UNIT IV

PROGRAMMABLE LOGIC CONTROLLER

- Introduction Programmable Logic Controller
- Basic structure of Programmable Logic Controller
- Input and output processing
- Programming
- Mnemonics
- Timers, counters and internal relays
- Data handling
- Selection of Programmable Logic Controller

Introduction Programmable Logic Controller

Need of PLC

- The programmable logic controller (PLC) device is widely used in industry to automate event based control, interlocking of operations and sequencing of operations. PLC is used in almost all process industries, where there is requirement of process safety and interlocks e.g. thermal power stations, steel industry, cement industry, pharmaceutical industry, petrochemical industry, fertilizer industry etc.

Definition

- A PLC is a digitally operating electronic device which uses a programmble memory for internal storage of instructions for implementing specific functions, such as logic sequencing, timing, counting and control through digital or analog input/output modules.

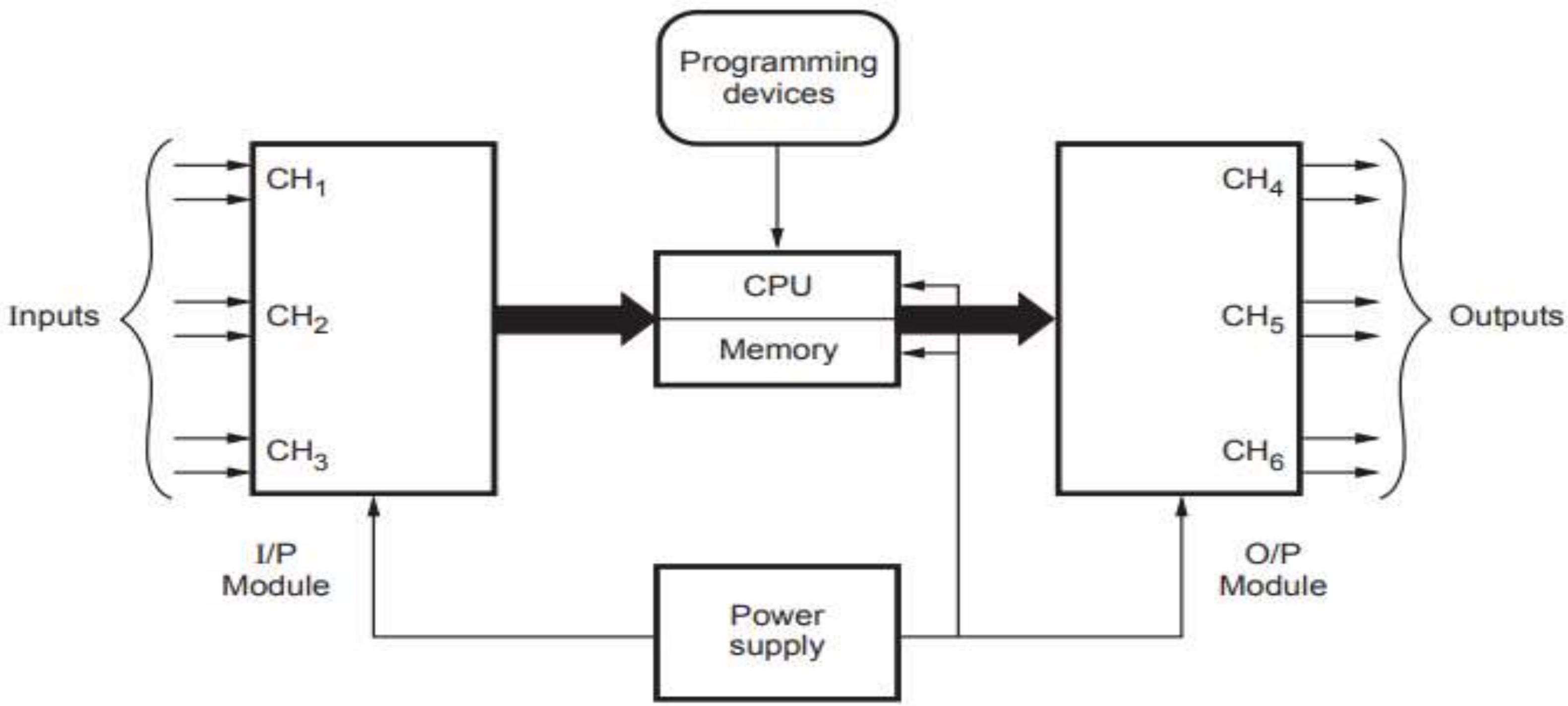
4.2.1 Features of PLC

1. Compact and rugged in construction.
2. PLC can be easily programmed.
3. Reprogramming is very easy.
4. It gives noiseless operation.
5. More reliable, low maintenance cost.
6. Interfacing of computer is possible for further processing and analysis.
7. Controlled outputs are available in different voltages [DC : +5 V, +12 V, + 24 V, AC : 9 V, 18 V, 24 V, 110 V]
8. Inbuilt timers, counters and registers.
9. PLCs can store data and programs.
10. I/O channels are isolated hence interfacing with sensors and actuators are easy.

4.3 Basic Components of PLC

- PLC consists of following blocks -
  1. Input module
  2. CPU
  3. Memory
  4. Programming device
  5. Output module

Fig. 4.3.1 shows basic PLC architecture.



1. Input module

- Inputs are real world signal giving the controller real time status of variables. These variables can be analog or digital. Typical analog input can be from process devices such as limit switch, thumbwheel switch, transducers such as thermocouples, RTDs, flow, pressure, strain gauges are converted into binary signals and transmitted over the input / output bus to the CPU.
- The input modules have certain number of channels per module. Each channel is equipped with an indicator light to show if the particular input is ON or OFF.

2. CPU

- It organises all controller activity, the CPU electronically scans the control plan logic stored in memory along with the status of input. It then executes a specified command to the appropriate output. In addition to logic processing, CPU performs other functions such as timing, counting, latching, comparing and retentive storage, communication.

  The word size of PLC varies from 4 bits to 16 bits.

3. Memory

- The programs to be executed are stored in the memory. The basic memory unit is word. Memory sizes vary from 256 words to 192 K words. The complexity or length of control plan determines the amount of memory required. In most PLC memories are expandable in fixed increments memory can be volatile or nonvolatile. Volatile memory is erased if power is removed. Three basic types of memories ROM, R/W memory and RAM.

4. Programming devices

- Programming device is used to communicate between user and PLC. (i.e. programming device is the interface between user and PLC). Programming language is used to convey the PLC by means of instructions, how to execute and carry out the control plan.
- PLCs are programmed with ladder logic, which is a graphical method of programming. The ladder logic is easy to program and flexible.
- **Ladder diagram / ladder logic :** A schematic representation of system hardware and process controller is called as **ladder diagram.** Various devices connected in parallel across the ac line forms a ladder like structure. Each parallel connection on the ladder is called as "rung". Special symbols are used to represent the various circuit elements in a ladder diagram.

5. Output module

- Output module convert the desired real outputs as per the instructions stored in CPU (memory). These signals are used to control the machine or process.

4.4 Basic Structure or (Internal Architecture) of a PLC System

☞ [AU : Dec.-2016, 16 Marks]

- Fig. 4.4.1 shows the internal architecture of a PLC system.

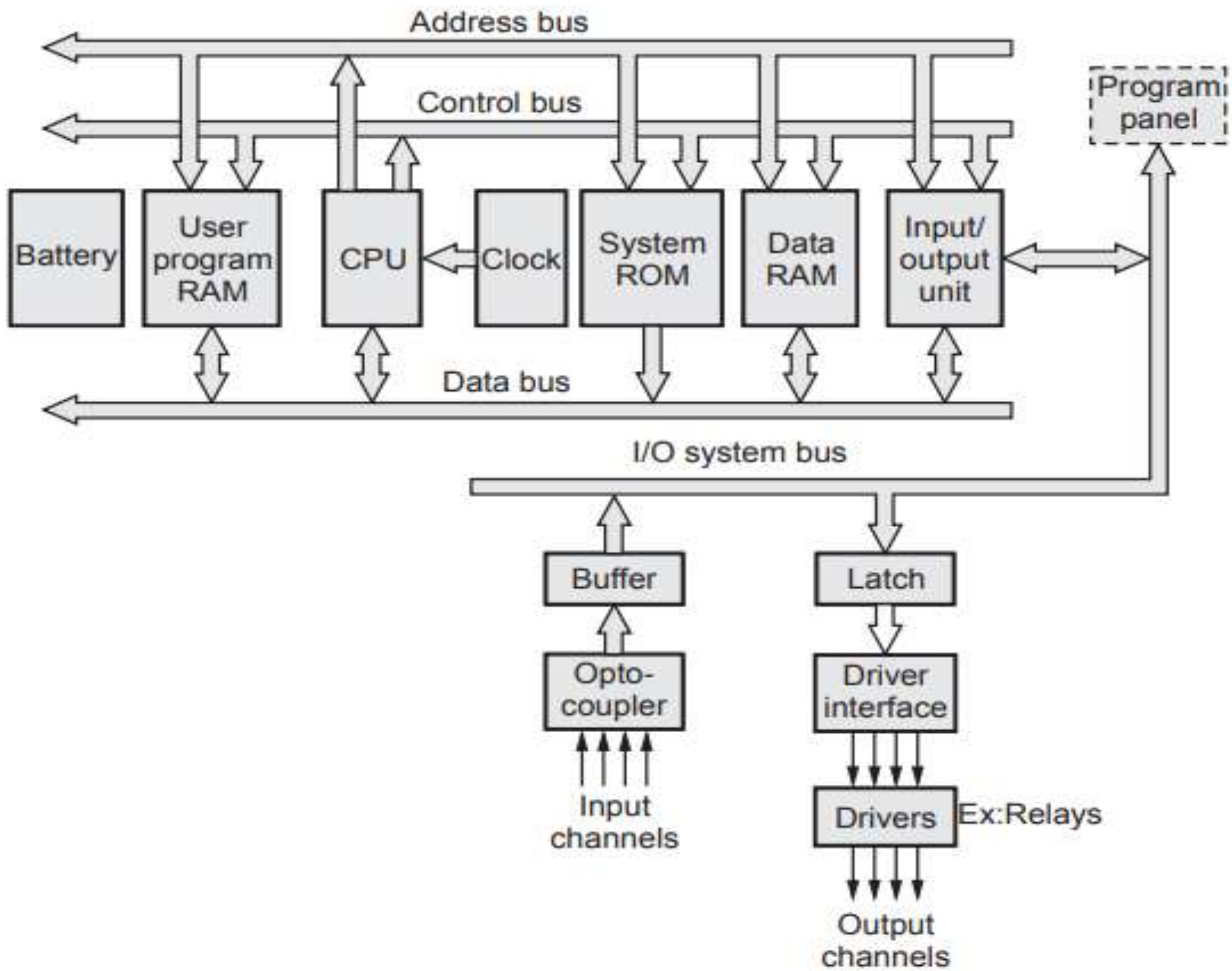


Fig. 4.4.1 Internal architecture of a PLC system

1. Central Processing Unit :

- The CPU controls and processes all the operations within the PLC.
- It is supplied with a clock with a frequency of typically between 1 to 8 MHz.
- This frequency determines the operating speed of the PLC and provides the timing and synchronization for all elements in the system.
- The information within the PLC is carried by means of digital signals.
- The processor is a microprocessor that executes a program to perform the operations specified in a ladder diagram or a set of Boolean equations.
- The CPU consists of the following units

i. Arithmetic and Logic Unit (ALU) :

- This unit performs data manipulation and arithmetic and logical operations on input I variable data and determines the proper state of the output variables.
- The arithmetic operation includes addition, subtraction etc., and logic operations include AND, OR, EXCLUSIVE - OR.

ii. Control Unit :

- A control unit is used to control the timing of operations.
- The processor functions under a permanent supervisory operating system that directs the overall operations from data input and output to execution of user programs.
- The controller can perform only one operation at a time. So, it scans each of the inputs sequentially, evaluates the ladder diagram program, provide each output(s), and then repeat the whole process.
- Hence, the timing control's necessary for a PLC system.

iii. Memory Unit :

- The sequence of instructions to be executed, programs are stored in the memory unit.
- During entering and editing including debugging, the program is stored in the temporary storages called RAM (Random Access Memory).
- For network programmed PLCs, the final PLCs program is downloaded into a special re-programmable ROM (EPROM, PROM, and EEPROM) in the PLC.
- Memory may be either volatile type or Non-volatile type.

a) Volatile Memory :

- Volatile memory or temporary memory or application memory is the user memory, where the user can enter and edit the program.
- Volatile memory will lose all its programmed contents if operating power is removed or lost.

b) Non Volatile Memory :

- Non-volatile memory or permanent memory or system memory is (used) a system memory that stores the monitor a booting programs, lookup tables etc.,

2. Buses :

- A set of parallel lines that provides communication between various devices of a system is termed as a Bus.
- The bus system carries information and data's to and from the CPU, Memory and I/O units.
- The information is transmitted in binary form as 0 or 1 .
- Digital signals or electrical signals are flowing inside the bus.
- The PLC system contains four buses.
- They are namely data bus, address bus, control bus and system bus.

i) Data Bus :

- The data bus contains 8, 16 or 32 parallel signal lines for sending data between the various devices of a system.
- An 8-bit microprocessor has an internal data bus which can handle 8-bit numbers.
- The double ended arrows on the bus line show that they are bidirectional.
- This means that CPU can read data in from memory or from I/O unit on these lines or it can send data out to memory or to I/O unit on these lines.
- Many devices in a system will have their outputs connected to the data bus, but only one device will have its output enabled at a time.

ii) Address Bus :

- The address bus contains 16, 20, 24 or 32 parallel signal lines to carry the address of the memory locations for accessing stored data.
- Every memory location is given a distinct unique address to locate easily and accessed by the CPU either to read or write data.

iii) Control Bus :

- The control bus contains 4 to 10 parallel signal lines to carry the signals used by the CPU that are related to internal control actions.
- Typical control bus signals are memory read, memory write, I/O read and I/O write.

iv) I/O System Bus :

- The I/O system bus provide the communication between the I/O ports and I/O units.

3. Input / Output Unit :

- The I/O units provide the interface between the system and the outside world, allowing for connections to be made through I/O channels to input / output devices.
- Programs are entered from a program panel through I/O unit.

4.7 Advantages of PLC over The Relay System

1. Enhanced reliability.
2. Ease in logic modification.
3. Interactive operator interface.
4. On line repair facility.
5. I/O forcing through software.
6. On line monitoring of user logics.
7. Finalization of control logic and fabrication of PLC can be done simultaneously.
8. Capability of self-diagnostics to find failure in the equipment.
9. Flexibility while setting and changing the logic during commissioning and operation.
10. Reliable components make these likely to operate for years before failure.
11. Trouble shooting aids make programming easier and reduce downtime.
12. Computational abilities allow more sophisticated control.

4.8 Disadvantages of PLC

1. There's too much work required in connecting wires.
2. There's difficulty with changes or replacements.
3. It's always difficult to find errors; And require skillful work force.
4. When a problem occurs, hold-up time is indefinite, usually long.

4.9 Application of PLC

There are many applications that you can find PLCs are use in the various industries. Here are the list of applications.

Material Handling	Power Station Plant
Conveyor System	Process Monitoring Control Packaging Machine
Pick and Place Robot Control	Electrical/Electronic Appliance Manufacturing
Pump Control	Disk Drive Manufacturing
Swimming Pool	Petrol/Chemical Plant
Water Treatment	Traffic Light System
Chemical Processing Plant	Plastic Manufacturing Industries
Paper and Pulp Industries	Train Control Station system

Glass Manufacturing
Precast Concrete Industries
Cement Manufactruing
Printing Industries
Electro-plating Plants
Food Processing
Machine Tools
Tobacco Industries
Plastic Moulding Machine
Semi-conductor Manufacturing Machine
Sugar Manufacturing Plant
Palm Oil Manufacturing Plant
Air Condition Control
Car Manufacturing Plant
Iron and Steel Mill
Diary Product Manufacturing Plant
Building Automation
Tyre Manufacturing
Integrated Circuit Chip Manufacturing
Sewage Treatment Plant
Security Control System
Lift Control System
Generator Control System
Amusement Park Control

4.10 Input Channel of PLC

- Sensors like proximity sensors, rotary encoders, optical sensors, limit switches are interfaced to PLC through it's input / output modules. The I/O modules provide signal conditioning and isolation so that the sensors can be connected directly.
- For input channel usually an optocoupler is used for isolation purpose. And for protection of input module voltage divider circuit and a protection diode is used as shown in Fig. 4.10.1.

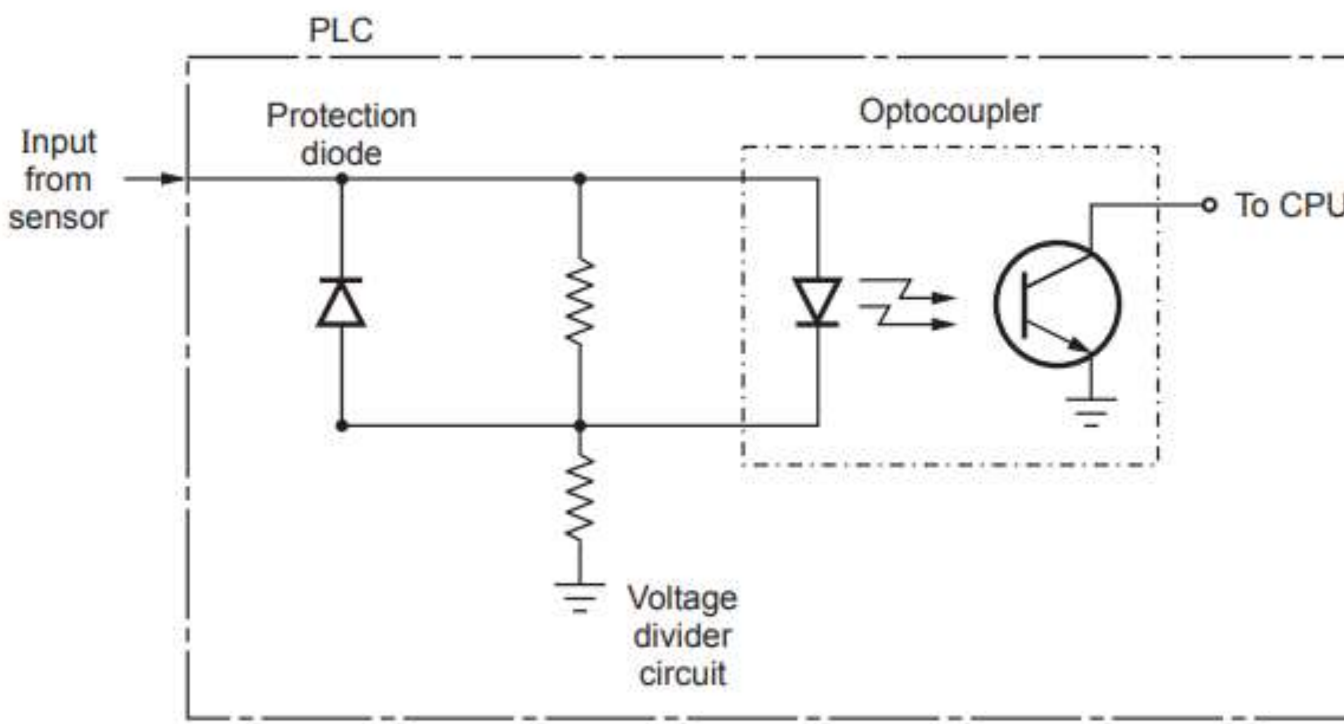


Fig. 4.10.1 Input channel protection

Output channel

- The external device or circuit is connected to PLC through a switching device. The output channel is specified by the type of switching element i.e. relay type, transistor type or triac type. The switching device (relay, transistor, triac) isolates the PLC from the external circuitry.

1) Relay output

- In relay type output the signal from PLC is used to operate a relay. Relay can switch currents of few milliamperes to few amperes to external circuit. Relay can switch both AC and DC signals. Relays can withstand high surge currents and voltage transients. Because of mechanical switching in relays, they are relatively slow to operate.

2) Transistor output

- In transistor type output, a transistor is used to switch current through external circuit. Transistors can switch faster than the relay. Transistors can be used for switching of DC signals only and can be destroyed by overcurrent and high reverse voltage. Hence proper protection circuits are to be provided. Also for switching higher current higher current capacity of transistor is needed.

3) Triac output

- Triac type outputs are used specially for switching of DC signals. Triacs may damage due to overcurrent. Hence for protecting triacs optoisolater and fuses are used.

Input/output voltage levels

- A range of inputs are available to a PLC e.g. 5 V, 24 V, 110 V, 240 V, digital/discrete i.e. on-off signals. Fig. 4.10.2 shows various input levels.

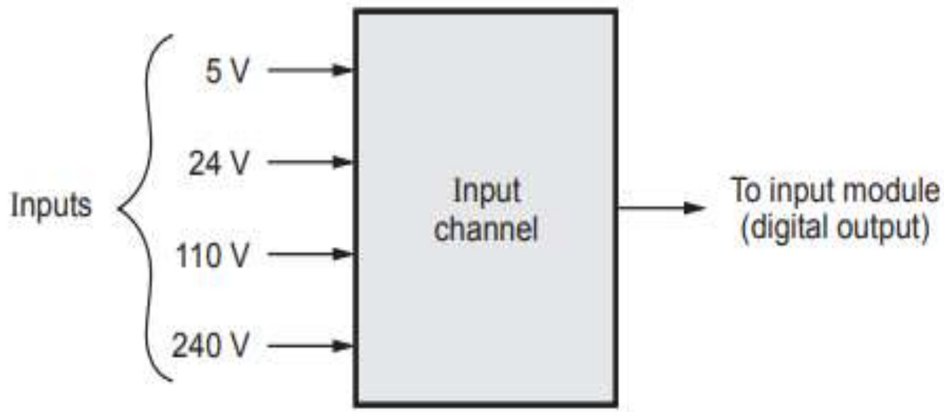
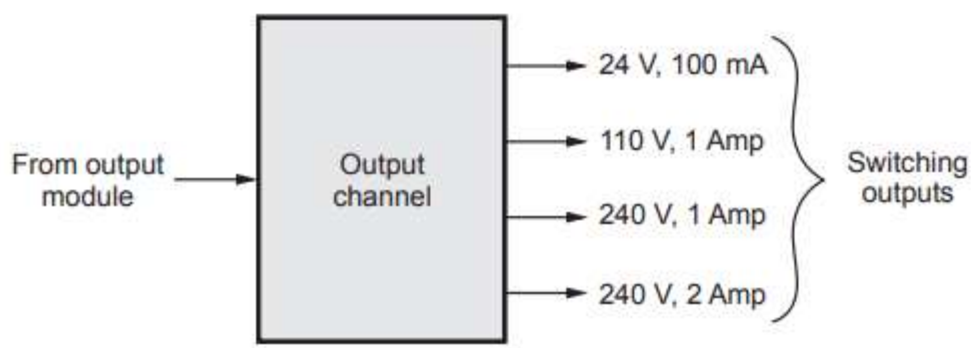


Fig. 4.10.2 Input voltage levels

- After signal conditioning and processing the output signal might be a 24 V, 100 mA switching signal, 110 V DC-1 A, 240 V-1 A. Fig. 4.10.3 shows various output levels



4.11 Output Channel of PLC

Current sourcing

- In current sourcing mode the input device receives current from the input module i.e. input module is the source of current.
- Similarly if the current flows from the output module to output load then the output module is referred to as sourcing.
- Fig. 4.11.1 shows input module and output module in current sourcing mode.

Fig. 4.11.1 Current sourcing

- Transistor output with current sourcing is shown in Fig. 4.11.2. An optoisolator provides isolation between PLC and external circuit.

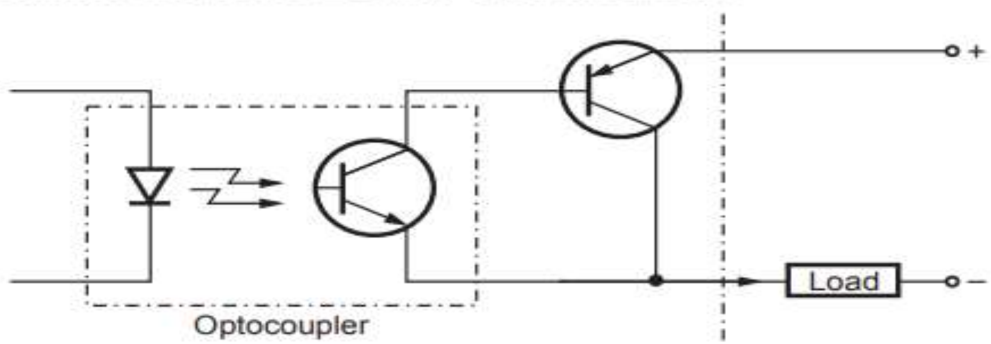


Fig. 4.11.2 Transistor output with current sourcing

Current sinking

- In current sinking mode an input device supplies current to the input module i.e. the input module is the sink for the current.
- Similarly if the current flows to the output module, it is referred to as current sinking. i.e. output device.
- Fig. 4.11.3 shows input and output module with current sinking.

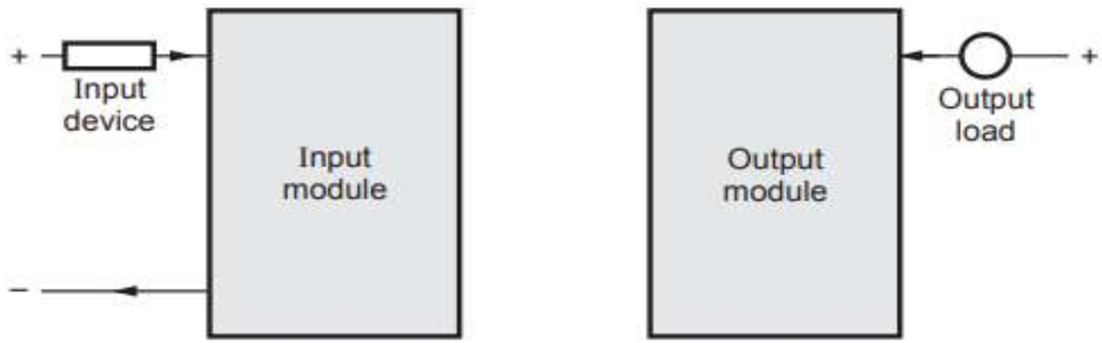


Fig. 4.11.3 Current sinking

- Transistor output in current sinking mode is shown in Fig. 4.11.4.

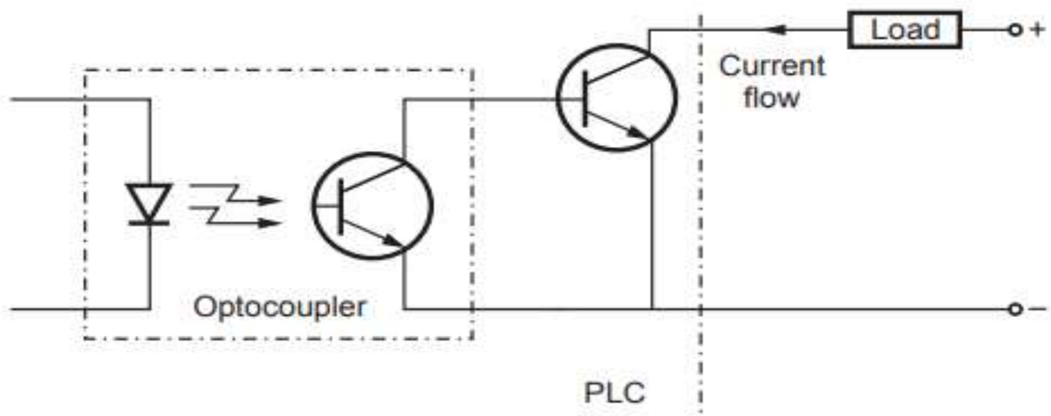


Fig. 4.11.4 Transistor output with current sinking

4.12 Ladder Diagram

- Ladder diagram is a graphical method for representing and programming an event driven sequential process.
- A special schematic representation of hardware elements and its connection used to make combination of hardware and description of sequence of events is called **ladder diagram.**
- Ladder diagram consists of two parallel lines which indicates a.c. supply lines. There are number of horizontal lines connecting these parallel lines. These horizontal lines define a specific operations and are called as rung.
- The entire structure looks like a ladder hence it is called as ladder diagram.

4.12.1 Elements of Ladder Diagram

- Variaus elements used in ladder diagram are listed here,

  1. Relays
  2. Motors
  3. Solenoids
  4. Lamps or Indicaters
  5. Switches

4.13 PLC Ladder Programming

☞ [AU : Dec.-2016, 2 Marks]

- Ladder diagram is a method of programming of PLCs. Writing a program is equivalent to drawing switching circuit i.e. ladder diagram is a systematic way of representing system hardware and controller.
- Ladder diagram consists of two vertical lines representing power lines. Circuit devices are connected as horizontal (parallel) across the AC power lines, which looks like a rungs of the ladder.
- Each rung of ladder consists of number of input conditions and a single command output.
- In drawing ladder diagrams, certain conventions are adopted.

1. The vertical lines of diagram represent the power rails between which the circuits are connected.
2. Each rung of ladder defines one operation in the control process.
3. The ladder diagram must be read from left-to-right and top-to-bottom. Fig. 4.13.1

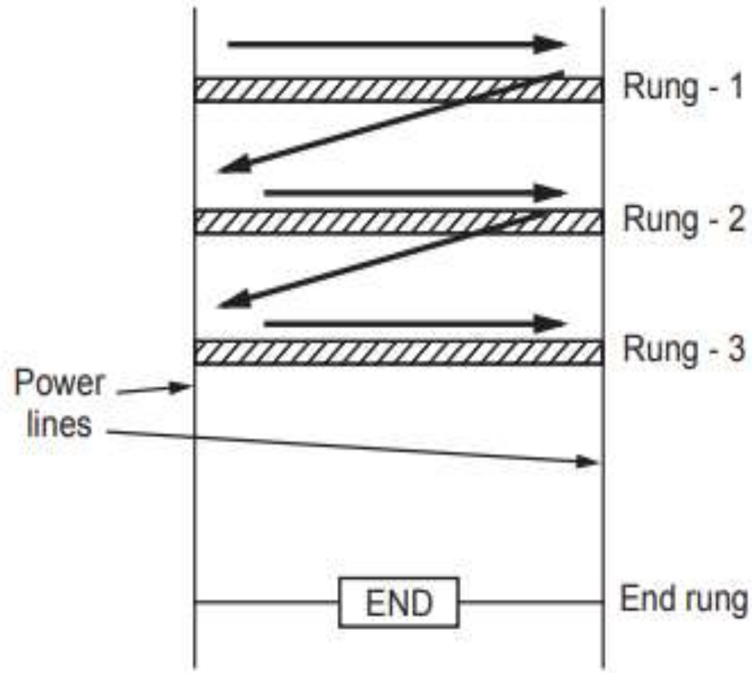


Fig. 4.13.1

4. In RUN mode, PLC goes through entire ladder program to the end. The end rung is clearly denoted then it comes back to the start. The process of going through all the rungs of program is termed as a **cycle**.

5. Each rung must start with atleast one input and one output.

   Inputs are control action e.g. closing contacts of switch. Outputs are device connected to PLC e.g. a motor.

6. Electrical devices are shown in their normal condition i.e. open or close contacts.

7. A particular device can appear in more than one rung in a ladder. Some identification number is used to identify device in each situation.

8. All inputs and outputs are identified by their addresses, the notation used depending on the PLC manufacturer. This is the address of the input or output in the memory of the PLC.

4.13.1 Symbols used in Ladder Diagram

A) Input devices

i) **Push button switch :** Input devices can be push button switches used to start or stop a system. The switch may be normally open (NO) or normally closed (NC) and may be activated by many sources.

Fig. 4.13.2 shows the symbols of push button switches.

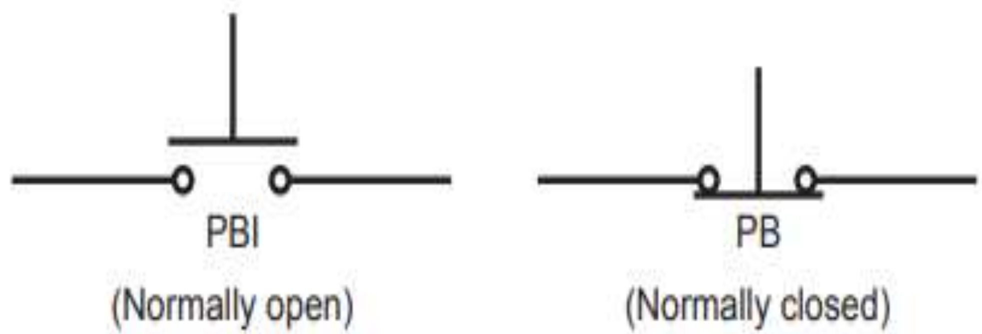


Fig. 4.13.2 Push button switches symbols

ii) **Limit switches :** Limit switches are used to sense presence or passage of a moving part. Fig. 4.13.3 shows a simple lever operated limit switch.

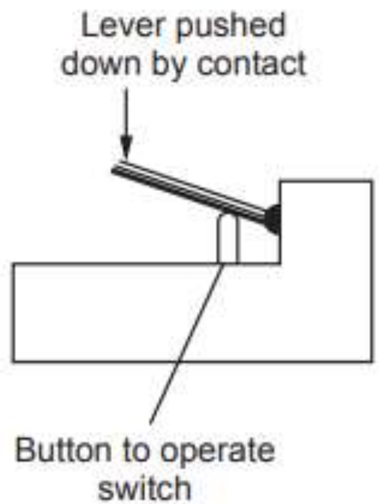


Fig. 4.13.3

The limit switch can be NO or NC type, its symbols are shown in Fig. 4.13.4.

Fig. 4.13.4 Limit switches symbols

- Some limit switches are attached to sensing device for sensing pressure, temperature and level. When any parameter (pressure, temperature or level) crosses certain limits they are actuated then NO contact will become NC and NC contact will become NO.

Fig. 4.13.5 shows symbols of these limit switches.

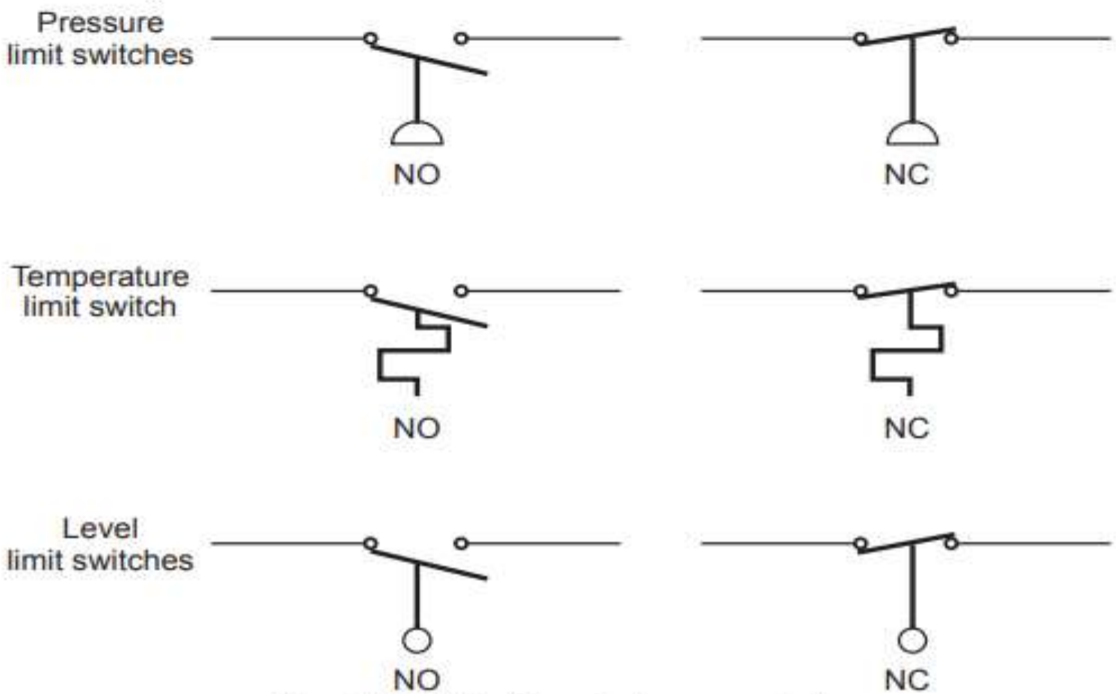


Fig. 4.13.5 Limit switches symbols

iii) **Relay contacts :** Actually control relay is an output device but once it is energized it's contacts NO or NC can be used as an input switch. Fig. 4.13.6 shows the representation of a control relay contacts.

Fig. 4.13.6 Control relay contact symbols

B) Output devices

- The output ports of PLC are of relay type or optoisolator with transistor or triac types depending on devices connected to them which are to be switched ON or OFF. Generally, the digital signal from an output channel of PLC is used to control an actuator which controls a process. The actuator is a device which transforms the electrical signal into some powerful action which controls the process.
- Some output devices are : Relays, contactors, valves, motors, solenoid and lights for visual indications. Fig. 4.13.7 shows the symbols of output devices.

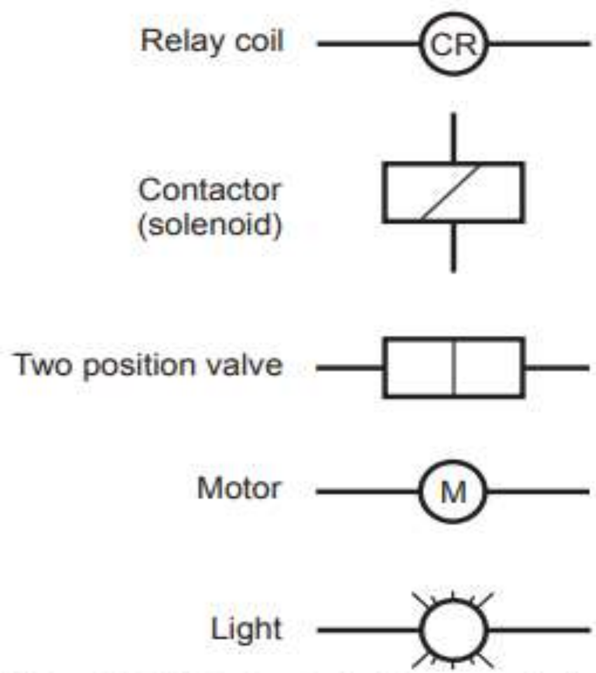


Fig. 4.13.7 Output device symbols

4.14 Selection Criteria of PLC

- PLC selection criteria consists of :

1. System (task) requirements
2. Application requirements
3. Electrical requirements
4. Speed of operation
5. Communication requirements
6. Operator interface
7. Physical environments
8. What input/output capacity is required ?
9. What type of inputs/outputs are required ?
10. What size of memory is required ?
11. What speed is required of the CPU ?
12. Software

4.15 PLC Programming

4.15.1 Structure of Rung

- Fig. 4.15.1 shows a ladder rung, starting with the input, normally open symbol for input contact is shown by | |.

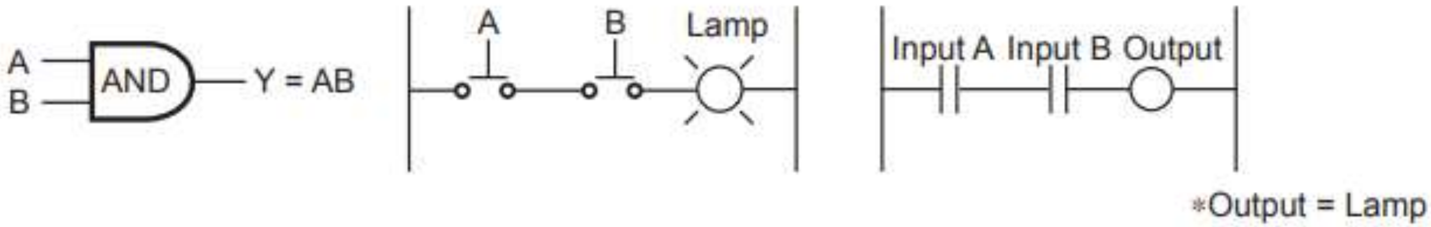
Fig. 4.15.1 A ladder rung

- In drawing ladder diagrams the addresses of each element are appended to it's symbol. When wiring up the inputs and outputs to the PLC, relevant input addresses must be connected to the input and output terminals with it's output addresses.

4.15.2 Logic Functions

1. AND Logic Function

- AND logic circuit represents series circuit.
- AND gate is composed with two inputs and one output.
- AND gate produce output when both the inputs are HIGH state.



Symbol AND circuit PLC AND logic

Fig. 4.15.2

Input A	Input B	Output A.B
0	0	0
0	1	0
1	0	0
1	1	1

AND system

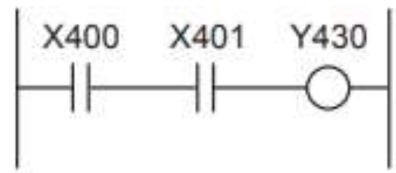


Fig. 4.15.3

Step	Instruction	Address	Parameter	Description
0	LD X400	X400	INPUT	Start a rung with open contacts
1	AND X401	X401	AND Logic	Open contant AND logic function
2	OUT Y430	Y430	OUTPUT	Output or terminate the rung

2. OR Logic Function

- OR logic circuit represents the parallel circuit.
- OR Gate is composed of two or more inputs and one output.
- OR operation is like addition of binary numbers.
- OR gate produce output when any one input are HIGH state.

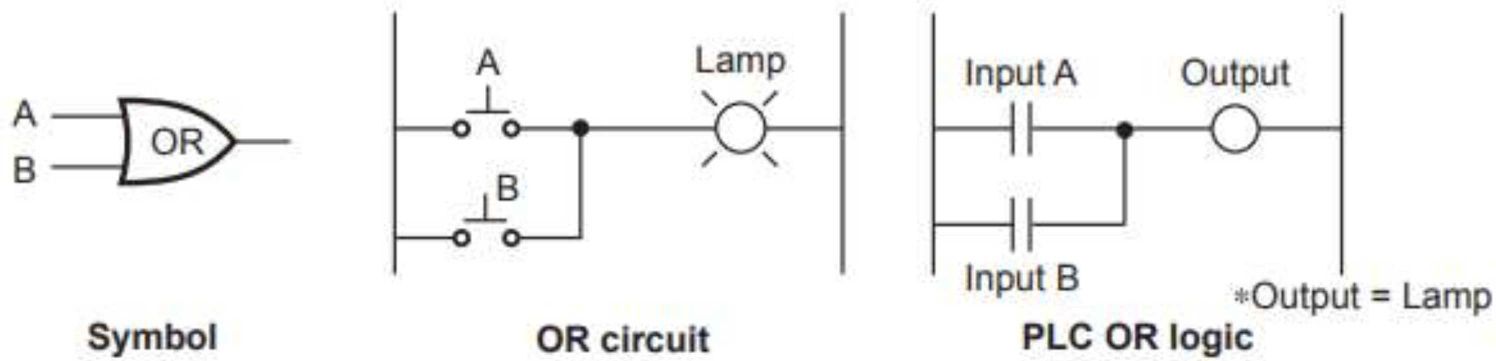


Fig. 4.15.4

Input A	Input B	Output (A + B)
0	0	0
0	1	1
1	0	1
1	1	1

OR system

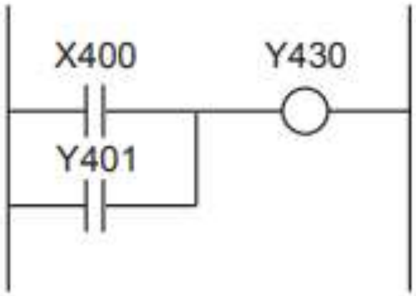


Fig. 4.15.5

Step	Instruction	Address	Parameter	Description
0	LD X400	X400	INPUT	Strat a rung with open contacts
1	OR X401	X401	OR Logic	Add as open content in parallel
2	OUT Y430	Y430	OUTPUT	Terminate the rung

3. NOT Logic Function

- NOT function is also known as Inverter.
- NOT gate is composed of single input and a single output.
- The bubble, or circle, at the output is the standard symbol used to represen inversion.
- In NOT gate, there is an output, when there is no input and no output when there is an input.

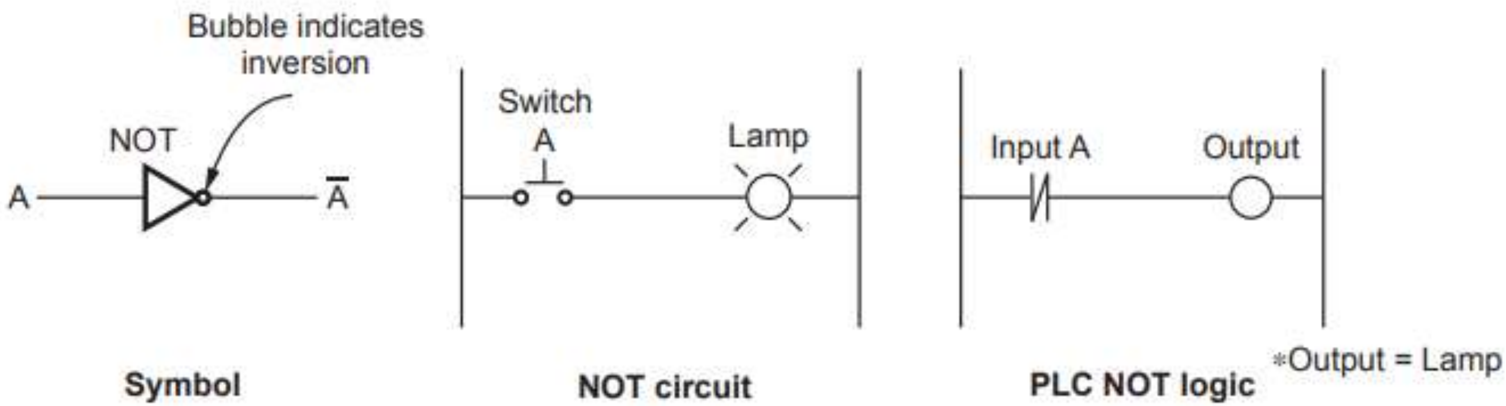


Fig. 4.15.6

Input (A)	Output ($\overline{A}$)
X = A	X = $\overline{A}$
0	1
1	0

4. NAND Logic Function

- NAND is a combination of AND and NOT gates.
- Arrangement shows AND gate followed by NOT gate. Hence it is called NOT AND gate.
- Both the inputs A and B have to be at low state to get the output at HIGH state.
- NAND Gate is composed of two or more input with a single output.
- Any one input is in LOW state also output will be HIGH state.

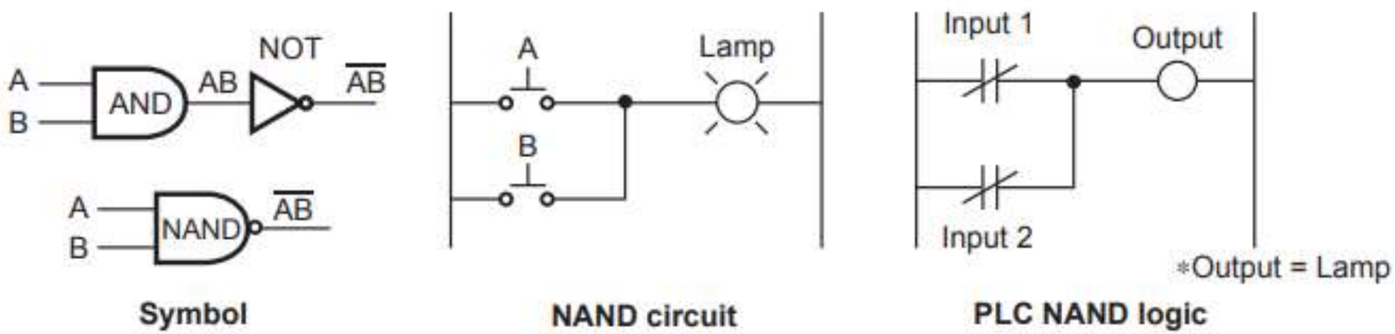


Fig. 4.15.7

Input A	Input B	Output $\overline{AB}$
0	0	1
0	1	1
1	0	1
1	1	0

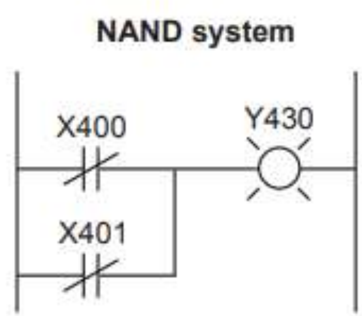


Fig. 4.15.8

Step	Instruction	Address	Parameter	Description
0	LDI X400	X400	Input	Start a rung with closed contacts
1	ANI X401	X401	NAND logic	Add a closed contact in series.
2	OUT Y430	Y430	Output	Terminate the rung

5. NOR Logic Function

- NOR is a combination of OR and NOT gates.
- Arrangement shows OR gate is followed by NOT gate. Hence it is called NOT OR gate.
- Both the inputs A and B have to be at LOW state to get the output at HIGH state.
- NOR gate is composed of two or more input with a single output.
- Any one input is in HIGH state also output will be LOW state.

Step	Instruction	Address	Parameter	Description
0	LDI X400	X400	INPUT	Start a rung with closed contacts
1	ORI X401	X401	NOR LOGIC	Add a closed contact in parallel.
2	OUT Y430	Y430	OUTPUT	Terminate the rung

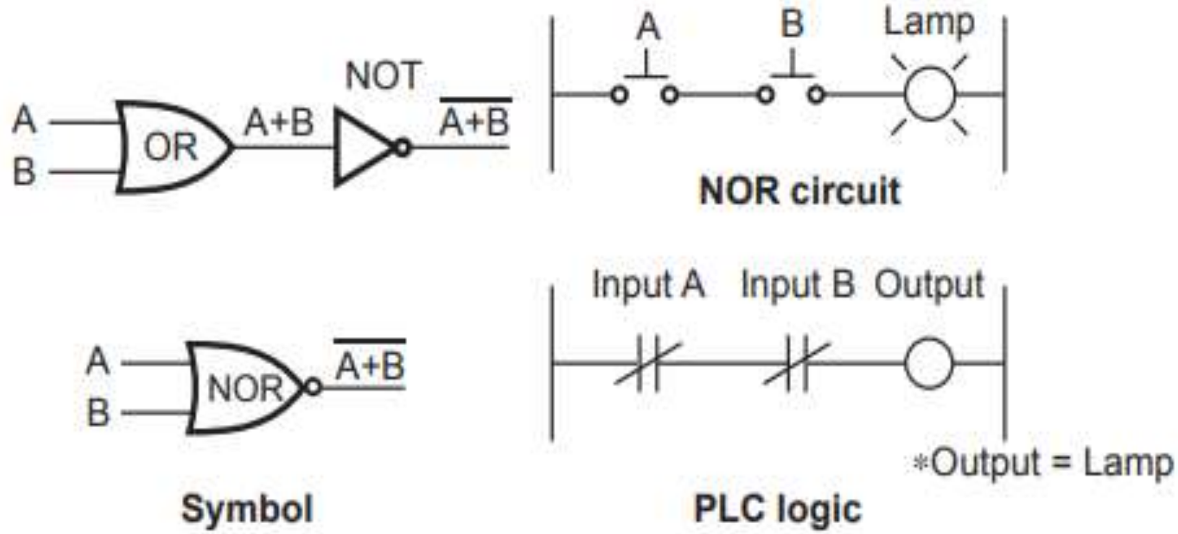


Fig. 4.15.9

Input A	Input B	Output ($\overline{A + B}$)
0	0	1
0	1	0
1	0	0
1	1	0

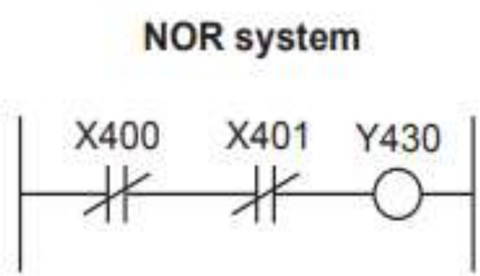
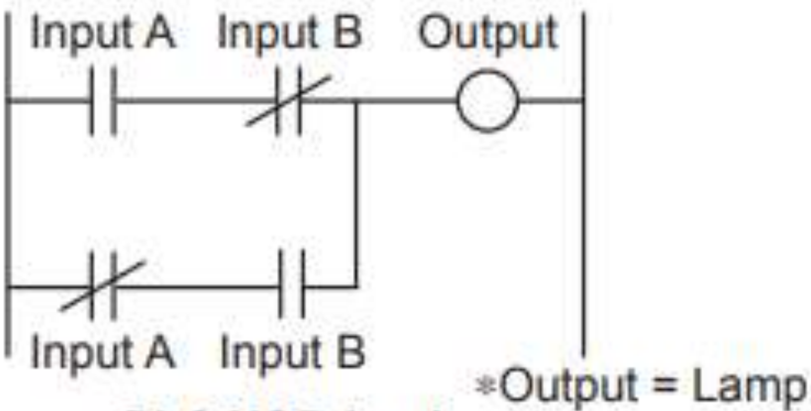


Fig. 4.15.10

6. Exclusive OR (XOR) Logic Function

- When both the inputs are at LOW state the output will be at LOW state.



PLC XOR Logic

Simplified

- When both the inputs are at HIGH state the output will be at LOW state.
- When any one input is HIGH state the output will be at HIGH state.

Input A	Input B	Output (A ⊕ B)
0	0	0
0	1	1
1	0	1
1	1	0

XOR System

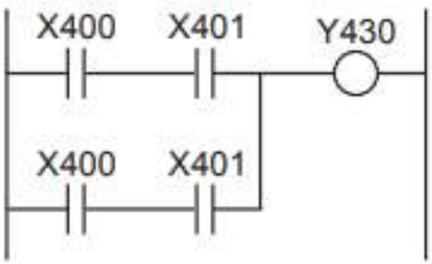


Fig. 4.15.12

Step	Instruction	Address	Parameter	Description
0	LD X400	X400	INPUT	Start a rung with an open contacts.
1	ANI X401	X401	NAND Logic	Add a closed contact in series with input.
2	LDI X400	X400	INPUT	Start a new rung with a closed contacts.
3	AND X401	X401	AND Logic	Add a open contact in series with input.
4	ORB	-	-	Do 'OR' operation between two sub circuits.
5	OUT Y430	Y430	OUTPUT	Terminate the Rung.

4.15.4 Timers

- A timer is a special counter ladder function that allows the PLC to perform timing operations based on a precise internal clock.
- PLC timer is an element in ladder logic programming taken from electrical systems. Timers are devices that count time increments.
- The timer creates a delay in both PLC programming and in relay boards on connection or instantaneous disconnection.
- Simply, when the input is activated the timer starts its operation keeping track of the time. When this time exceeds the programmed time then the timer activates its output.
- You could set the PLC timer from millisecond (ms) to an hour (hr) time span in the programming of the Ladder Diagram (LD) PLC.

Types of Timers :

- Though there are many types of timer functions available in PLCs, the following three are most commonly found :

1. ON delay timer (TON)
2. OFF delay timer (TOFF)
3. Retentive Timer (RTO)

1. ON delay timer (TON)

- The Timer On Delay instruction begins to count time base intervals when rung conditions become true.
- As long as rung conditions remain true, the timer increments its accumulated value (ACC) according to time base interval until the accumulated value reaches the preset value (PRE).

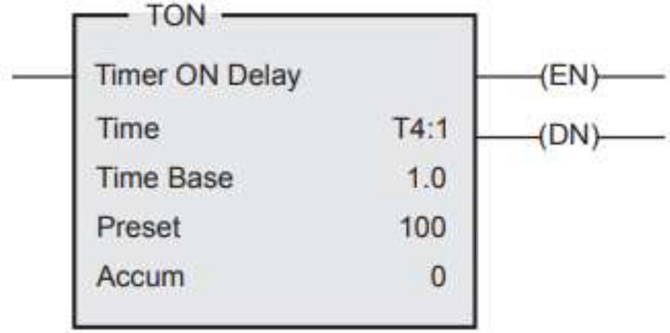
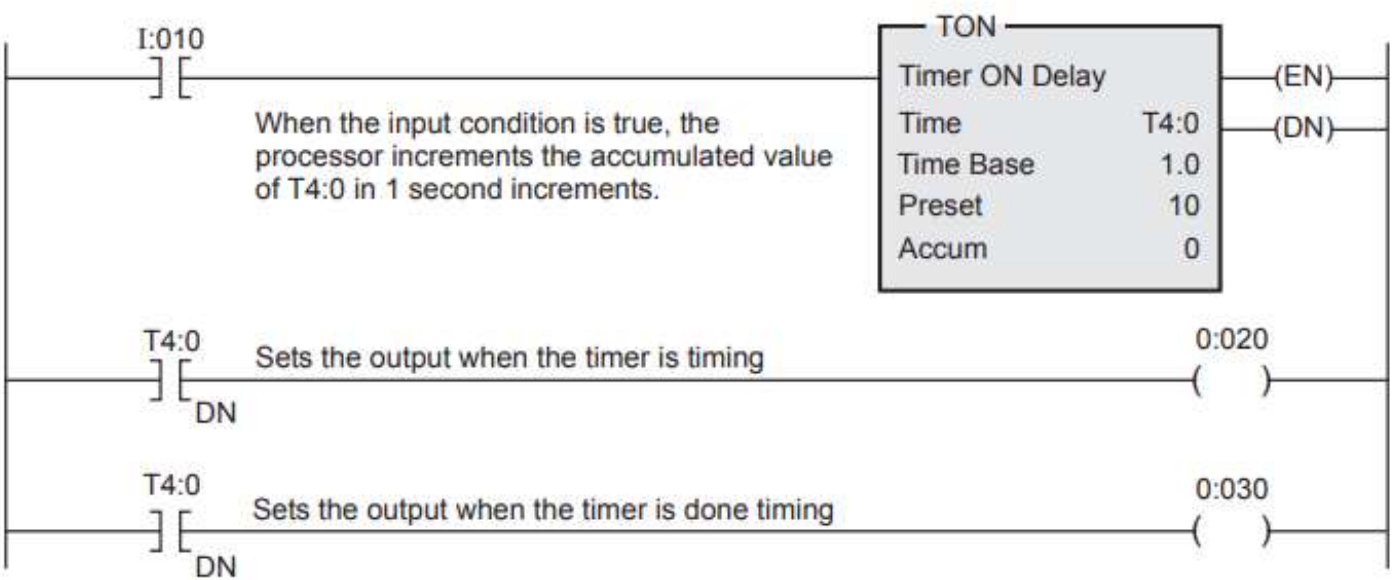
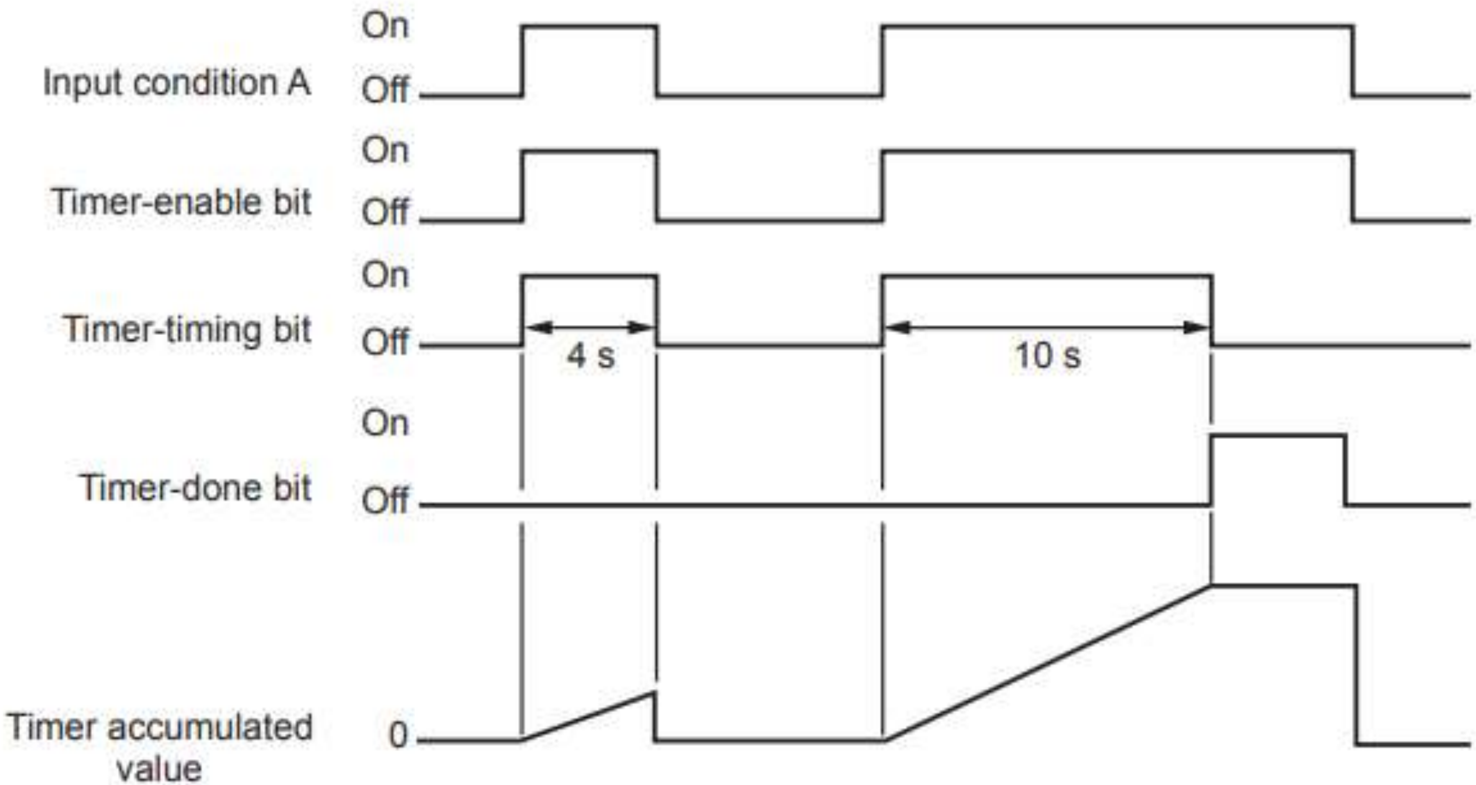


Fig. 4.15.15 ON delay timer (TON)

- The accumulated value is reset when rung conditions go false, regardless of whether the timer has timed out.





- The Timer On Delay has three control bits.
  - Done (DN) : This bit is on when the Accumulated value = Preset Value
  - Timer Timing (TT) : This bit is on when the timer is timing. (Accumulated value < Preset Value)
  - Enabled (EN) : This bit is on when the timer is energized.

2. Timer Off Delay (TOF)

- The Timer Off Delay instruction begins to count time base intervals when the rung makes a true to false transition.
- As long as rung conditions remain false, the timer increments its accumulated value (ACC) until it reaches the preset value (PRE).

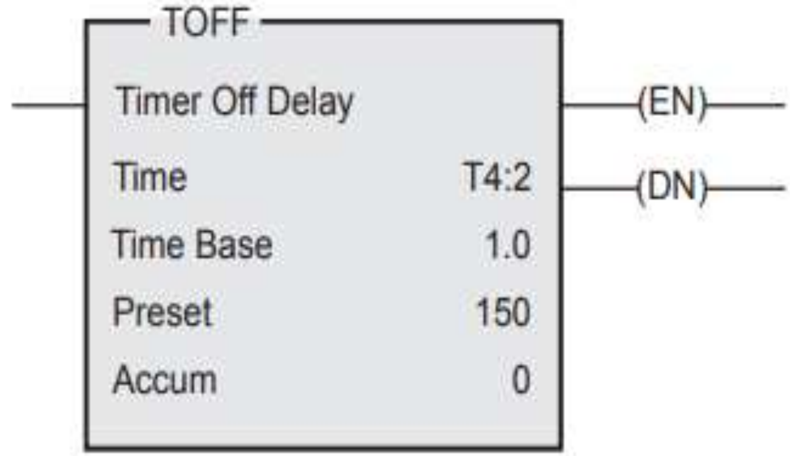
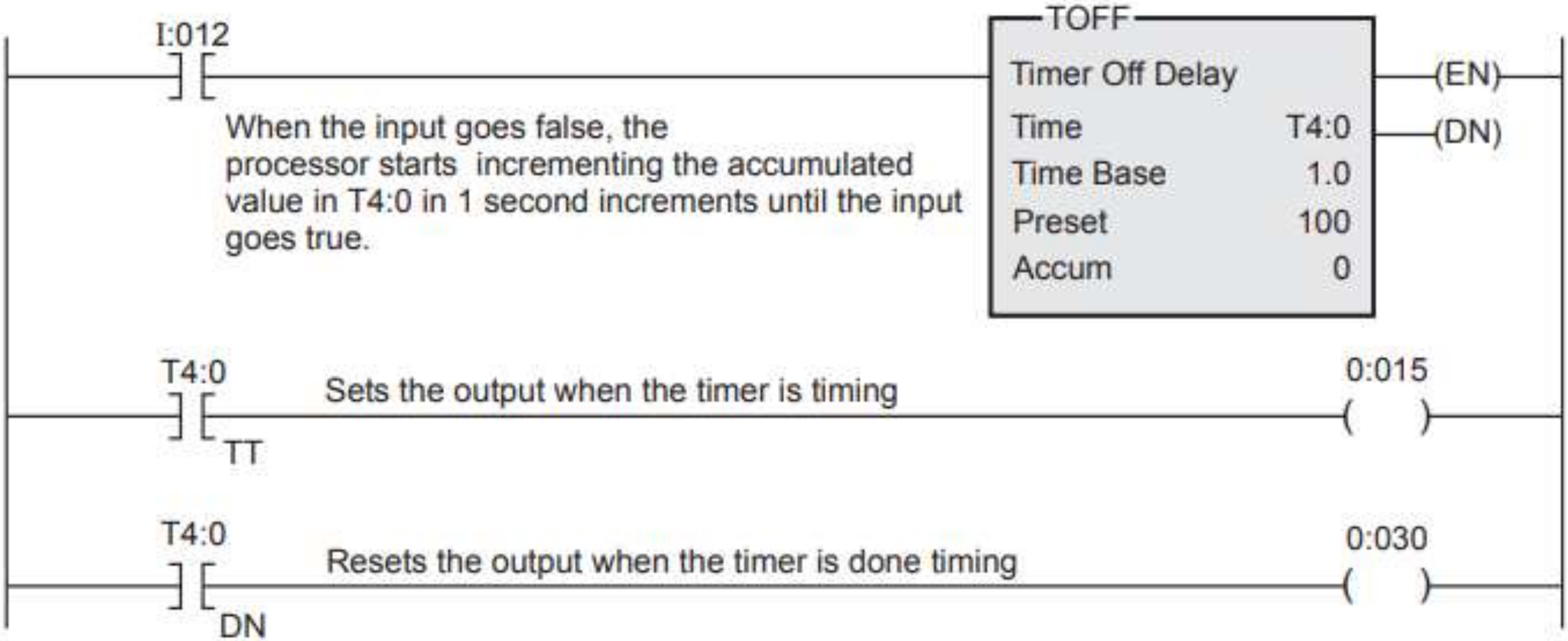


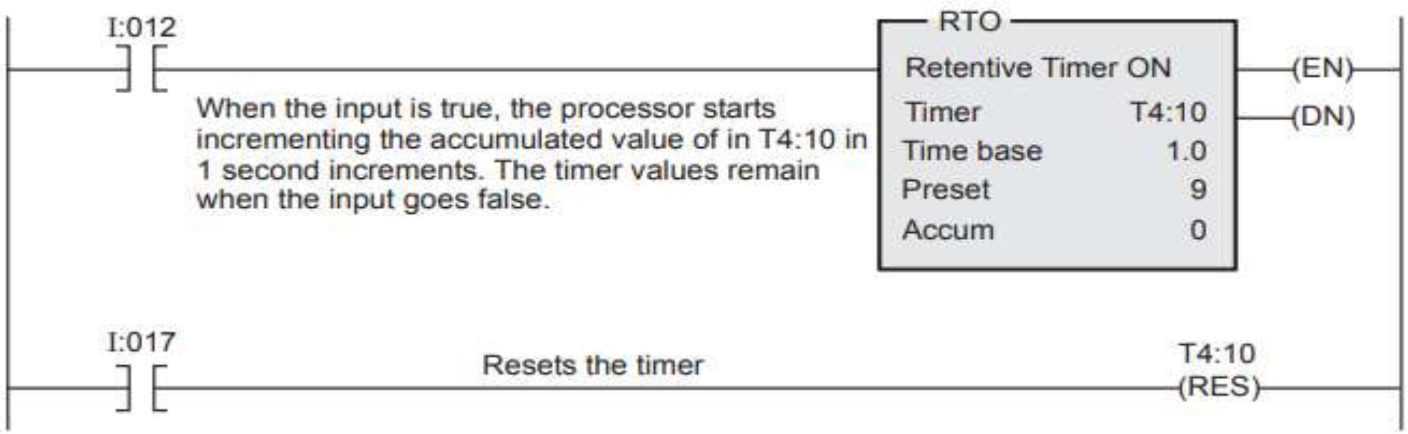
Fig. 4.15.16 Timer Off Delay (TOF)

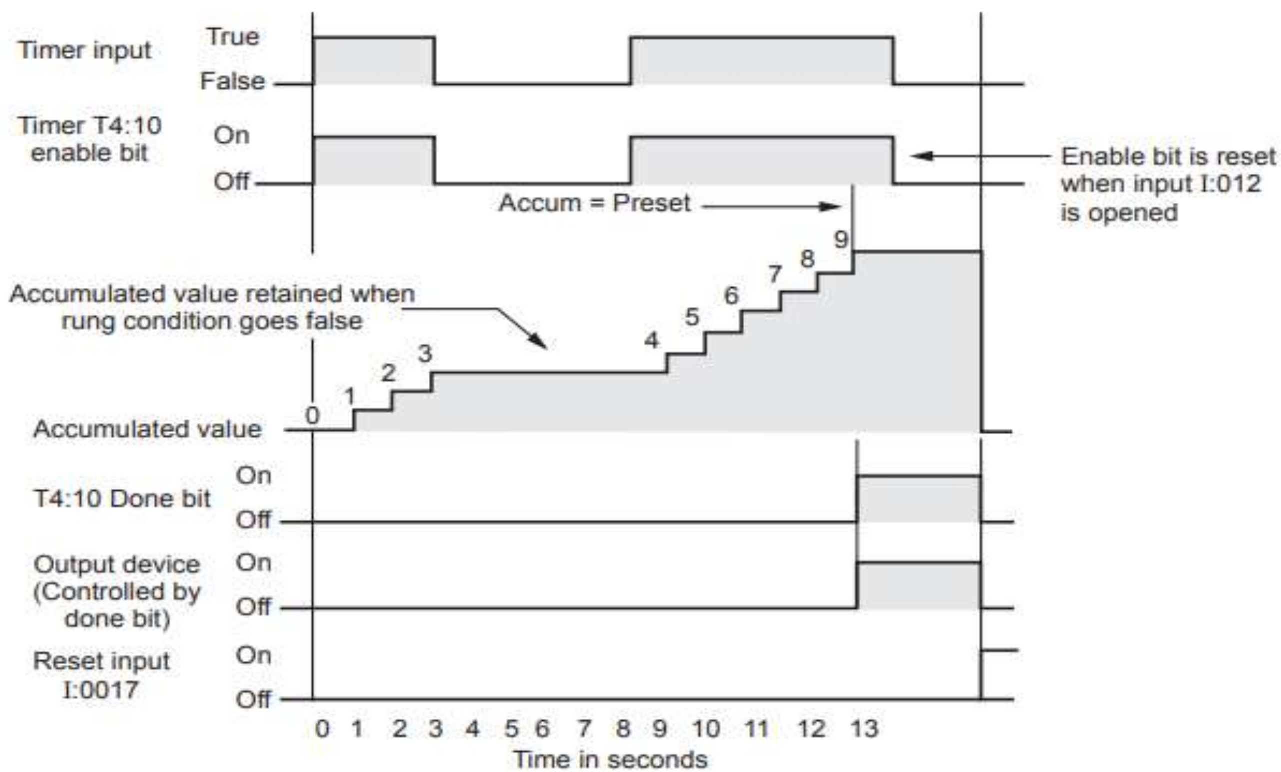
- The accumulated value is reset when rung conditions go true regardless of whether the timer has timed out.
- Similar to TON, The Timer Off Delay has three control bits.
  - Done (DN) : This bit is on when the Accumulated value = Preset Value
  - Timer Timing (TT) : This bit is on when the timer is timing. (Accumulated value < Preset Value)
  - Enabled (EN) : This bit is on when the timer is energized.


I:012
When the input goes false, the processor starts incrementing the accumulated value in T4:0 in 1 second increments until the input goes true.
TOFF
Timer Off Delay
Time T4:0
Time Base 1.0
Preset 100
Accum 0
(EN)
(DN)
T4:0
TT
Sets the output when the timer is timing
0:015
T4:0
DN
Resets the output when the timer is done timing
0:030

3. Retentive Timer On (RTO)

- A retentive timer accumulates time whenever rung condition becomes true, and it maintains the current time when the rung condition goes false or when power is removed.
- Once the device accumulates time equal to its Preset value, the contacts of the device change state.
- Loss of power to the device after reaching its preset value does not affect the state of the contacts.
- The retentive timer must be intentionally reset with a separate signal for the accumulated time to be reset.


I:012
RTO
Retentive Timer ON
Timer T4:10
Time base 1.0
Preset 9
Accum 0
(EN)
(DN)
When the input is true, the processor starts incrementing the accumulated value of in T4:10 in 1 second increments. The timer values remain when the input goes false.
I:017
Resets the timer
T4:10
(RES)


Timer input
True
False
Timer T4:10 enable bit
On
Off
Enable bit is reset when input I:012 is opened
Accum = Preset
Accumulated value retained when rung condition goes false
0
1
2
3
4
5
6
7
8
9
Accumulated value
T4:10 Done bit
On
Off
Output device (Controlled by done bit)
On
Off
Reset input I:0017
On
Off
0 1 2 3 4 5 6 7 8 9 10 11 12 13
Time in seconds

4.15.5 Counters

- A counter is a PLC instruction that either increment (counts up) or decrements (counts down) an integer number value when prompted by the transition of a bit from 0 to 1 ("false" to "true").
- A counter is set to some preset number value and, when this value of input pulses has been received, it will operate its contacts. Normally open contacts would be closed, normally closed contacts get opened.
- Counter instructions come in three basic types :
  1. Up Counters
  2. Down counters
  3. Up/down counters.
- For both UP and Down counters there is only one trigger is needed to start the counting, but for up/down counter it is needed two triggers, one for up and other for down counter.

1. UP counters :

- Up counter is an increment counter. which means it counts "up" with each off-to-on transition input to its "CU" input.

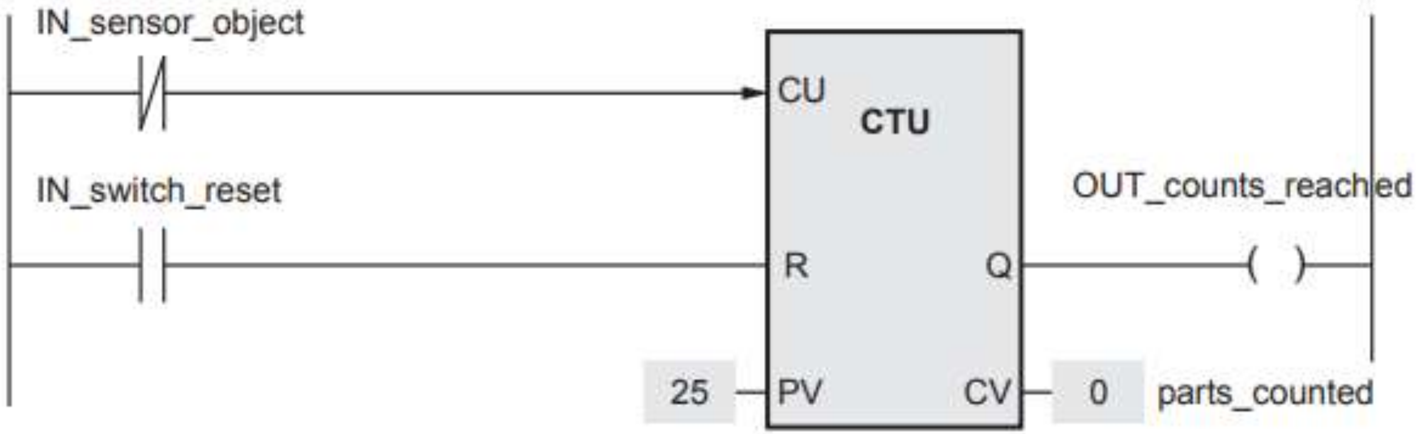
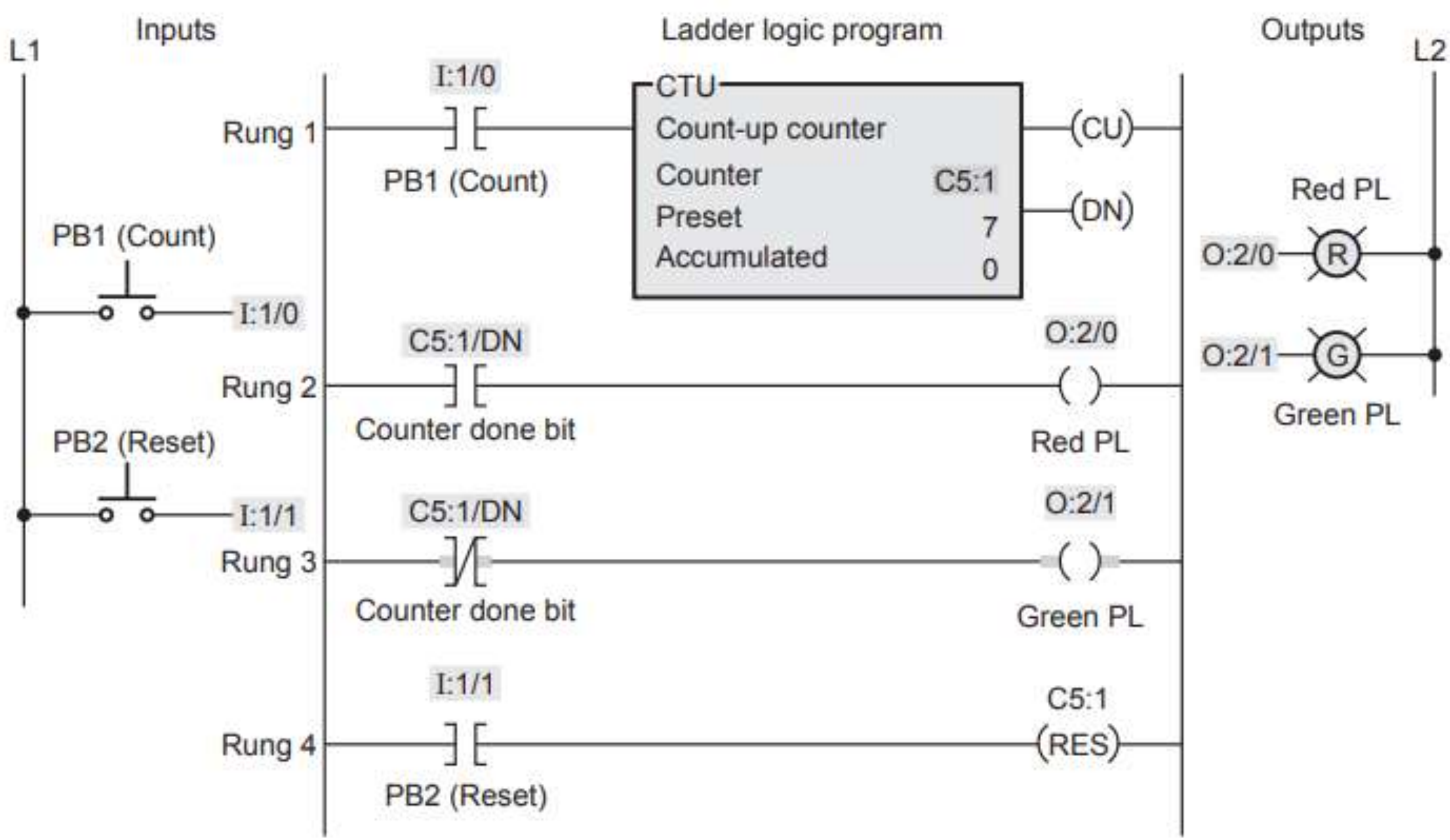


Fig. 4.15.17 Up Counter

- Whenever there is a true value entry in the CU input, the counter will turn on and CV will display the count.
- This counter output must be activated whenever the current value is equal to or greater than the preset value (Q is active if $CV \geq PV$).
- The counter output instruction will increase by 1 each time the counted event occurs.

Example program for UP counter :

- Operating pushbutton PB1 provides the off-to-on transition pulses that are counted by the counter.
- The preset value of the counter is set to 7.
- Each false-to-true transition of rung 1 increases the counter's accumulated value by 1.



- After 7 pulses, or counts, when the preset counter value equals the accumulated counter value, output DN is energized.
- As a result, rung 2 becomes true and energizes output O:2/0 to switch the red pilot light on.
- At the same time, rung 3 becomes false and de-energizes output O:2/1 to switch the green pilot light off.
- The counter is reset by closing pushbutton PB2, which makes rung 4 true and resets the accumulated count to zero.
- Counting can resume when rung 4 goes false again.

2. Down counter :

- The down-counter instruction will count down or decrease by 1 each time the counted event occurs.
- Each time the countdown event occurs, the accumulated value decreases.
- Normally, the down counter is used together with the ascending counter to form an up / down counter.

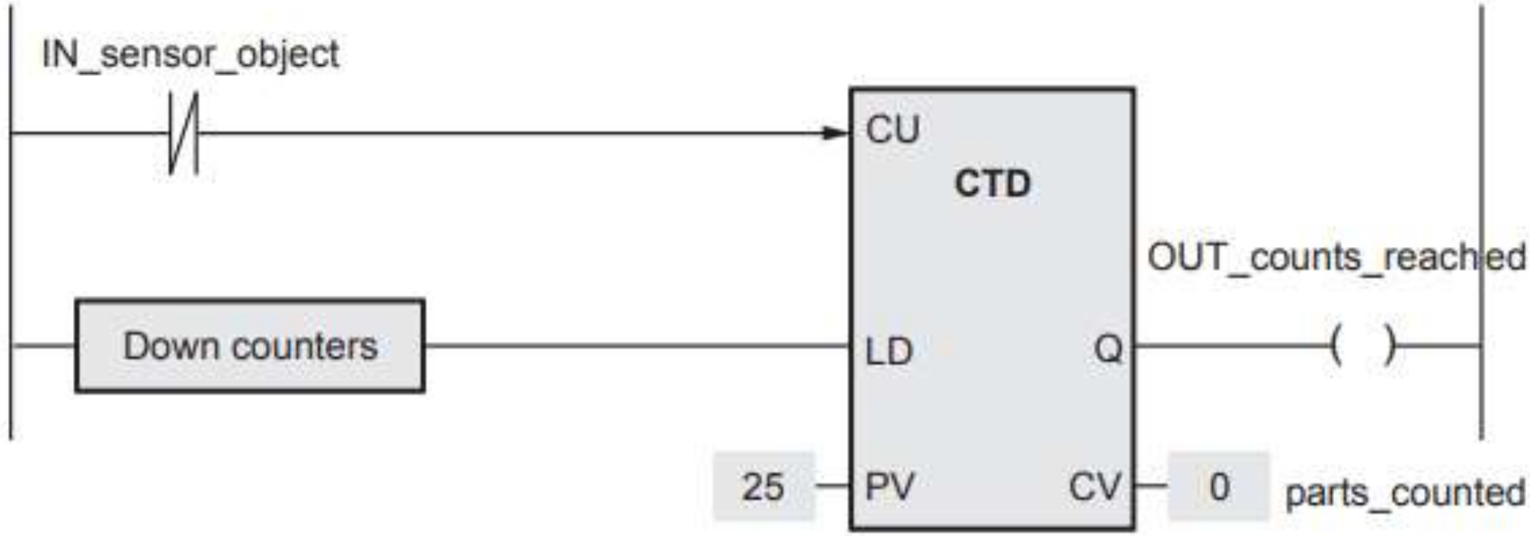
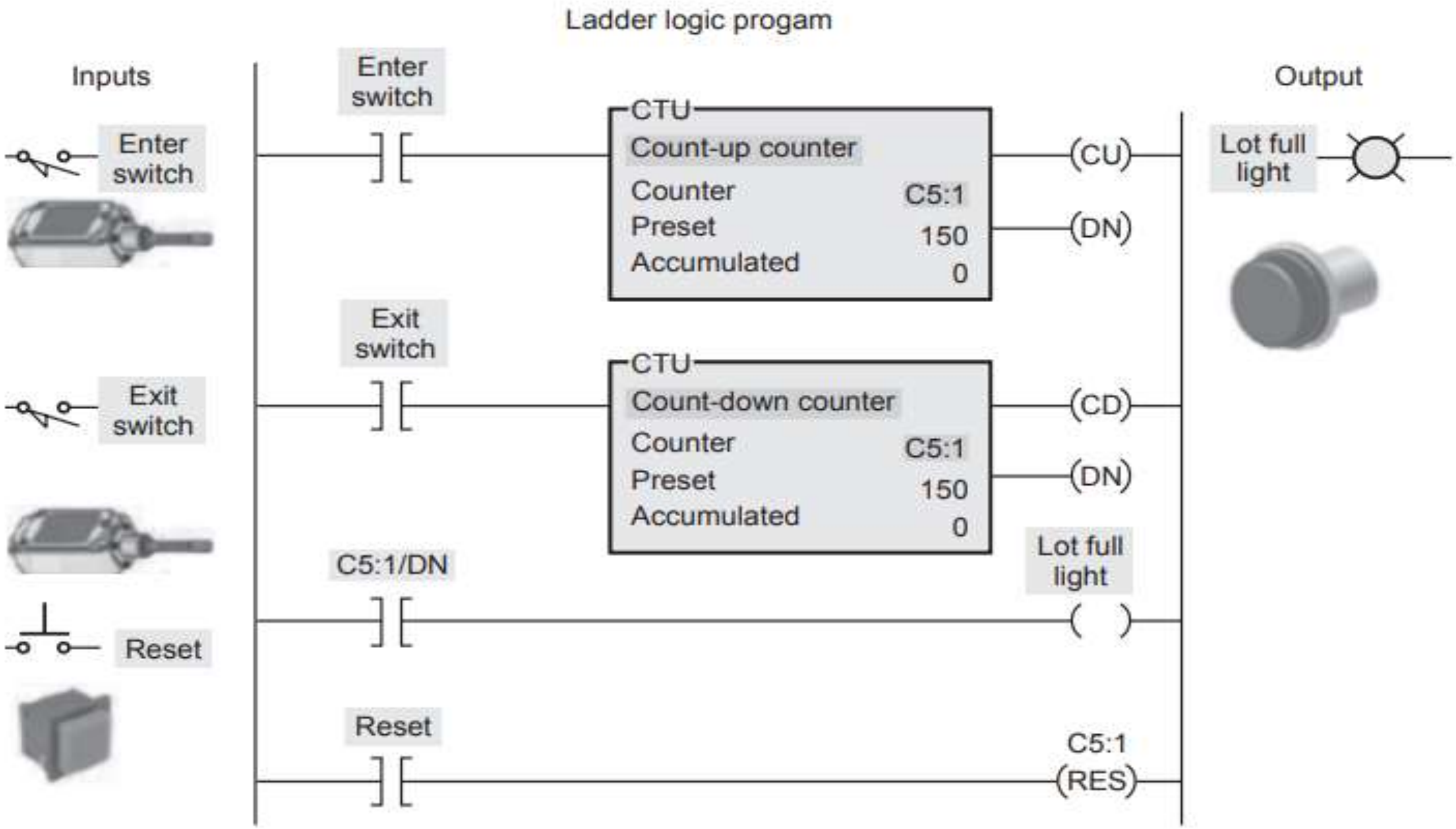


Fig. 4.15.18 Down Counter

Example for Down counter :

- One application for an up/down-counter is to keep count of the cars that enter and leave a parking garage.
- A typical PLC program that could be used to implement this.
- The operation of the program can be summarized as follows :



- As a car enters, the enter switch triggers the up counter output instruction and increments the accumulated count by 1.

- As a car leaves, the exit switch triggers the down counter output instruction and decrements the accumulated count by 1.
- Because both the up- and down-counters have the same address, C5:1, the accumulated value will be the same in both instructions as well as the preset.
- Whenever the accumulated value of 150 equals the preset value of 150, the counter output is energized by the done bit to light up the Lot Full sign.
- A reset button has been provided to reset the accumulated count.

4.15.6 Mnemonics used in PLC

- The mnemonics codes used by different PLC manufactures differ but an international standard (IEC 1131-3) has been proposed and is widely used.
- Table 4.15.2 below shows core mnemonics.
- For the rest of the following instructions, Mitsubishi mnemonics will be used.

IEC 1131-3	Mitsubishi	OMRON	Siemens	Operation	Ladder diagram
LD	LD	LD	A	Load operand into result register	Start a rung with open contacts
LDN	LDI	LD NOT	AN	Load negative operand into result register	Start a rung with closed contacts
AND	AND	AND	A	Boolean AND	A series element with open contacts
ANDN	ANI	AND NOT	AN	Boolean AND with negative operand	A series element with closed contacts
OR	OR	OR	O	Boolean OR	A parallel element with open contatcs
ORN	ORI	OR NOT	ON	Boolean OR with negative operand	A parallel element with closed contatcs
ST	OUT	OUT	=	Store result register into operand	An output from a rung

Table 4.15.2 Some instruction code mnemonics

4.15.7 Internal Relay

- An internal relay behaves like relays with their associated contacts, buy they are not actual relays whose simulations are controlled by the PLC software.
- Internal relays can be very useful in the implementation of switching sequences.
- They are often used when there are programs with multiple input conditions.

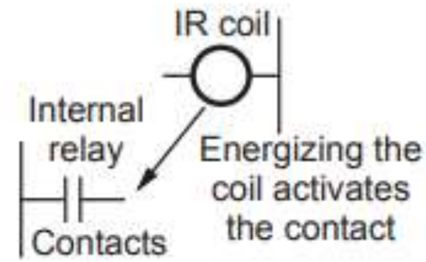
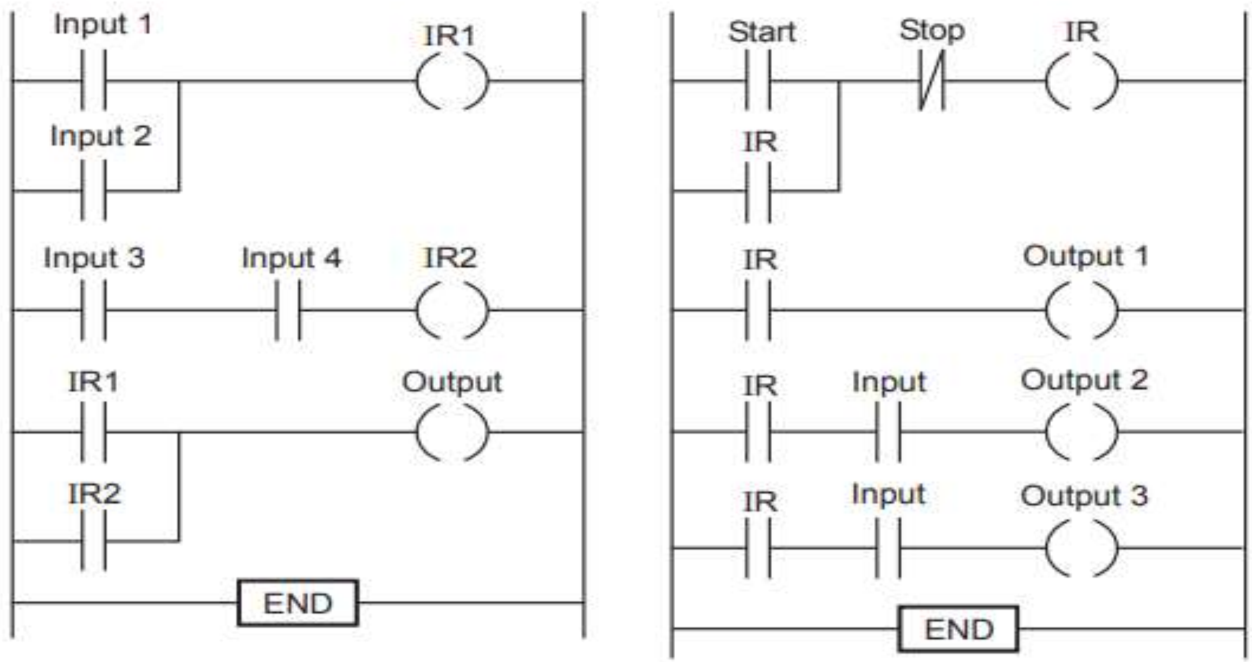


Fig. 4.15.20 Internal Relay

- They are also known as auxiliary relays or markers.
- In using an internal relays, it has to be activated on one rung of a program and then its output used to operate switching contacts on another rung of a program.
- Consider the situation where the excitation of an output depends on two various input activities.
- Figure 4.15.21 (a) shows how we can draw a ladder diagram using internal relays.
- The first rung shows one input arrangement being used to control the coil of internal relay IR1.
- The second rung shows the other input arrangement controlling the coil of inter-nal relay IR2.

- The contacts of the two relays are then put in an OR situation to control the output.
- Another use of internal relays is for the starting of multiple outputs.
- Figure 4.15.21 (b) shows such a ladder program.



(a) An output controlled by two input

(b) Starting of multiple outputs

Fig. 4.15.21

- When the start contacts are closed, the internal relay is activated and latches the input.
- It also starts Output 1 and makes it possible for Outputs 2 and 3 to be activated.

4.16 Data Handling

☞ [AU : Dec.-2016, 16 Marks]

- The steps involved in data handling with a PLC system are :

1. Moving data from one memory location to another
2. Comparison of magnitudes of data
3. Arithmetic operations
4. Data conversion.

Data - Handling Instruction	Source Address	Destination Address

1. Data Movement : ☞ **[AU : Dec.-2016, 8 Marks]**

Instruction : MOV

Function : To copy a value from one address to another

Program :

```
LD    X400
MOV
D1
D2
```

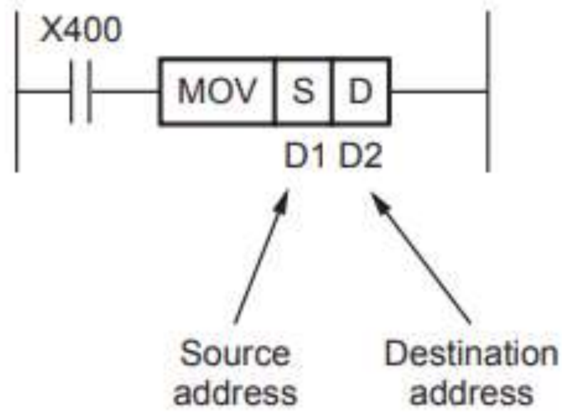


Fig. 4.16.1

When there is an input to X400,

- The data moves from the designated source address to the designated destination address.
- The data transfer might move a constant into a data register.

2. Data Comparison : ☞ [AU : Dec.-2016, 8 Marks]

- The data comparison instruction gets the PLC to compare two data values.
- It compare a pre - set value (1) to the input value (2)

Instruction : < or LES

= or EQU

> or GRT

< or LEQ

or <> or NEQ

> or GEQ

- For data comparison the typical instruction will contain the data transfer instruction to compare the data from source address and designation address.

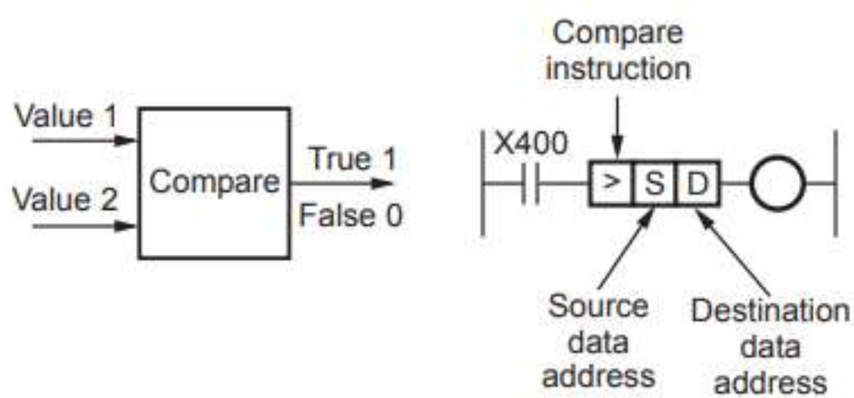


Fig. 4.16.2

3. Data Arithmetic Operations :

- PLCs are offered with the ability to carry out the arithmetic operations such as addition, subtraction, multiplication and division only.
- They cannot carry out exponential functions.
- Addition and subtraction operations are used to alter the value of data held in data registers.
- Multiplications are used to multiply some input before adding to or subtracting it from another.

4. Code Conversions :

- All the internal operations in the CPU of a PLC are carried out through binary numbers.
- Most PLCs provide BCD-to-binary and binary-to-BCD conversion for use.
- When a decimal (input) signal is given, BCD conversion is used.
- Similarly, when a decimal output is required, Decimal conversion is used.

- The data at the source address is in BCD and converted to binary and placed at the destination address.

Fig. 4.16.4

4.17 Master and Jump Controls

4.17.1 Master Control Relay (MCR)

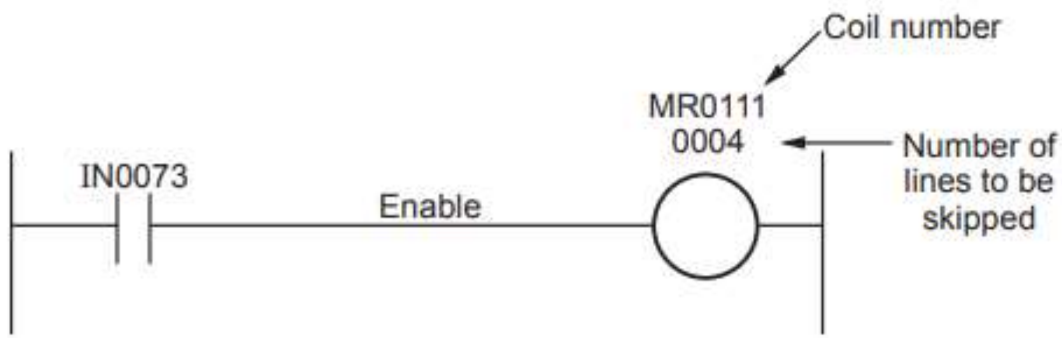


Fig. 4.17.1 Master Control Relay

- The MASTER CONTROL RELAY (MCR) function operation is similar to the SK function.
- Fig. 4.17.1 shows typical MCR function.
- When its enable line is energized, it turns on.
- When MCR is off, the number of following ladder diagram lines specified are turned off.
- In contrast to the SK operation, where lines were skipped, the MCR turns the following specified number of lines to the off state.
- Fig. 4.17.2 shows how the MCR function operates in a program.
(See Fig. 4.17.2 on next page)

- When its enable line is energized, it turns on.
- When MCR is off, the number of following ladder diagram lines specified are turned off.
- In contrast to the SK operation, where lines were skipped, the MCR turns the following specified number of lines to the off state.
- Fig. 4.17.2 shows how the MCR function operates in a program.
(See Fig. 4.17.2 on next page)
- There are eight lines. The third line is the MCR function. The other seven lines are contact-coil functions.
- When MCR is on, the other seven lines operate normally. When MCR is off, the next three lines, 4 through 6, are turned off. Lines 1, 2, 7 and 8 are unaffected.
- With MCR off, there is no way to turn on coils 4 through 6 by energizing their enable lines. When MCR is turned on, the ladder operates in the normal manner.

4.14 Selection Criteria of PLC

- PLC selection criteria consists of :

1. System (task) requirements
2. Application requirements
3. Electrical requirements
4. Speed of operation
5. Communication requirements
6. Operator interface
7. Physical environments
8. What input/output capacity is required ?
9. What type of inputs/outputs are required ?
10. What size of memory is required ?
11. What speed is required of the CPU ?
12. Software

1. **System requirements**

- The starting point in determining any solution must be to understand what is to be achieved.
- The program design starts with breaking down the task into a number of simple understandable elements, each of which can be easily described.

2. **Application requirements**

- Input and output device requirements. After determining the operation of the system, the next step is to determine what input and output devices the system requires.
- List the function required and identify a specific type of device.
- The need for special operations in addition to discrete (On/Off) logic
- List the advanced functions required beside simple discrete logic.

3. Electrical Requirements

- The electrical requirements for inputs, outputs, and system power; When determining the electrical requirements of a system, consider three items :
  - i. Incoming power (power for the control system);
  - ii. Input device voltage; and
  - iii. Output voltage and current.

4. Speed of Operation

- How fast the control system must operate (speed of operation) ?
- When determining speed of operation, consider these points :
- How fast does the process occur or machine operate ?
- Are there "time critical" operations or events that must be detected ?
- In what time frame must the fastest action occur (input device detection to output device activation) ?
- Does the control system need to count pulses from an encoder or flow-meter and respond quickly ?

5. **Communication**

- If the application requires sharing data outside the process, i.e. communication. Communication involves sharing application data or status with another electronic device, such as a computer or a monitor in an operator's station.
- Communication can take place locally through a twisted-pair wire, or remotely via telephone or radio modem.

6. **Operator Interface**

- If the system needs operator control or interaction. In order to convey information about machine or process status, or to allow an operator to input data, many applications require operator interfaces.
- Traditional operator interfaces include pushbuttons, pilot lights and LED numeric display.
- Electronic operator interface devices display messages about machine status in descriptive text, display part count and track alarms.
- Also, they can be used for data input.

7. **Physical Environment**

- The physical environment in which the control system will be located. Consider the environment where the control system will be located.
- In harsh environments, house the control system in an appropriate IP-rated enclosure.
- Remember to consider accessibility for maintenance, troubleshooting or reprogramming.