSE.



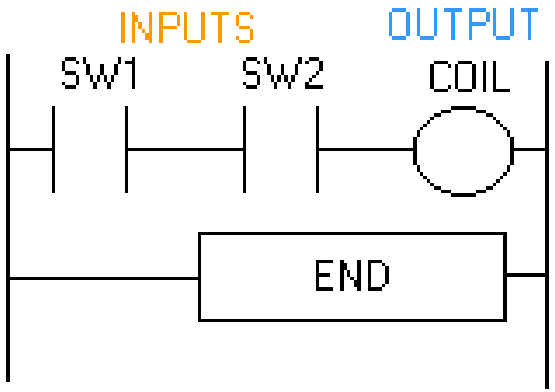


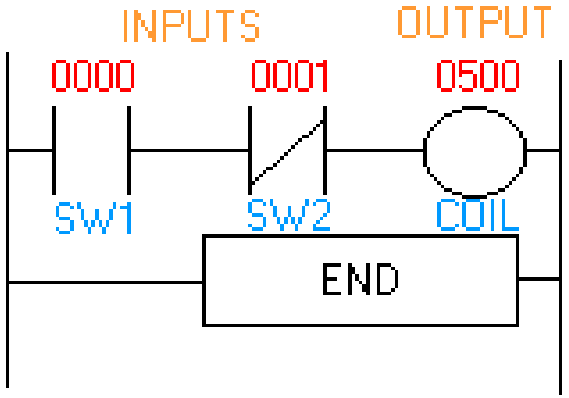
LADDER DIAGRAM

A ladder diagram (also called contact symbology) is a means of graphically representing the logic required in a relay logic system.

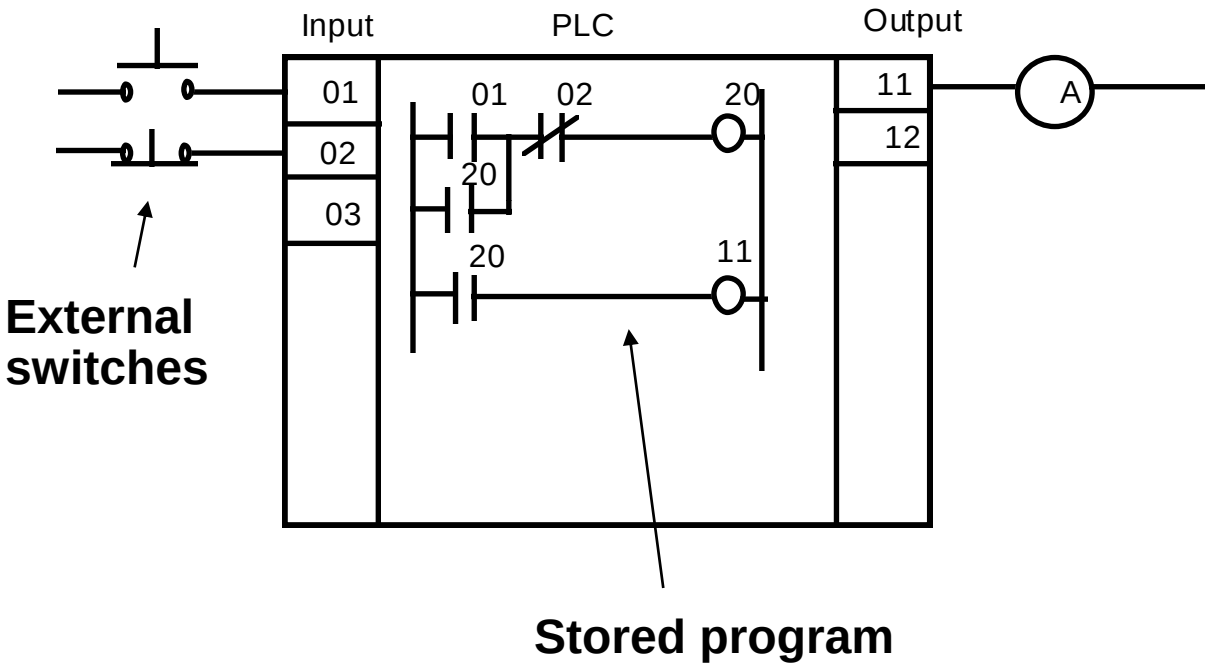


LADDER REPRESENTATION

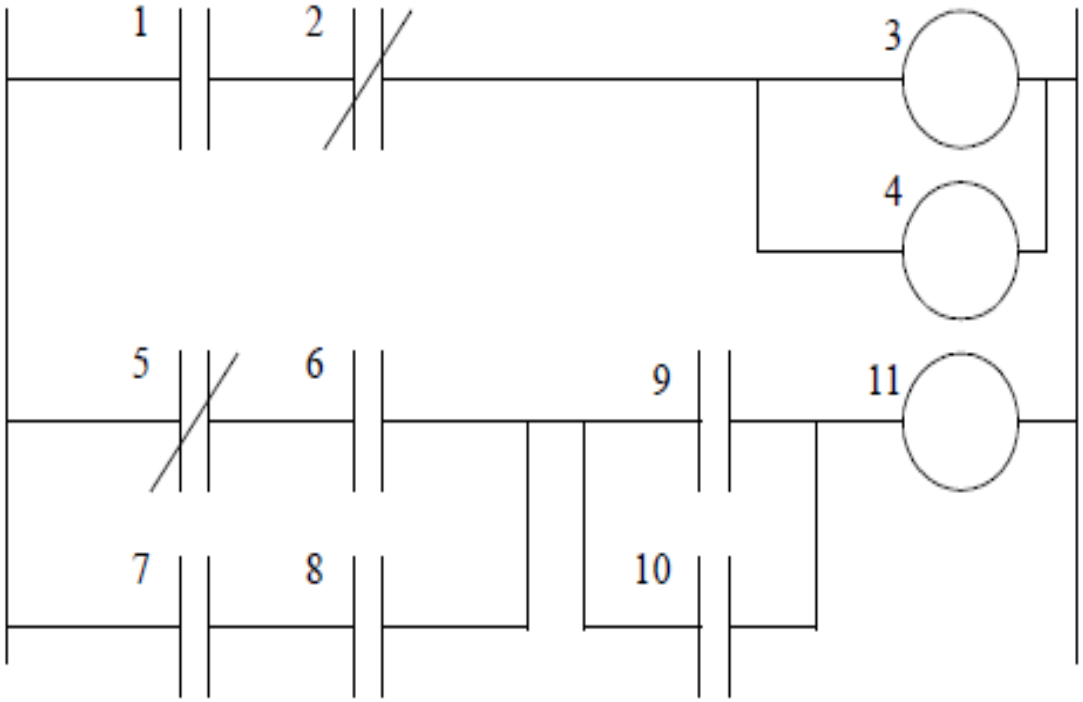




PLC WIRING DIAGRAM

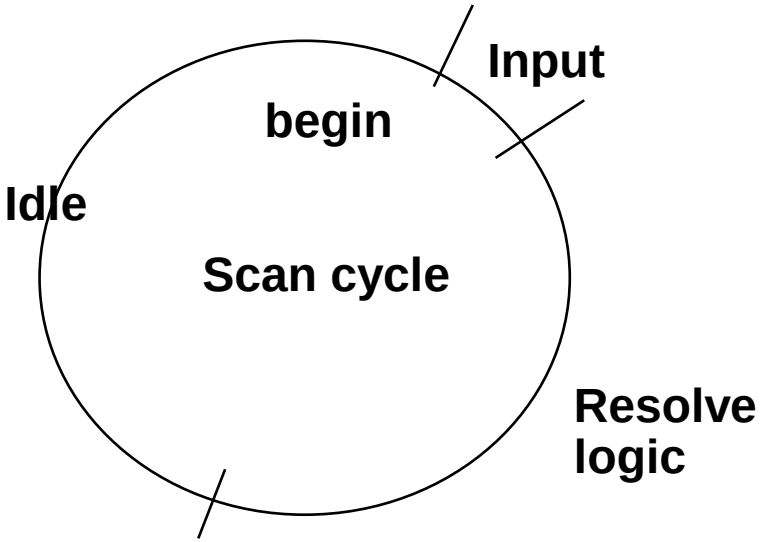


LADDER LOGIC EXECUTION SEQUENCE

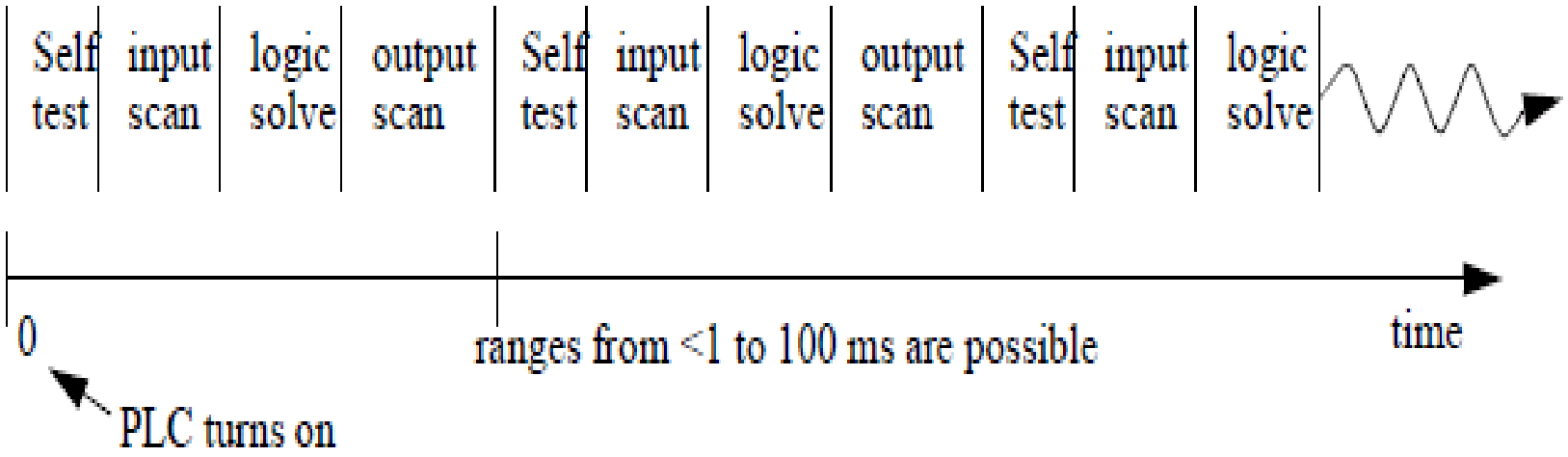


PLC SCANNING OF LADDER PROGRAM

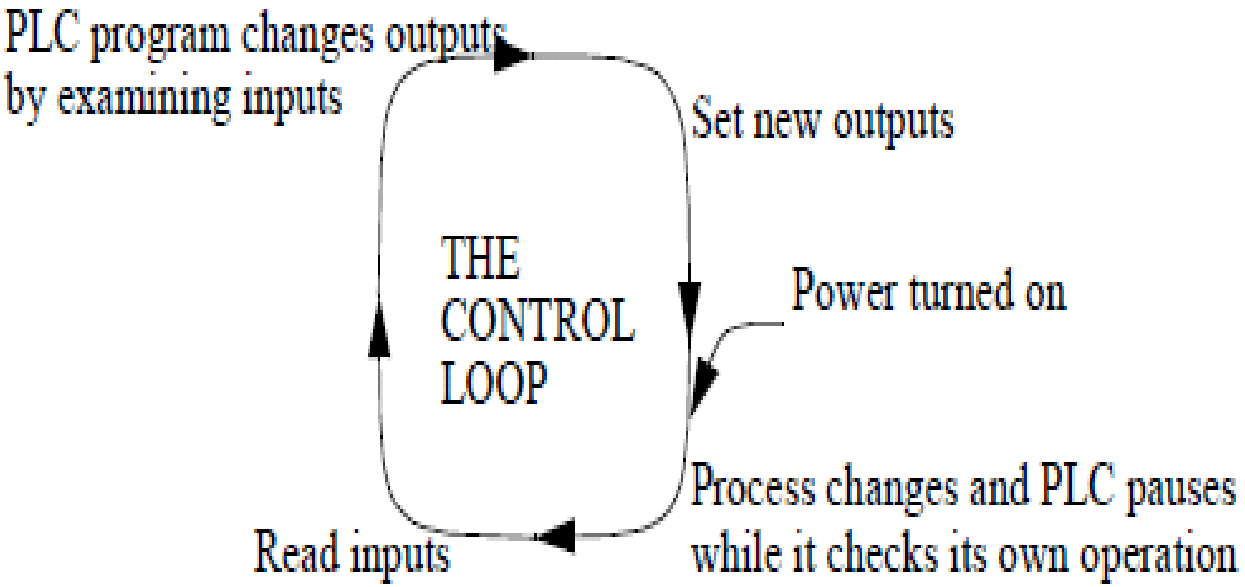
A PLC resolves the logic of a ladder diagram (program) rung by rung, from the top to the bottom. Usually, all the outputs are updated based on the status of the internal registers. Then the input states are checked, and the corresponding input registers are updated. Only after the I/Os have been resolved, is the program then executed. This process is run in an endless cycle. The time it takes to finish one cycle is called the scan time.



PLC Scan Cycle



Scan Cycle of a PLC



Seven step sequence for development and implementation of logic:

- Development of block diagram or P&ID (Piping and Instrumentation Diagram).
- Listing of input and output devices
- Development of a flow chart of the process
- Developing a cause-and-effect diagram
- Actual development of logic (ladder logic)
- Validation of logic on simulators; debugging, safety interlocks
- Actual execution; optimization

PLC INSTRUCTIONS

1) Relay,
2) Timer and counter,
3) Program control,
4) Arithmetic,
5) Data manipulation,
6) Data transfer, and
7) Others, such as sequencers.

LOGIC STATES

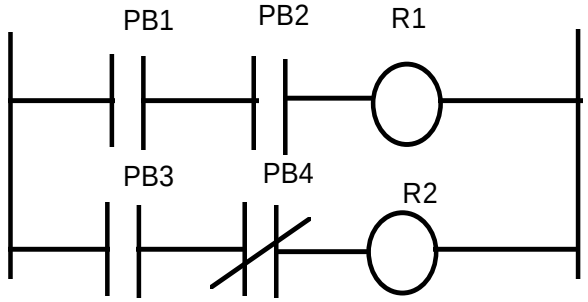
ON : TRUE, contact closure, energize, etc.

OFF: FALSE, contact open , de-energize, etc.

Do not confuse the internal relay and program with the external switch and relay. Internal symbols are used for programming. External devices provide actual interface.

AND & OR LOGIC

AND

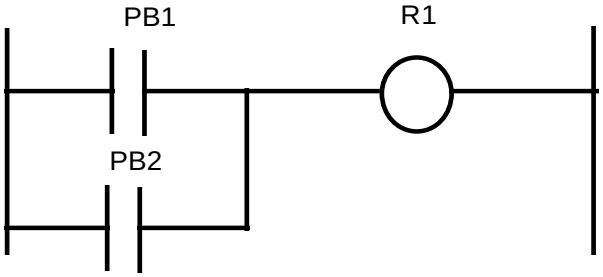


R1 = PB1.AND.PB2

R2 = PB2.AND.~PB4

I/P A	I/P B	Output
0	0	0
1	0	0
0	1	0
1	1	1

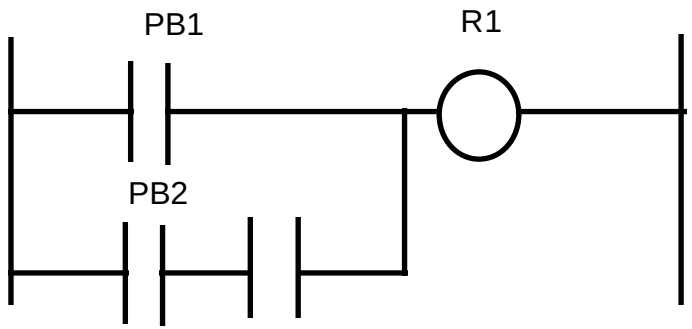
OR



R1 = PB1 .OR. PB2

I/P A	I/P B	Output
0	0	0
1	0	1
0	1	1
1	1	1

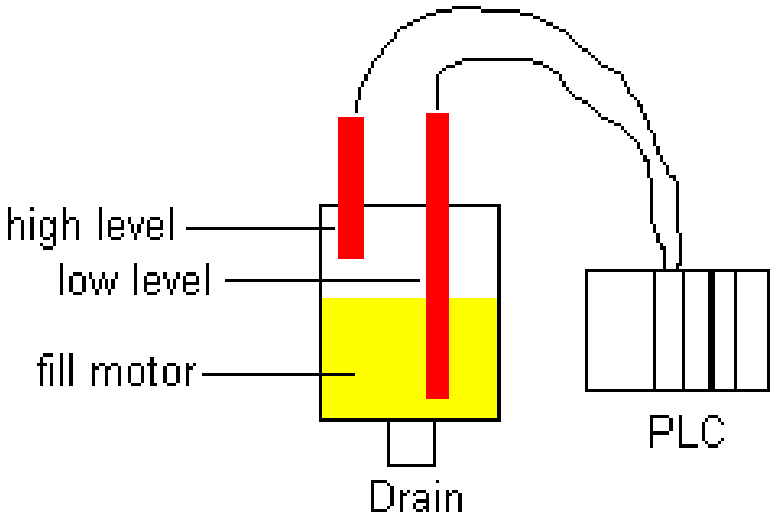
COMBINED AND & OR LOGIC



R1 = PB1 .OR. (PB2 .AND. PB3)

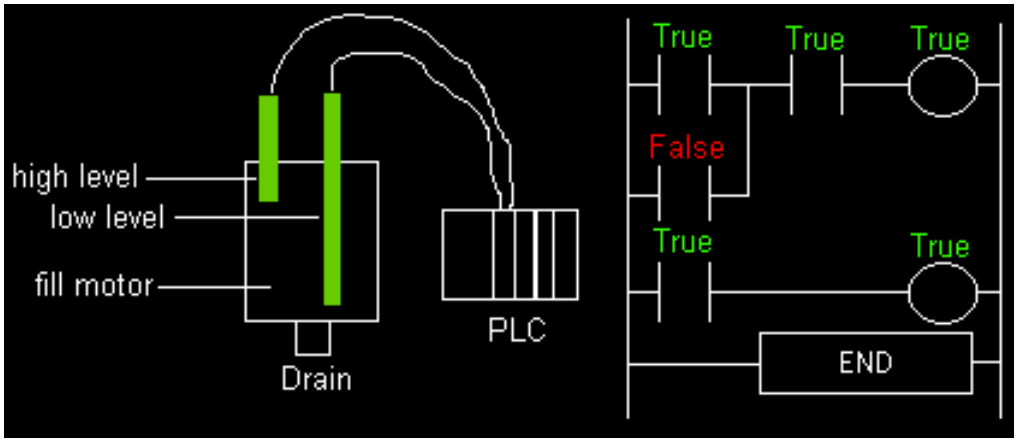
Programming a PLC

Oil is consumed randomly. The tank needs to be refilled by turning on a pump. Two hydrostatic switches are used to detect a high and low level.

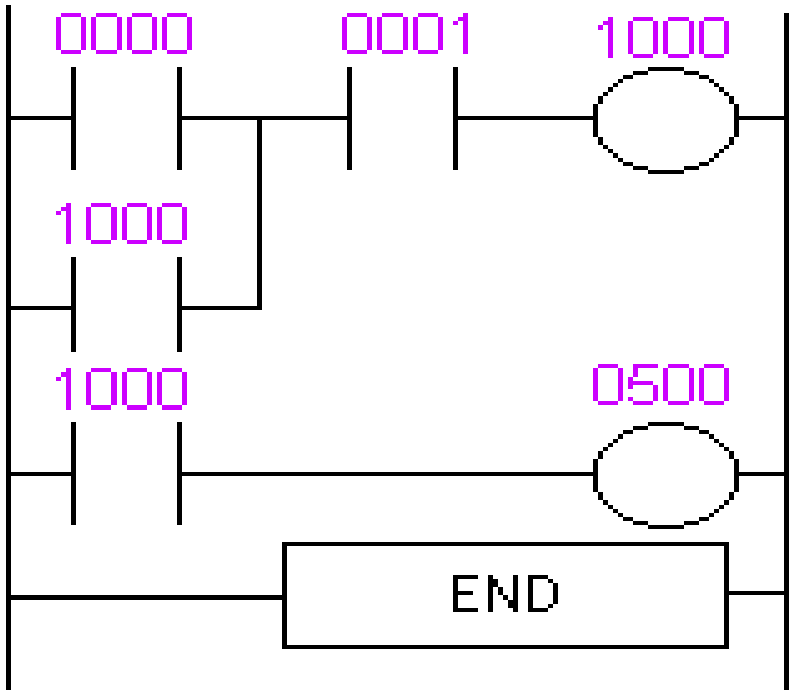


Dispensing oil from a tank

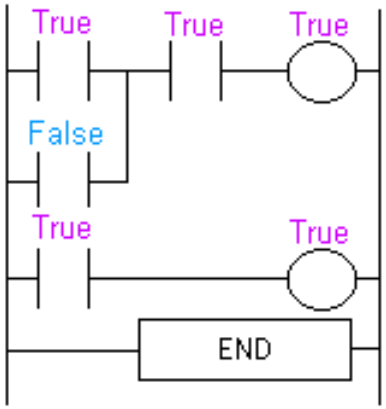
How does it work?

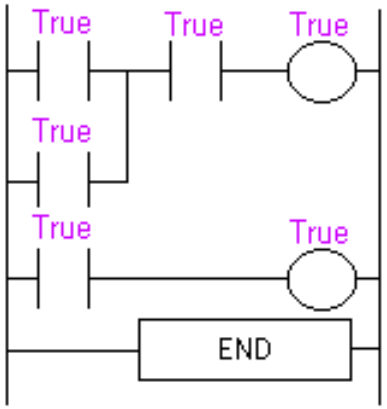


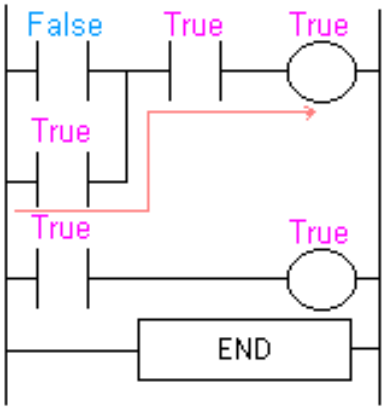
Ladder Logic for Tank

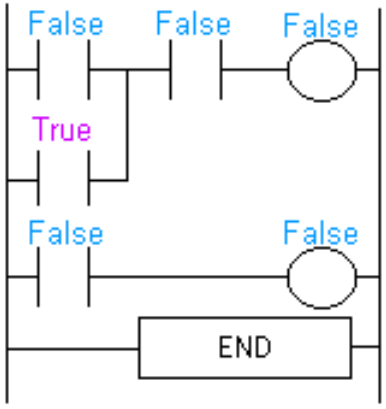


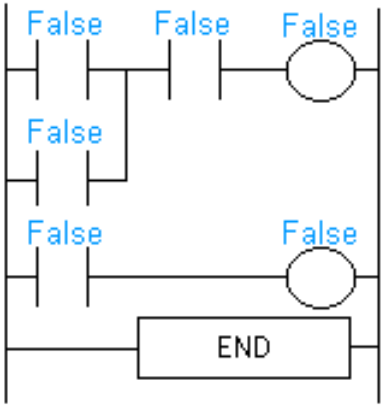
Logic for Ladder Solution

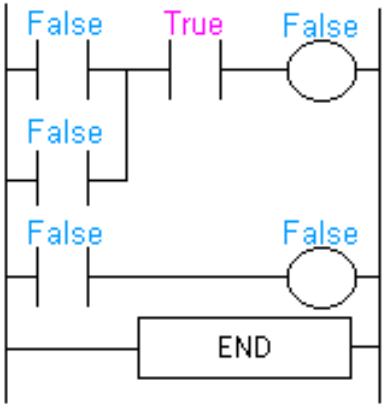










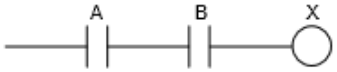


PLC PROGRAMMING

AND, OR LOGIC

AND		
Input A	Input B	Out X
0	0	0
0	1	0
1	0	0
1	1	1

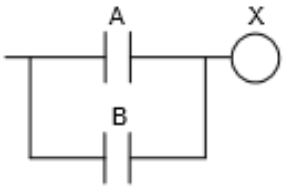
$A \cdot B = X$



LD A
AND B
OUT X

OR		
Input A	Input B	Out X
0	0	0
0	1	1
1	0	1
1	1	1

$A + B = X$



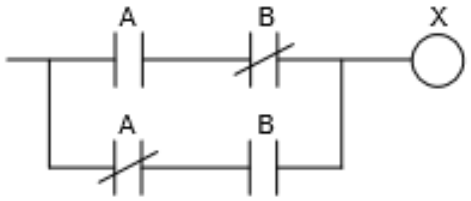
LD A
OR B
OUT X

PLC PROGRAMMING

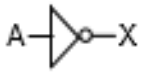
NOT, XOR LOGIC

XOR		
Input A	Input B	Out X
0	0	0
0	1	1
1	0	1
1	1	0

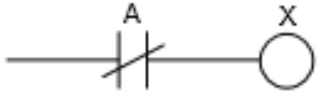
$$(A \cdot \overline{B}) + (\overline{A} \cdot B) = X$$



NOT	
Input A	Out X
0	1
1	0



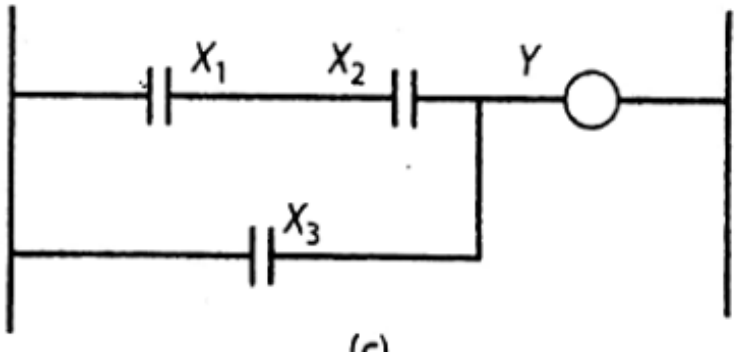
$$\overline{A} = X$$



PLC PROGRAMMING

Draw a Ladder Diagram of the Equation given below

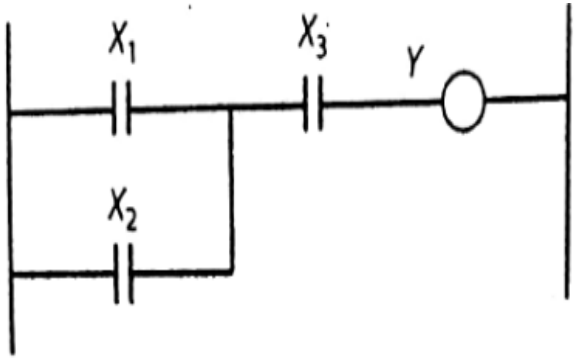
Y=(X1X2)+X3



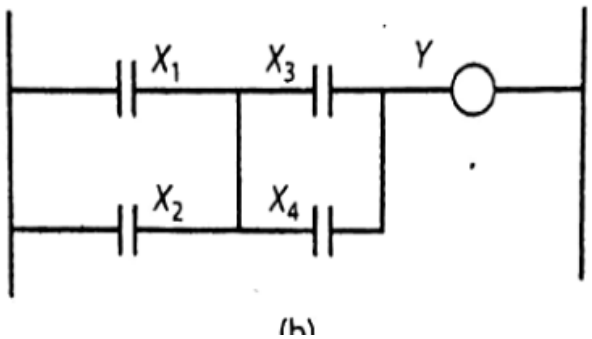
PLC PROGRAMMING

Draw a Ladder Diagram of the Equation given below

Y=(X1+X2)X3



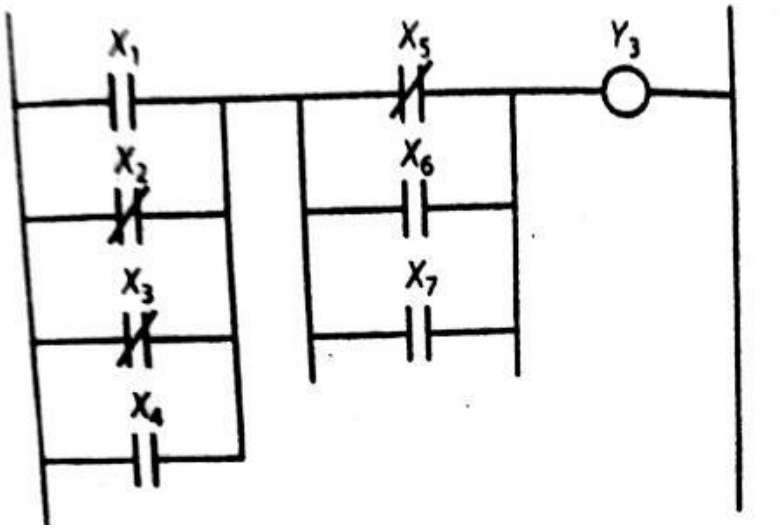
Y=(X1+X2)(X3+X4)



(b)

PLC PROGRAMMING

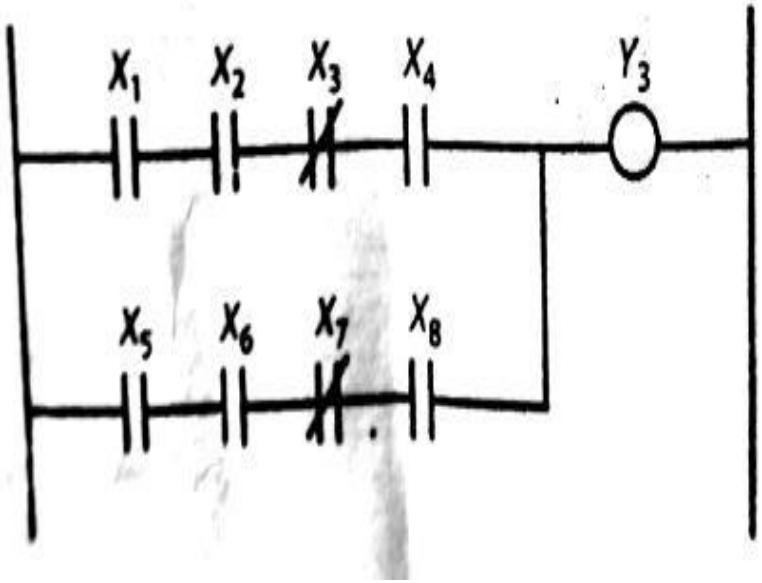
Draw a PLC program for the given Ladder Diagram




```
LD X1
ORI X2
ORI X3
OR X4
LDI X5
OR X6
OR X7
ANB
OUT Y3
```

PLC PROGRAMMING

Draw a PLC program for the given Ladder Diagram



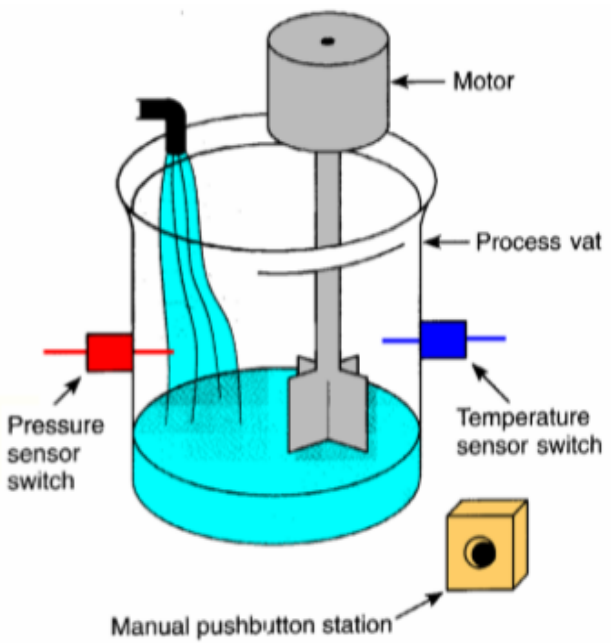

```
LD X1
AND X2
ANI X3
AND X4
LD X5
AND X6
ANI X7
AND X8
ORB
OUT Y3
```

PLC APPLICATIONS

PLC Mixer Process Control Problem

Mixer motor to automatically stir the liquid in the vat when the temperature and pressure reach preset values

Alternate manual pushbutton control of the motor to be provided

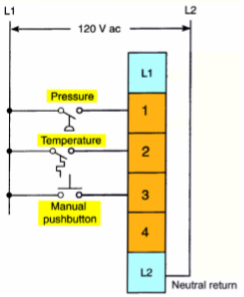


The temperature and pressure sensor switches close their respective contacts when conditions reach their preset values

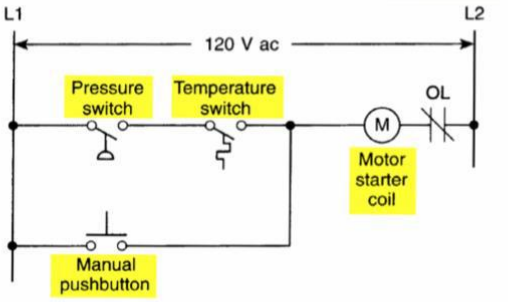
PLC APPLICATIONS

PLC Input Module Connections

- The same input field devices are used
- These devices are wired to the input module according to the manufacturer's labeling scheme



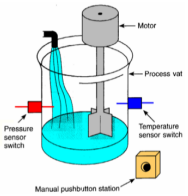
Process Control Relay Ladder Diagram



Motor starter coil is energized when both the pressure and temperature switches are closed or when the manual pushbutton is pressed

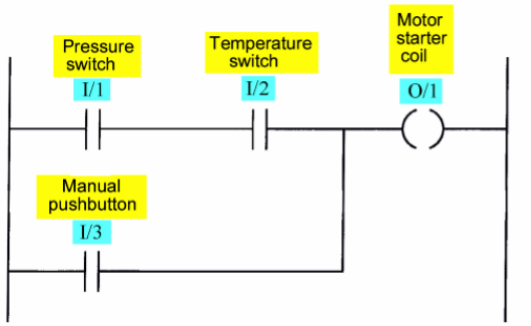
PLC Mixer Process Control Problem

Mixer motor to automatically stir the liquid in the vat when the temperature and pressure reach preset values



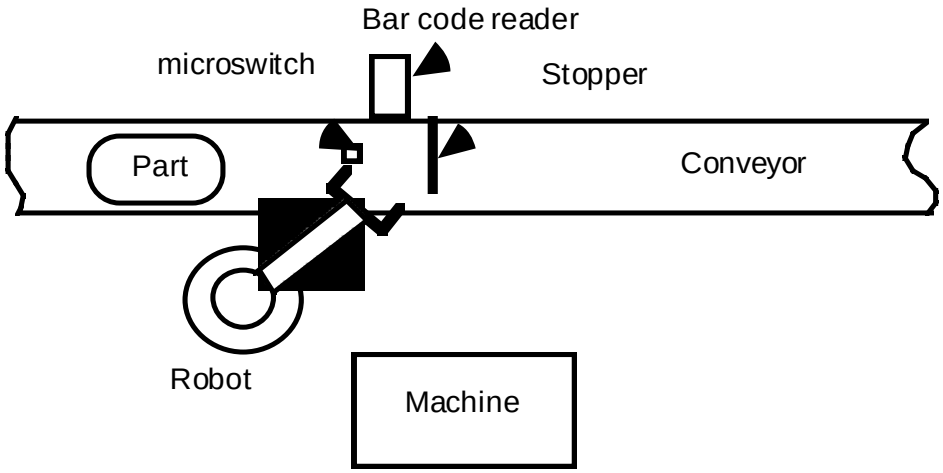
nd
vitches
ve contacts when conditions reach

PLC Ladder Logic Program



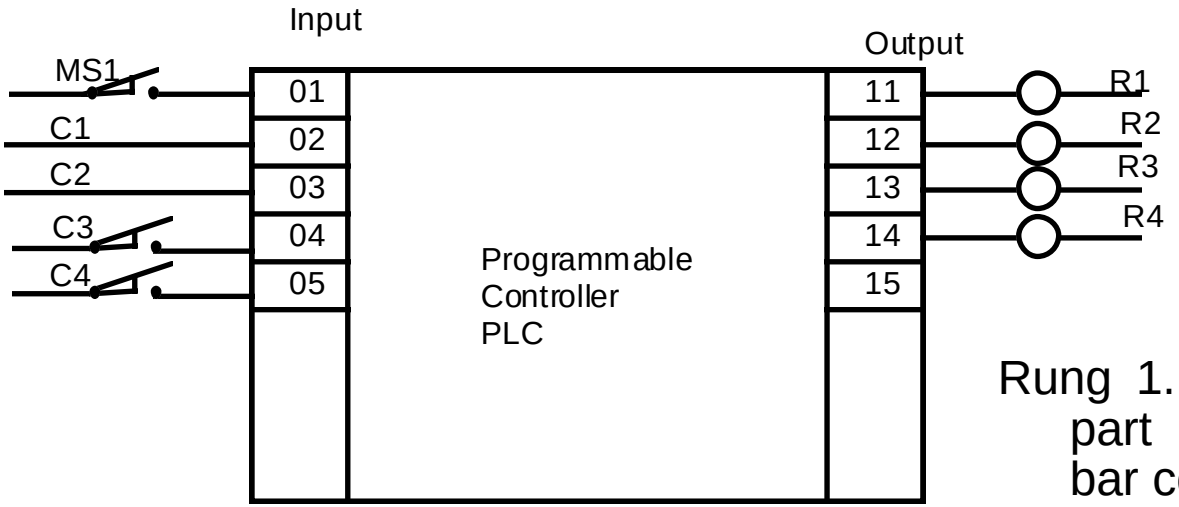
- The format used is similar to that of the hard-wired relay circuit

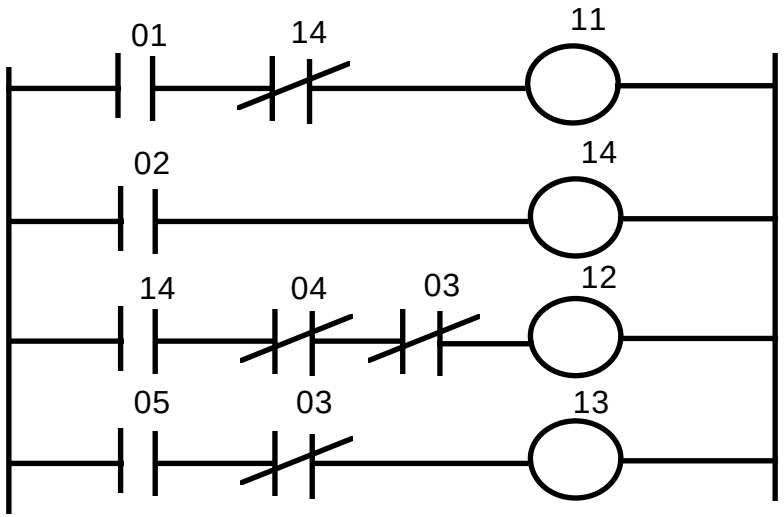
PROGRAMMING EXAMPLE 2



id	description	state	explanation
MSI	microswitch	1	part arrive
R1	output to bar code reader	1	scan the part
C1	input from bar code reader	1	right part
R2	output robot	1	loading cycle
R3	output robot	1	unloading cycle
C2	input from robot	1	robot busy
R4	output to stopper	1	stopper up
C3	input from machine	1	machine busy
C4	input from machine	1	task complete

SOLUTION





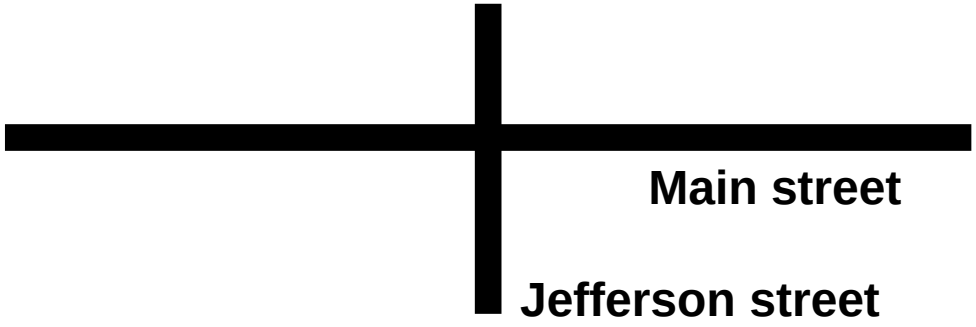
Rung 1. If part arrives and no part is stopped, trigger the bar code reader.

Rung 2. If it is a right part, activate the stopper.

Rung 3. If the stopper is up, the machine is not busy and the robot is not busy, load the part onto the machine.

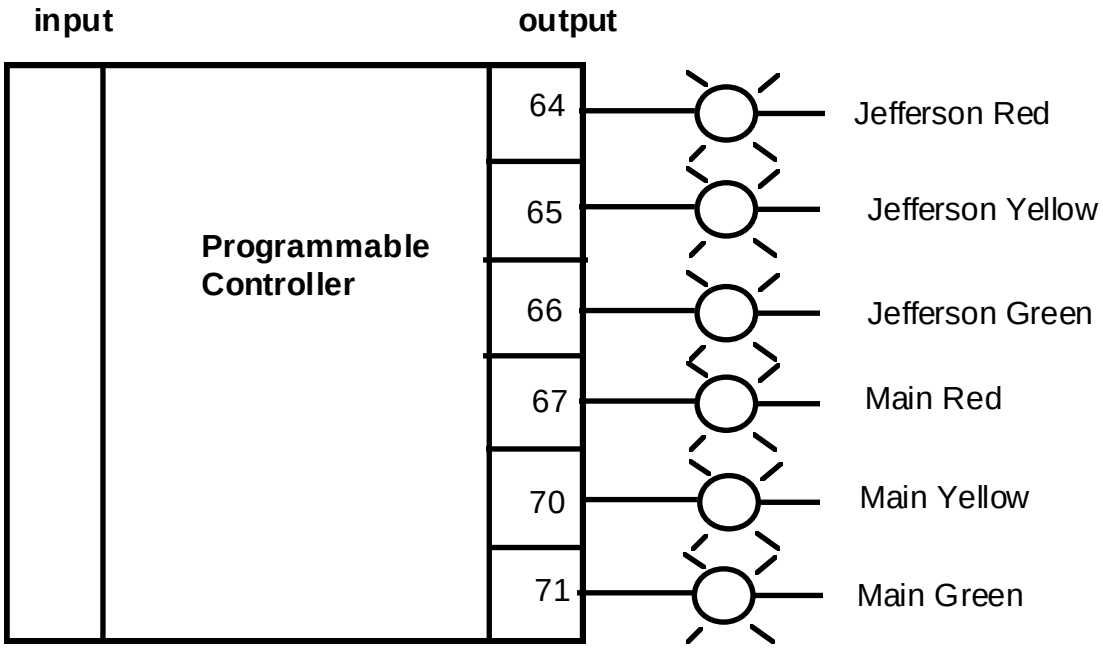
Rung 4. If the task is completed and the robot is not busy, unload the machine.

EXAMPLE 3 TRAFFIC LIGHTS

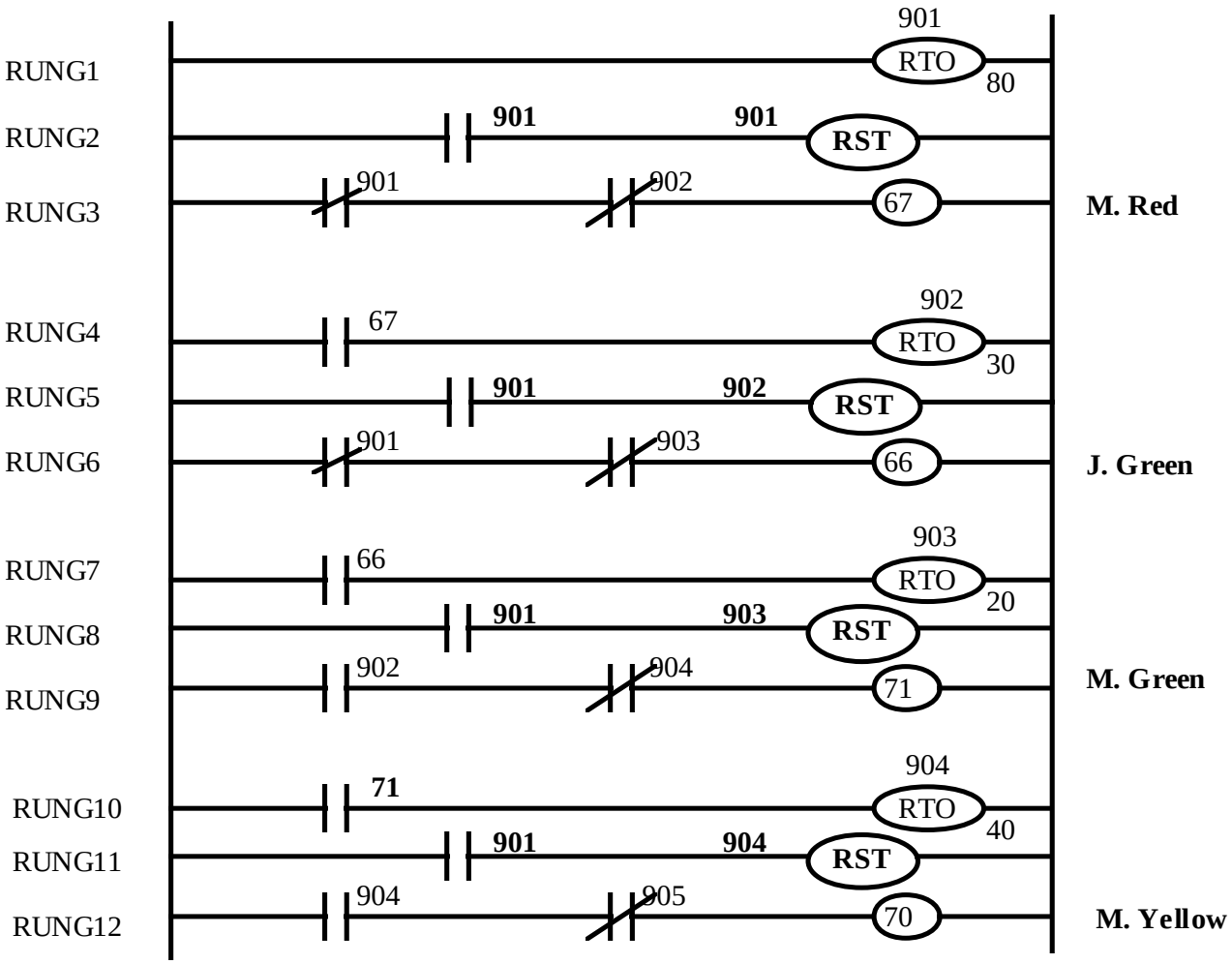


	Cycle time		
Street	Red	Yellow	Green
Main	3	1	4
Jefferson	5	1	2

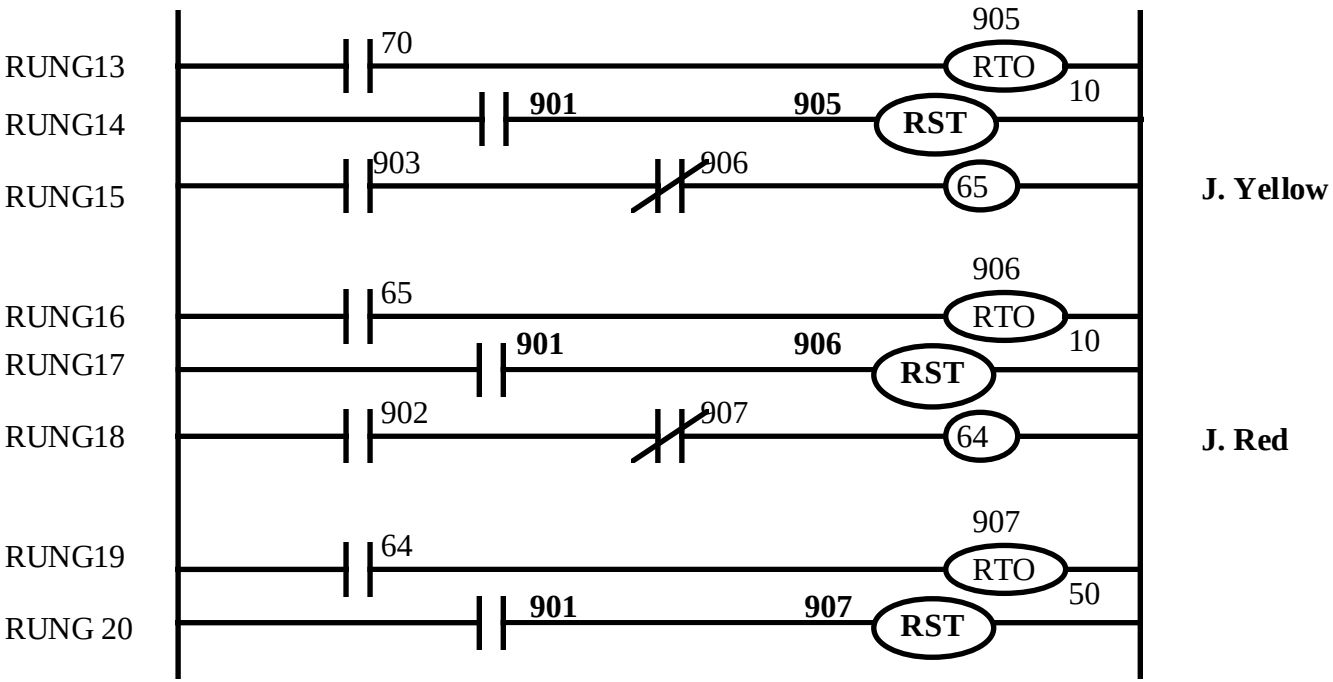
WIRING DIAGRAM



PROGRAM (1)


RUNG1
901
RTO
80
RUNG2
901
901
RST
RUNG3
901
902
67
M. Red
RUNG4
67
902
RTO
30
RUNG5
901
902
RST
RUNG6
901
903
66
J. Green
RUNG7
66
903
RTO
20
RUNG8
901
903
RST
RUNG9
902
904
71
M. Green
RUNG10
71
904
RTO
40
RUNG11
901
904
RST
RUNG12
904
905
70
M. Yellow

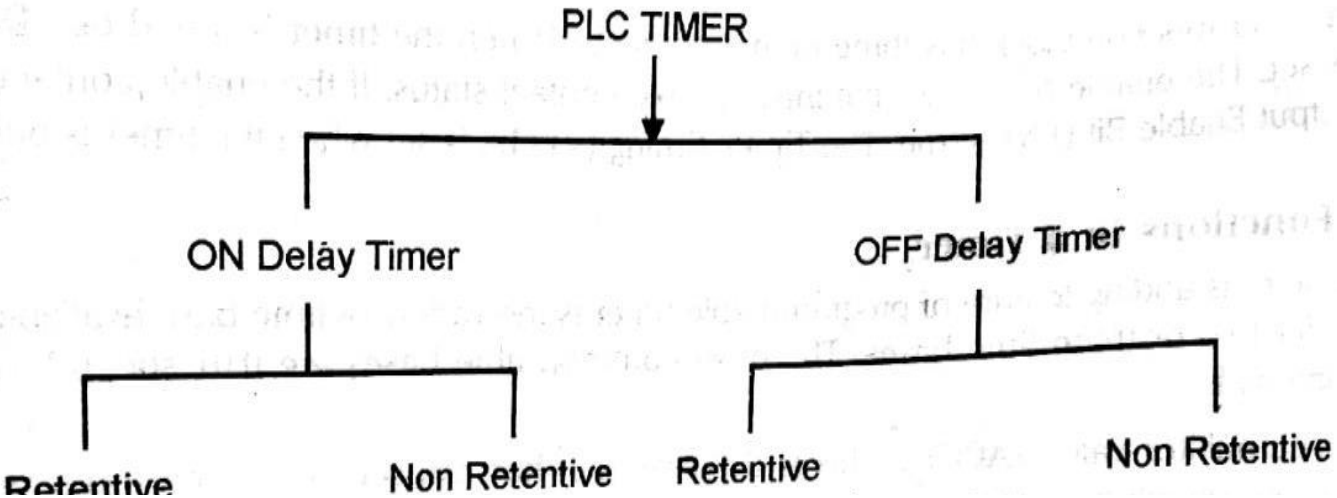
PROGRAM (2)


RUNG13
RUNG14
RUNG15
RUNG16
RUNG17
RUNG18
RUNG19
RUNG 20
70
905
RTO
10
901
905
RST
903
906
65
J. Yellow
65
906
RTO
10
901
906
RST
902
907
64
J. Red
64
907
RTO
50
901
907
RST

TIMERS AND COUNTERS

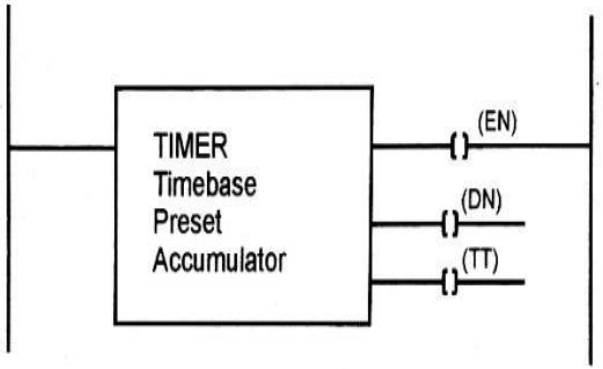
A timer is device that introduce a time delay in a circuit or system during its ON or OFF condition. PLC timer, the time delay is introduced by programming

Classification of timers



TIMERS AND COUNTERS

Functional Block of Timer



- When Timer is time out, DONE BIT (DN) is set.
- The ENABLE BIT follows the input enable contact status
- If the enable contact is true then output ENABLE BIT (EN) is true
- The timer timing (TT) bit is set when the timer is operating

SCADA

- **Supervisory Control and Data Acquisition (SCADA)**

Supervisory Control and Data Acquisition (SCADA) is a control system architecture that uses computers, networked data communications and graphical user interfaces for high-level process supervisory management also uses peripheral devices such as PLC and PID controllers to interface with the process plant or machinery.

- **Need for SCADA**
- **Objectives of SCADA**
- **SCADA Architecture**
- **Functions of SCADA**
- **SCADA Usages**

Thank you!