Lecture notes for Programmable Logic Controller

Subject Code :

Subject : PLC AND SCADA

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UNIT I

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Programmable Logic Controller- Block diagram

1. Aim and Objective:

To study of the Programmable Logic Controller.

2. Prerequisites:

Electrical Machines

Power electronics

Control system

Basic C programming

3. Pre Test- MCQ type

1. Construction of BLDC is exactly similar to the _______________
   a) Conventional DC motor
   b) Induction motor
   c) Permanent magnet synchronous motor
   d) Totally different construction

ANSWER: c) Permanent magnet synchronous motor

2. Typical brushless motor doesn't have _______________
   a) Commutator
   b) Permanent magnet
   c) Electronic controller
   d) Fixed armature

ANSWER: a) Commutator

3.PWM DUTY RATIO IS-----------------

a) TON/(TON+TOFF)*100
b) ((TON+TOFF)/TON)*100
c) ((TON+TOFF)/TOFF)*100

ANSWER : TON/(TON+TOFF)*100
4.Advantages of Digital signal processing

a) Fast processing – parallel
b) Guarantee accuracy – no of bits
c) Exact reproduction or repeatability
d) All of the above

ANSWER : d) All of the above

4. Programmable Logic Controller:

4.1. Introduction:

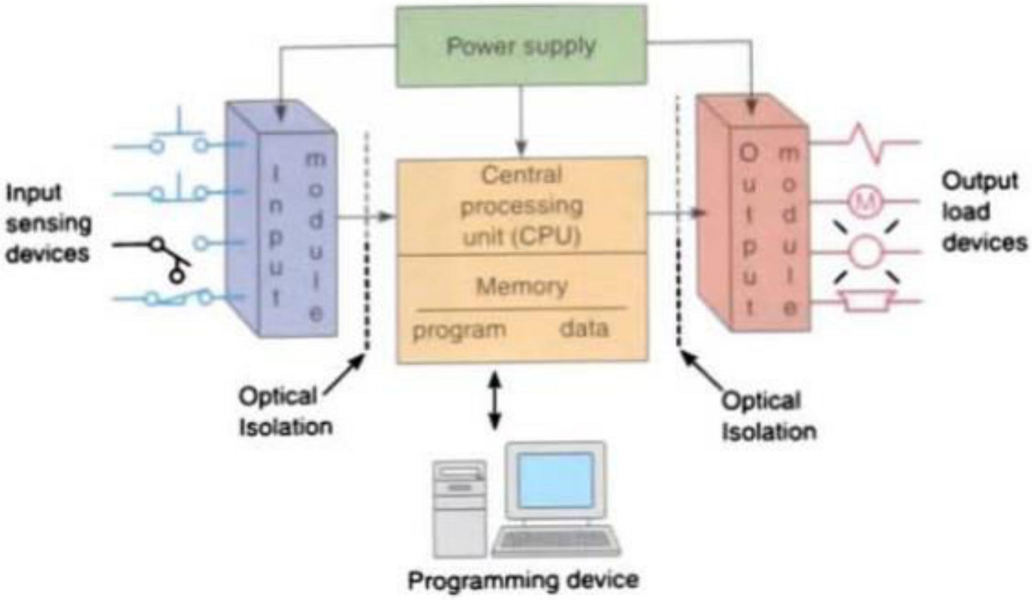
A programmable logic controller (PLC) is a specialized Programmable device which is used to control machines and processes.

It uses a programmable memory to store instructions and execute specific functions that include on/off control, timing, counting, sequencing, arithmetic, and data handling.

Advantages

- *Increased Reliability*
- *More Flexibility*
- *Lower Cost*
- *Communications Capability*
- *Faster Response Time*
- *Easier to Troubleshoot*

4.2 PLC Block diagram



Central Processing Unit

It is heart of the PLC . CPU is used to store the program, reads the status of inputs through the input module and execute the stored program and appropriate output to be activated based on the logic

CPU has two memory section one section used to store the program and other section is used to store the data

Input Module

- The I/O system forms the interface by which field devices are connected to the controller.
- The purpose of this interface is to condition the various signals received from or sent to external field devices.
- Input devices such as pushbuttons, limit switches, sensors. Selector switches. and thumbwheel switches are hardwired to terminals on the input modules.

Output Module

- Output devices such as small motors, motor starters, solenoid valves. and indicator lights are hardwired to the terminals on the output modules.

Programming device

- The programming device is used to enter the desired program into the memory of processor.
- Ladder logic programming language uses instead of words, graphic symbol...
- It is a special language written to make. it easier for people familiar with relay logic control to program

Power Supply

Leading manufacturer for PLC

- Allen Bradley
- ABB
- Siemens
- Mitsubishi PLC
- Hitachi PLC
- Delta PLC
- General Electric (GE) PLC
- Honeywell PLC

4.3Input/Output Module

- The I/o system provides an interface between the hardwired components in the field and the CPU.

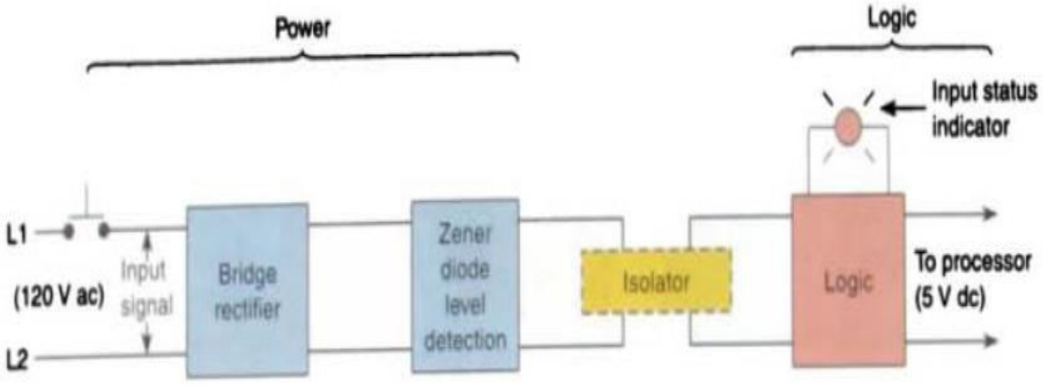
Input Module

Discrete Input Module

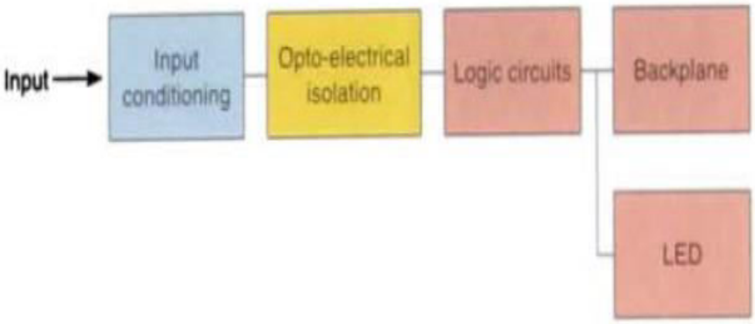
- This type of interface connects field input devices of the ON/OFF nature such as selector switches, pushbuttons and limit switches.
- Likewise, output control is limited to devices such as lights, small motors, solenoids, and motor starters that require simple ON/OFF switching.
- It is interface between the Input field device and CPU of PLC

Input modules perform four tasks in the PLC control system.

- sense when a signal is received from a sensor on the machine
- convert the input signal to the correct voltage level for the particular PLC
- isolate the PLC from fluctuations in the input signal's voltage or current
- send a Signal to the processor indicating which sensor originated the signal



Block diagrams of a discrete input module.



An input filter removes unwanted signal from the electrical interference or key bouncing issue

Opto –electrical isolating section is used to protects the any short circuit fault or high voltage surge from high voltage circuit to logic circuit which normally operated by low voltage

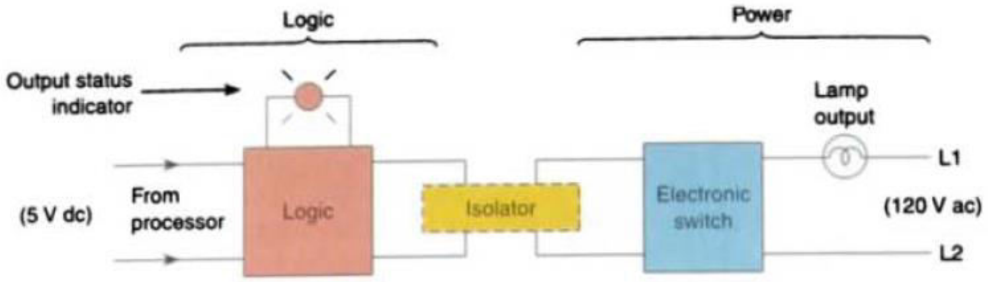
Logic section in the module is used to process the input signal based the pre designed logic and turns ON or OFF the LED

Discrete Output Module

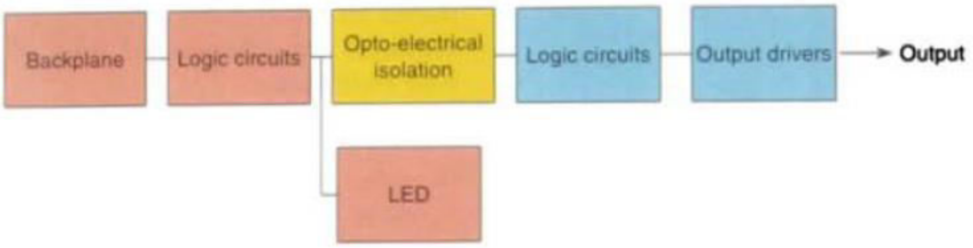
- Discrete output modules typically use the same form of opto-isolation to allow the PLC’s computer circuitry to send electrical power to loads:
- it is composed of two basic sections:

  the *power section and* the *logic section , coupled by an isolation* circuit.

- The output interface can be thought of as a simple electronic switch to which power is applied to control the output device.



(*a*) Block diagram of a discrete output module.



- Discrete output modules are used to turn real world output devices either on or off.
- These modules can be used to control any two-state device. and they are available in ac and dc versions and in various voltage ranges and current ratings.
- Output modules can be purchased with *transistor.* triac. or relay output.
- Triac outputs can be used only for control of ac devices. whereas transistor outputs can be used only for control of dc devices. Relay outputs can be used with ac or dc devices.

Analog I/O Module

- Interface with an analog sensor or control device with CPU of PLC through ADC.
- Analog-to-Digital Converter, circuit designed to convert an analog electrical signal into a multi-bit binary word

- Voltage (0 to 10 volt, 0 to 5 volt)
- Current (0 to 20 mA, 4 to 20 mA)

Thermocouple (millivoltage)

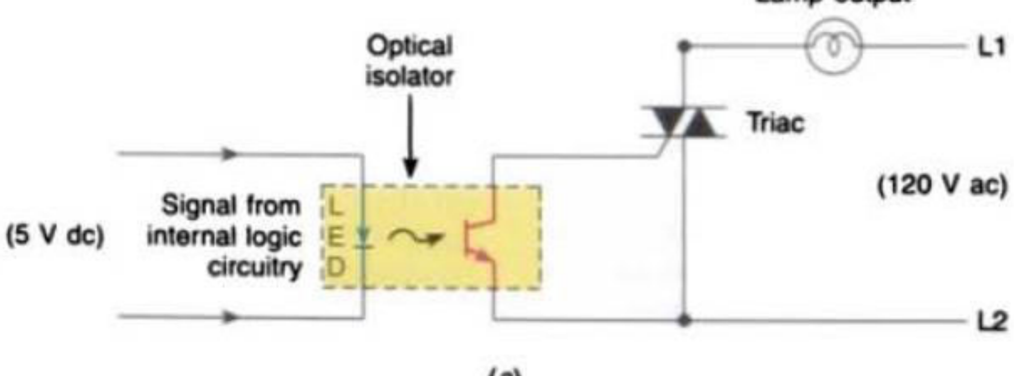
Analog input modules

- *Analog input interface modules contain the* circuitry necessary to accept analog voltage or current signals from analog field devices.
- These inputs are converted from an analog to a digital value by an *analog-lo-digital (AID)* converter circuit.
- The conversion value, which is proportional to the analog signal, is expressed as a 12-bit binary or as a 3-digit binary-coded decimal (BCD) for use by the processor.

  Analog input interface module connection to a thermocouple

- A varying dc voltage in the millivolt range. proportional tothe temperature being monitored. is produced by the thermocouple.
- This voltage is amplified and digitized by the analog input module and then sent to the processor on command from a program instruction.
- Because of the low voltage level of the input signal, a shielded cable is used in wiring the circuit to reduce unwanted electrical noise signals that can be induced in the conductors from other wiring.
- This noise can cause temporary operating errors that can lead to hazardous or unexpected machine operation

AC output Module

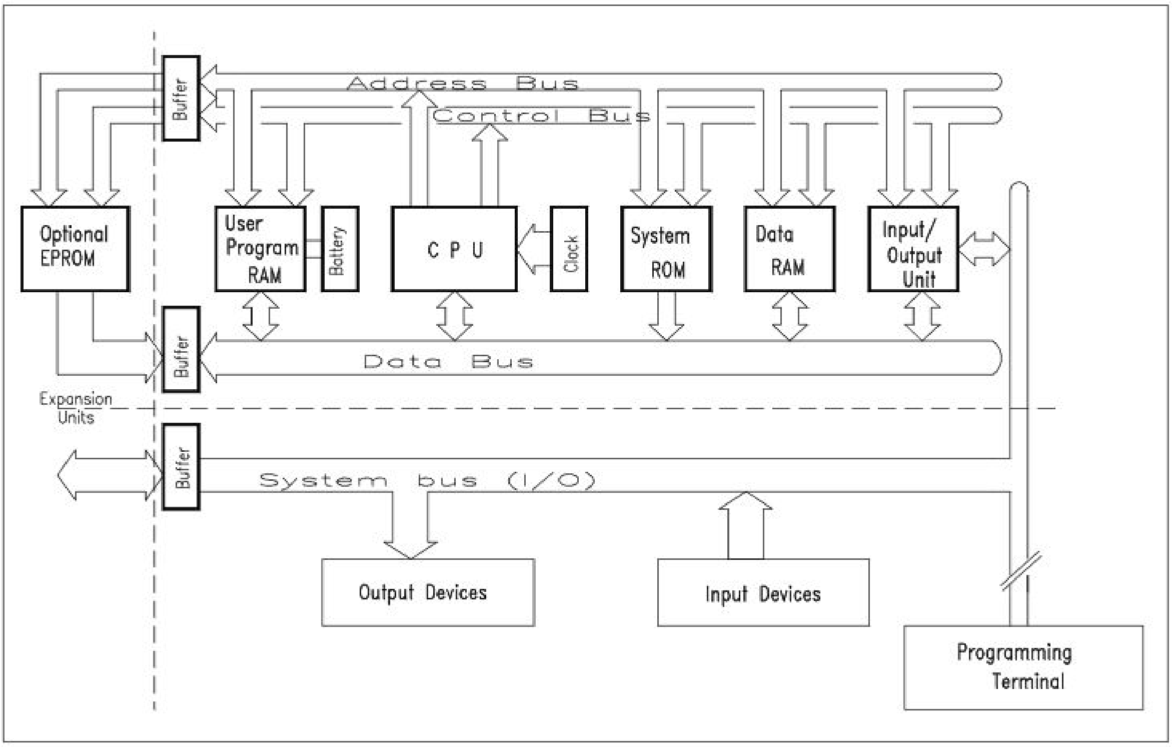


(a)

- When the processor calls for an output, a voltage is applied across the LED of the isolator.
- The LED then emits light, which switches the phototransistor into conduction. This in turn (5 V dc)switches the *triode DC semiconductor switch (triac) into conduction. which in turn turns* on the lamp.
- Since the triac conducts in either direction, the output to the lamp is alternating current. The triac, rather than having ON and OFF status. actually has LOW and HIGH resistance levels, respectively.
- In its OFF state (HIGH resistance), a small leakage current of a few milliamperes still flows through the triac.
- As with input circuits, the output interface is usually provided with LEDs that indicate the status of each output.

4.4.CPU Module

- The CPU contains the same type of microprocessor found in a personal computer.
- The difference is that the program used with the microprocessor is designed to facilitate industrial control rather than provide general purpose computing.
- The CPU executes the operating system, manages memory, monitors inputs, evaluates the user logic (ladder program),and turns on the appropriate outputs.
- The CPU of a PLC system may contain more than one microprocessor.
- The advantage of using multiprocessing is that control and communication tasks can be divided up. And the overall operating speed is improved.



Processor operating mode

RUN, PROG, and REM(Remote).

4.5.Power supply Module

- ❑ The power supply module is a necessary and important component of the control system.
- ❑ It is used to safely regulate and supply the voltage necessary for the PLC and other modules installed on the rack.
- ❑ The module is typically installed in the first slot of the rack.
- ❑ The output voltage of the power supply that we use is typically 24 volts DC.
- ❑ The output current varies depending on the number of the modules needed in the control system.
- ❑ For instance, this output current could be 2, 5 or 10 Ampere.

❑ Depending on which and how many modules are used, the output current of the power supply may need to be higher.

5.Post test MCQ

Which one of the following is not advantages of PLC

Increased Reliability

less Flexibility

Lower Cost

Easier to Troubleshoot

Which module is used for implementing the logic and controlling the communications among the modules PLC.

Power supply module

Communiation module

Processor module

Input module

The ----------------provides an interface between the hardwired components in the field and the CPU

Communication module

Power supply module

Processor module

Input and Output module

In Discrete output module, Relay outputs can be used control the

AC Devices

DC Devices

Both AC and DC devices.

None of the above

6. Conclusion

The block diagram of Programmable Logic Controller discussed and briefed about the each of the block in details

7. References

1. Gary Dunning, “Introduction Programmable Logic Controllers”, CENGAGE Learning, 3rd Ed., 2006.

2. John R. Hackworth, Frederick D. Hackworth Jr., “Programmable Logic Controllers”, Pearson, 2004.

3. Bolton, “Programmable Logic Controllers”, Elsevier, 4th Ed., 2006.

Assignment

1. Explain the PLC block diagram in detail
2. Describe about the analog input and output module of the PLC
3. Write short about the PLC operation and PLC scan cycle.

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UNIT-2 Basic Programming of PLC

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1. Aim and Objective

   Learn about the programming of the PLC

   Implementation of basic logic gates using ladder programming

2. Prerequisites

   Basic knowledge of logic gates

   PLC block diagram

3. Pre Test- MCQ type

1. The output of the two input NAND gate is high when

a) Only If the both inputs are high
b) Only If the both inputs are low
c) Only If the one input is high other one is low
d) If at least one of the input is low

2. A XOR gate has inputs A and B and output Y. Then the output equation is

a) Y = AB
b) Y = AB + A’ B
c) Y = A’ B + A B’
d) Y = AB + A’ B’

3. A solenoid is an example of an ---------------output device.
a) True
b) False
c)None of the above

4.Which module is used for implementing the logic and controlling the communications among the modules PLC.

a)Power supply module

b) Communication module

c) Processor module

d) Input module

5. Which one of the following is an input device?
a) Motor

b) Light
c) Valve
d) Sensor

4. Basic programming of PLC

The 5 most popular types of PLC Programming Languages are:

- **Ladder Diagram (LD)**
- **Sequential Function Charts (SFC)**
- **Function Block Diagram (FBD)**
- **Structured Text (ST)**

Instruction List (IL)

4.1 Ladder Diagram (LD)

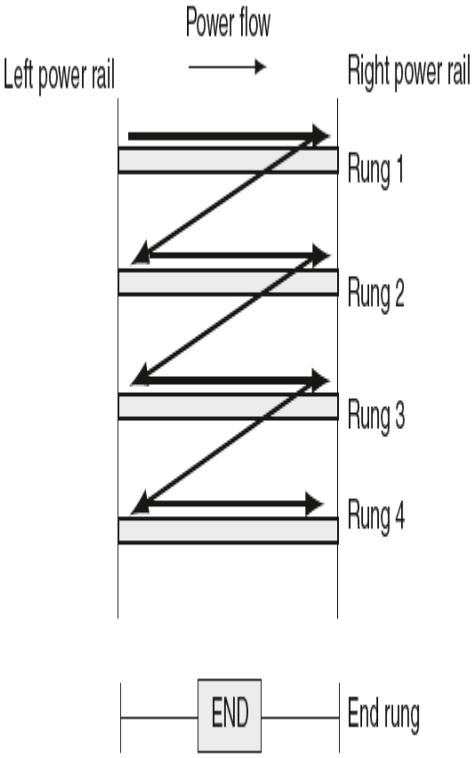
- Ladder logic is the simplest form of PLC programming.
- It is also known as "relay logic". The relay contacts used in relay controlled systems are represented using ladder logic.
- Functional Block Diagram (FBD) is a simple and graphical method to program multiple functions in PLC

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

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.



1. The vertical lines of the diagram represent the power rails between which circuits are connected. The power flow is taken to be from the left-hand vertical across a rung.

2. Each rung on the ladder defines one operation in the control process.

3. A ladder diagram is read from left to right and from top to bottom, showing the scanning motion employed by the PLC.

The top rung is read from left to right. Then the second rung down is read from left to right and so on.

4. Each rung must start with an input or inputs and must end with at least one output. The term input is used for a control action, such as closing the contacts of a switch, used as an input to the PLC. The term output is used for a device connected to the output of a PLC, e.g., a motor.

5. Electrical devices are shown in their normal condition. Thus a switch, which is normally open until some object closes it, is shown as open on the ladder diagram. A switch that is normally closed is shown closed.

6. A particular device can appear in more than one rung of a ladder. For example, we might have a relay that switches on one or more devices. The same letters and/or numbers are used to label the device in each situation.

7. The inputs and outputs are all 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.

8.The instructions used are the relay equivalent of normally open (NO) and normally closed (NC) contacts and coils.

9.Contact symbolism is a simple way of expressing the control logic in terms of symbols that are used on relay control schematics.

10.A rung is the contact symbolism required to control an output. Some PLCs allow a rung to have multiple outputs.

11.A complete ladder logic program thus consists of several rungs. each of which controls an output.

12.Because the PLC uses ladder logic diagrams. the conversion from any existing relay logic to programmed logic is simple.

13. Each rung is a combination of input conditions (symbols) connected from left to right, with the symbol that represents the output at the far right.

14.The symbols that represent the inputs are connected in series, parallel. or some combination of the two to obtain the desired logic.

15.Because the PLC uses ladder logic diagrams. the conversion from any existing relay logic to programmed logic is simple.

16. Each rung is a combination of input conditions (symbols) connected from left to right, with the symbol that represents the output at the far right.

17.The symbols that represent the inputs are connected in series, parallel. or some combination of the two to obtain the desired logic.

RUNG

- A type of line diagram that uses the input and output symbols used by **PLC** ladder logic.
- Line diagrams are converted to programming diagrams before being entered into a **PLC**

4.2 PLC Instructions

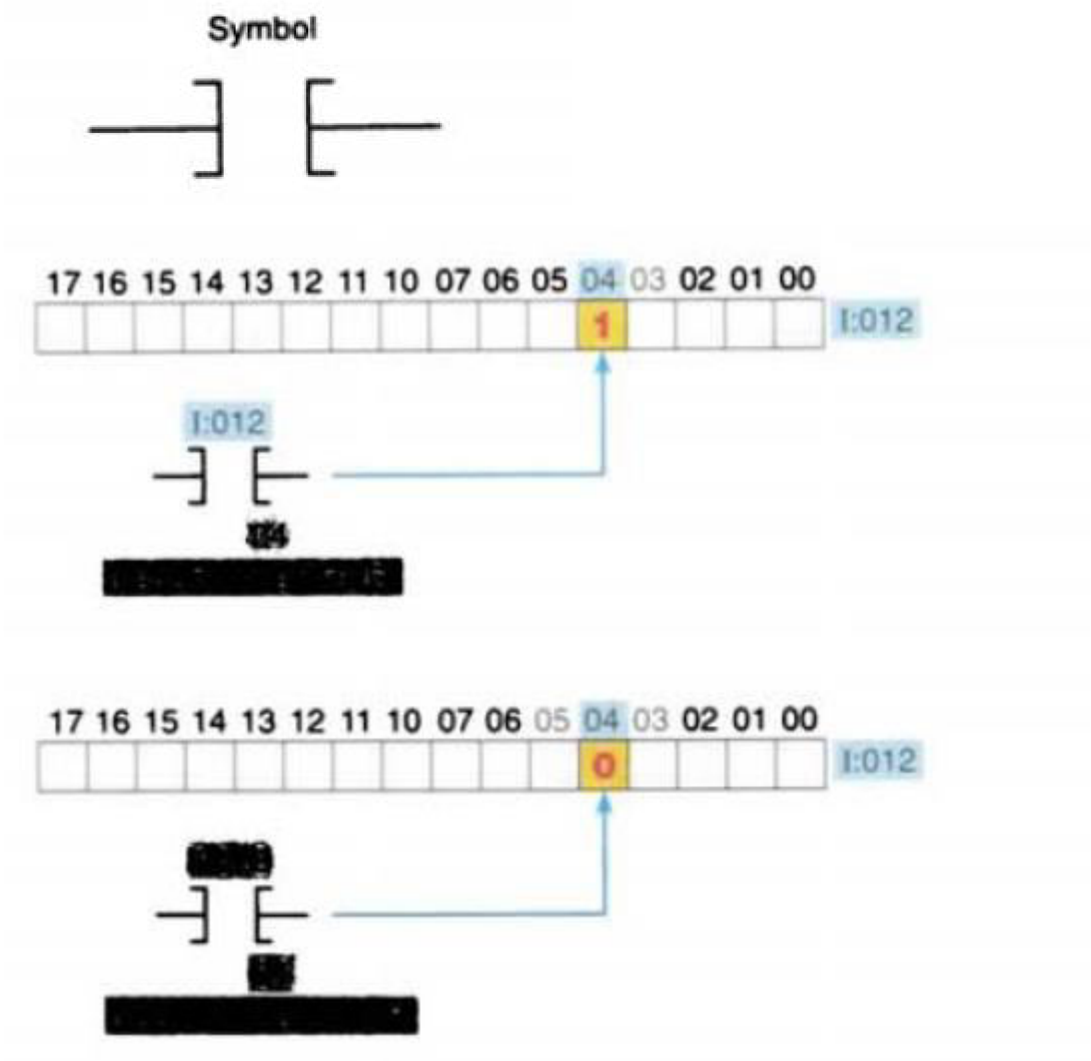
RELAY-TYPE INSTRUCTIONS

- 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 EXAMINE IF CLOSED,EXAMINE IF OPEN, and OUTPUT ENERGIZE

Normally open

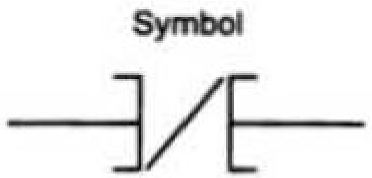
- Analogous to the normally open relay contact. For this instruction.
- we ask the processor to EXAMINE IF (the contact is) CLOSED.
- The status bit will be either1(ON) or 0 (OFF)
- The status bit is examined for an ON condition.
- If the status bit is I (ON). Then the instruction is TRUE.

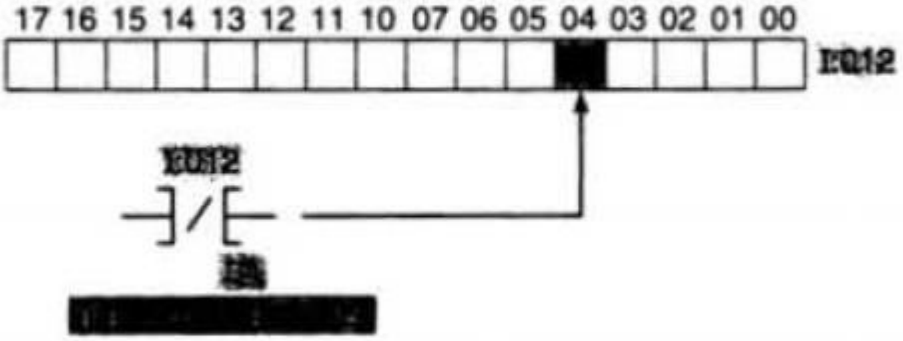
- If the status bit is 0 (OFF). Then the instruction is FALSE.

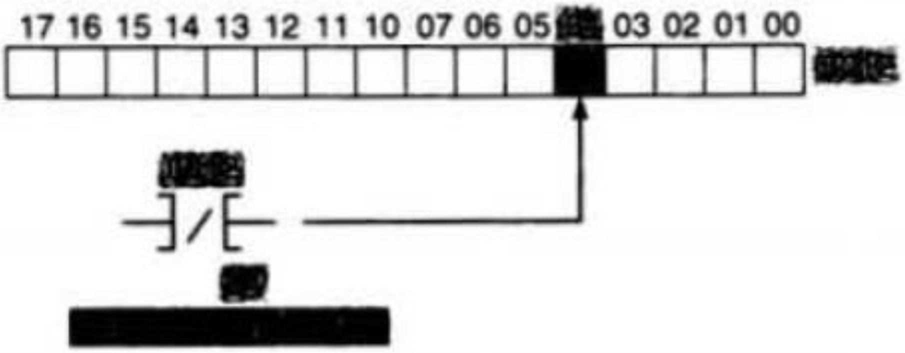


Normally closed

- 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.



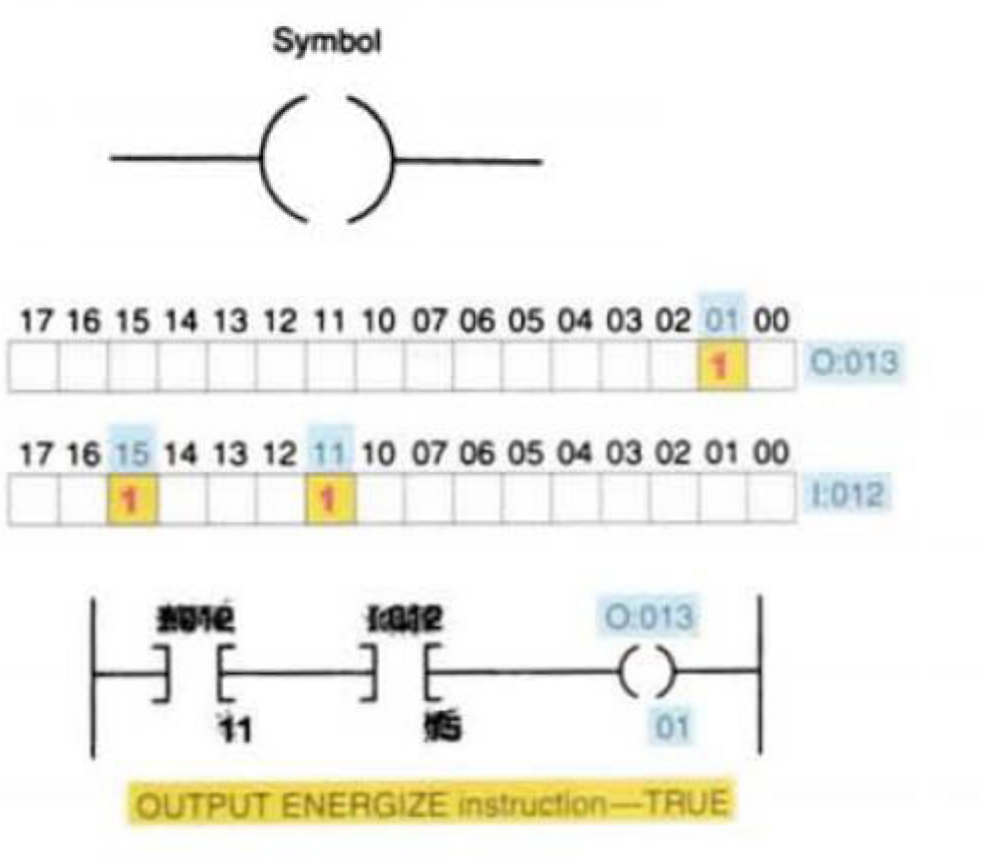




Relay coil (OTE)

- 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.

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



Branching instructions

- Branch instructions are used to create parallel paths of input condition instructions.
- This allows more than one combination of input conditions (OR logic) to establish logic continuity in a rung.
- The rung will be true if either instruction A or *B is TRUE.*

Types

1. **Parallel input Branching**

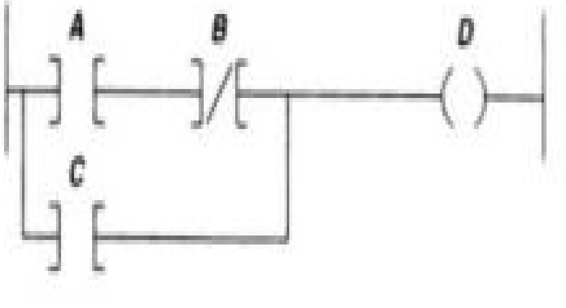
2. Parallel input Branching with Output branching

3. Parallel output branching with input

4. Nested branching

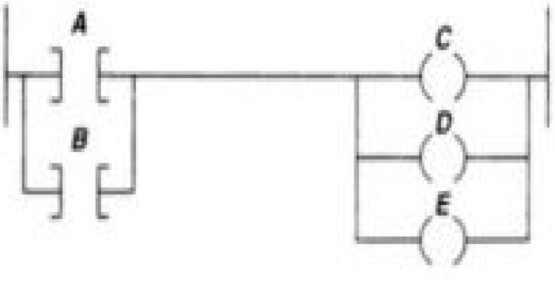
Parallel input Branching

- Input branching by formation of parallel branches can be used in your application program to allow more than one combination of input conditions,
- If at least one of these parallel branches forms a true logic path, the rung logic is enabled.
- If none of the parallel branches forms a true logic path. rung logic is not enabled and the output instruction logic will not be TRUE.
- In the example shown, either A and *B or C pro*vides a true logical path.



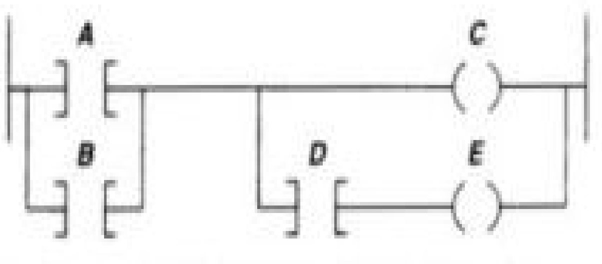
Parallel input Branching with Output branching

- branches can be established at both input and output portions of a rung. With output branching.
- you can Program parallel outputs on a rung to allow a true logic path to control multiple outputs.
- When there is a true logic path. all parallel outputs become TRUE.
- either A or *B* provides a true logical path to all three output instructions: C, D, and *E.*



Parallel output branching with input

- Additional input logic instructions (conditions) can be programmed in the output branches to enhance condition contra) of the outputs.
- When there is a true logic path, including extra input conditions on an output branch. That branch becomes TRUE.
- either *A and D or Band D provide a* true logic path to *E.*



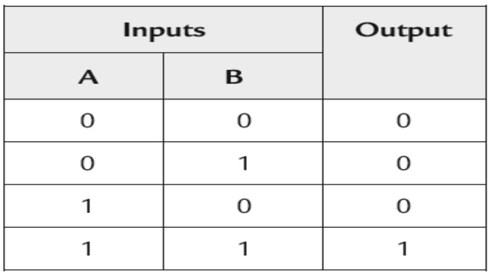
Nested

- Input and output branches can be *nested to* avoid redundant instructions and to speed up processor scan time.
- Input and output branches can be *nested to* avoid redundant instructions and to speed up processor scan time.

4.3. Implementation of logic gates using ladder

AND Logic

It is a basic gate. Whenever the all the input condition must true then output becomes true



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

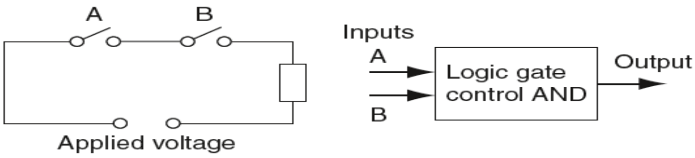
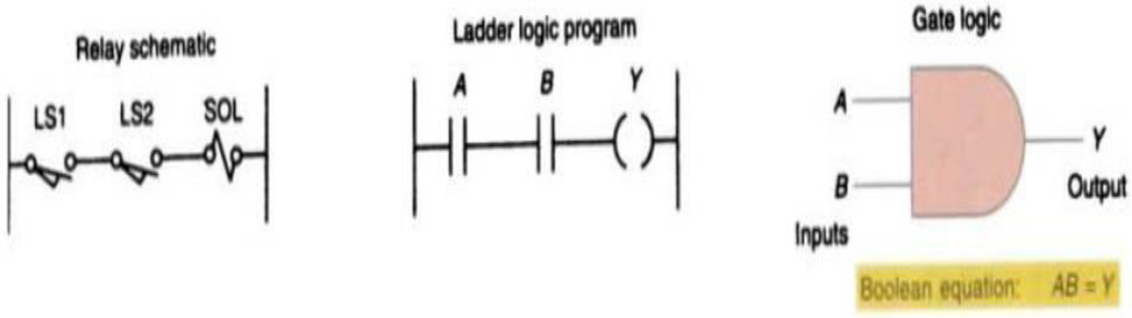


Figure (a)Truth table of the AND logic (b) block diagram of AND logic

Logic equation

$$Y = A \cdot B$$
or
$$Y = AB$$

Ladder Logic diagram for AND Logic



OR LOGIC

It is basic gate. Whenever any one of the input conditions is true the output becomes true

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

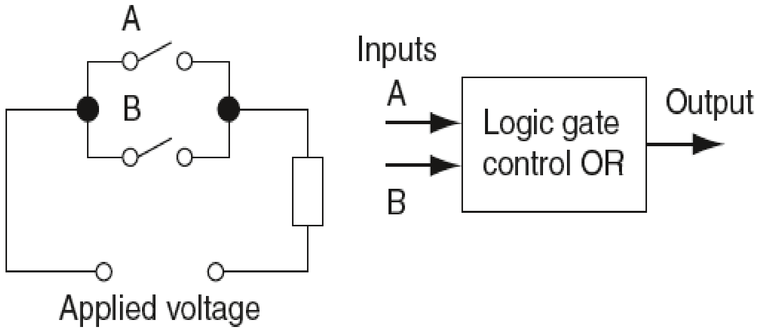
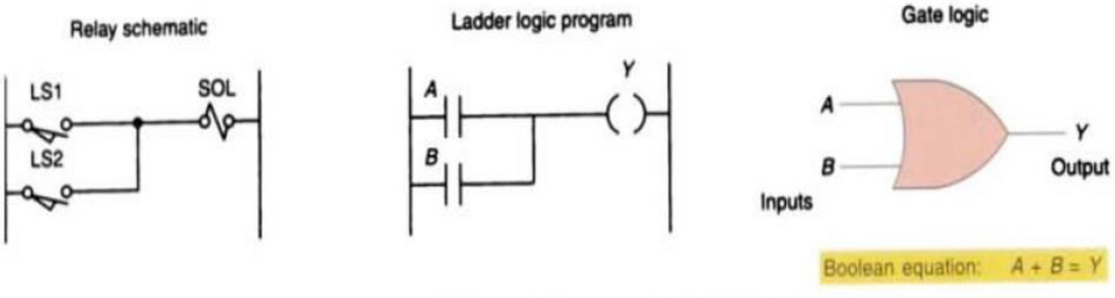


Figure (a)Truth table of the OR logic (b) block diagram of OR logic

Logic equation

$$Y= A+B$$

Ladder logic diagram of the OR logic



- Two limit switches connected in parallel and used to control a solenoid valve.

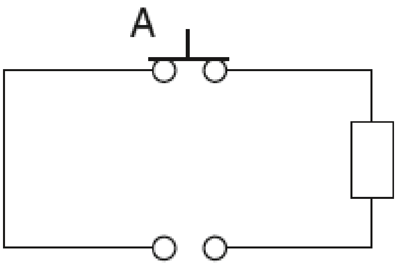
NOT logic

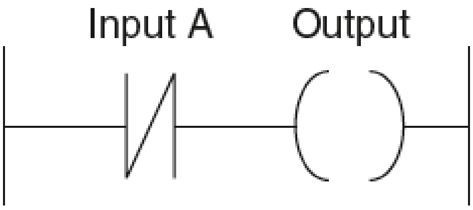
It is one of the basic logic gate output always the complement of input

Truth Table of NOT logic

Input A	Output
0	1
1	0

Ladder logic diagram of NOT logic



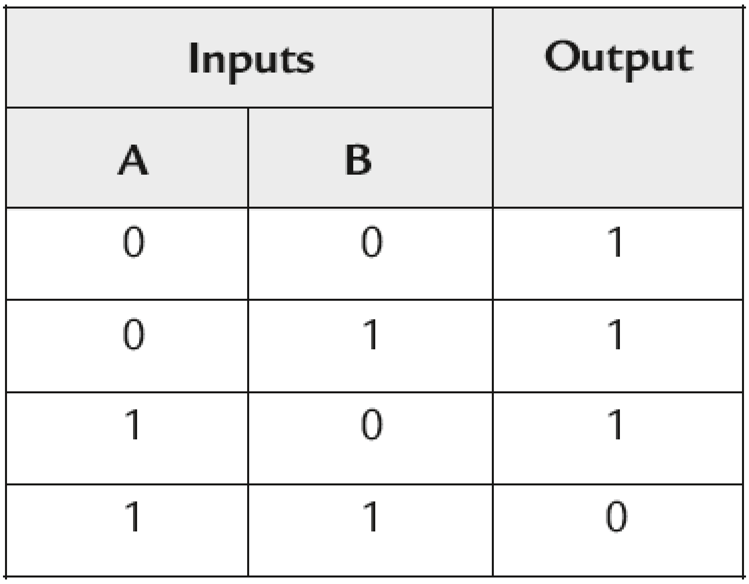


NAND LOGIC

It is an universal gate. Whenever the all the input must true condition the output becomes false or

If any one of the inputs is false condtion then output becomes true.

Truth Table of the NAND Logic

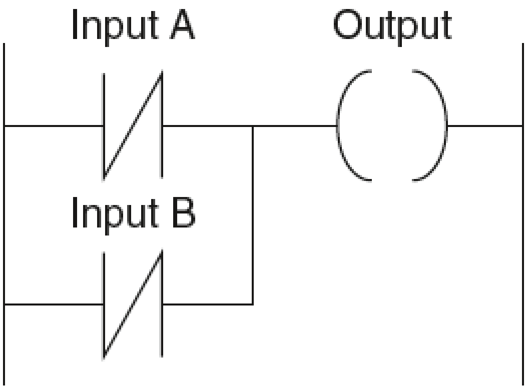


Inputs		Output
A	B	
0	0	1
0	1	1
1	0	1
1	1	0

Logic Equation of the NAND Logic

$$Y = \overline{AB}$$

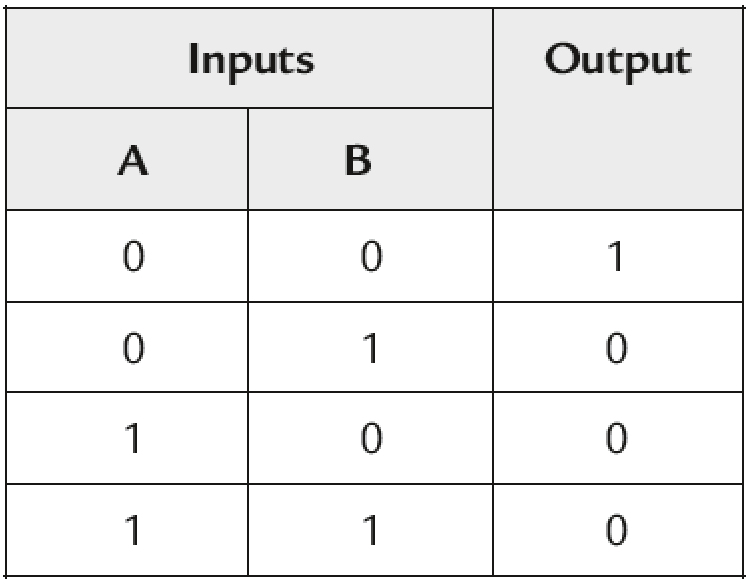
Ladder Logic diagram for NAND logic



NOR Logic

It is an universal gate. Whenever all the input conditions are false then output becomes true

TRUTH TABLE of the NOR logic

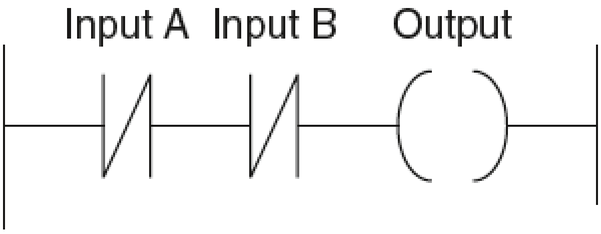


Inputs		Output
A	B	
0	0	1
0	1	0
1	0	0
1	1	0

LOGIC equation

$$Y = \overline{A + B}$$

Ladder logic diagram for NOR logic



Exclusive OR

- The output of this circuit is ON only when pushbutton A or *B is pressed, but not both.*

<u>**Case 1**</u>When A= 0 and B= 0:

Let us analyze main rung. When I1 = 0, the normally open instruction is false and, normally closed instruction is true, but since normally open instruction is false, there is no logical continuity and output cannot be energized. Similar analysis can be done in parallel rung, normally closed instruction will be true and normally open instruction will be false and output is not energized.

Case 2 When A= 0 and B = 1:

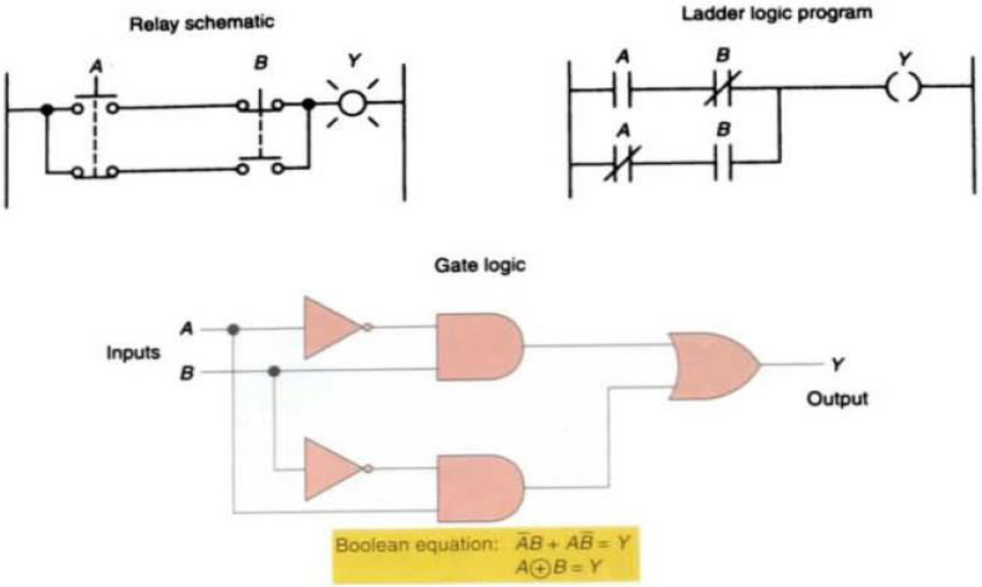
In main rung, normally open instruction will be false and, normally closed instruction will be true, but since there is no logical continuity this rung logic cannot energize the output. But, in parallel rung, normally closed instruction will be true, as well as normally open instruction will also be true, hence there is logical continuity, and output is energized.

Case 3 When I1 = 1 and I2 = 0:

This case is similar to case 2, only the role of inputs are interchanged i.e. here main rung is true and energizes the output and parallel rung is false.

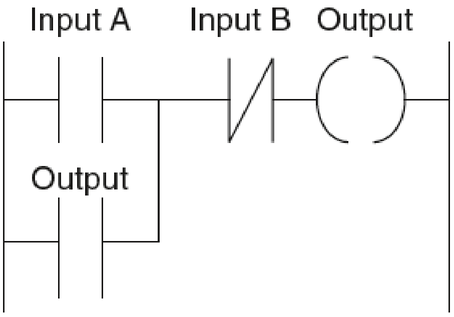
Case 4

- When both inputs are true, the main ladder rung as well as the parallel ladder rung goes false. In main rung, normally open instruction is true but normally closed instruction is false. Hence, there is no logical continuity. In parallel ladder rung, normally closed instruction is false and normally open instruction is true, and here also there is no logical continuity. Hence, the output is not energized.



Latch circuit

- There are often situations where it is necessary to hold an output energized, even when the input ceases.
- A simple example of such a situation is a motor, which is started by pressing a push button switch.
- Though the switch contacts do not remain closed, the motor is required to continue running until a stop push button switch is pressed.
- The term latch circuit is used for the circuit used to carry out such an operation.
- It is a self-maintaining circuit in that, after being energized, it maintains that state until another input is received.



4.4.Simple Programs

- A lighting control system is to be developed. The system will be controlled by four switches, SWITCH1, SWITCH2, SWITCH3, and SWITCH4.

  These switches will control the lighting in a room based on the following criteria:

  1. Any of three of the switches SWITCH1, SWITCH2, and SWITCH3, if turned ON can turn the lighting on, but all three switches must be OFF before the lighting will turn OFF.

  2. The fourth switch SWITCH4 is a Master Control Switch. If this switch is in the ON position, the lights will be OFF and none of the other three switches have any control.

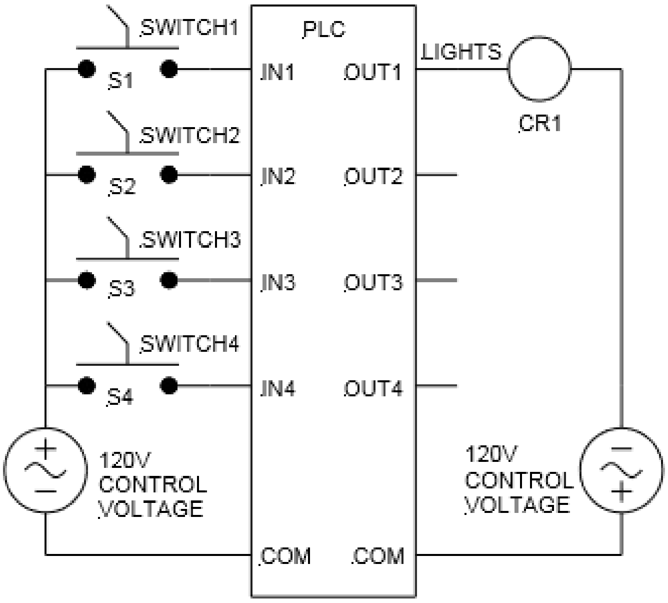
Design the wiring diagram for the controller connections, assign the inputs and outputs and develop the ladder diagram which will accomplish the task.

Number of PLC Inputs Required

- INPUT IN1 = SWITCH1
- INPUT IN2 = SWITCH2
- INPUT IN3 = SWITCH3
- INPUT IN4 = SWITCH4 (Master Control Switch)

Number of PLC Outputs Required

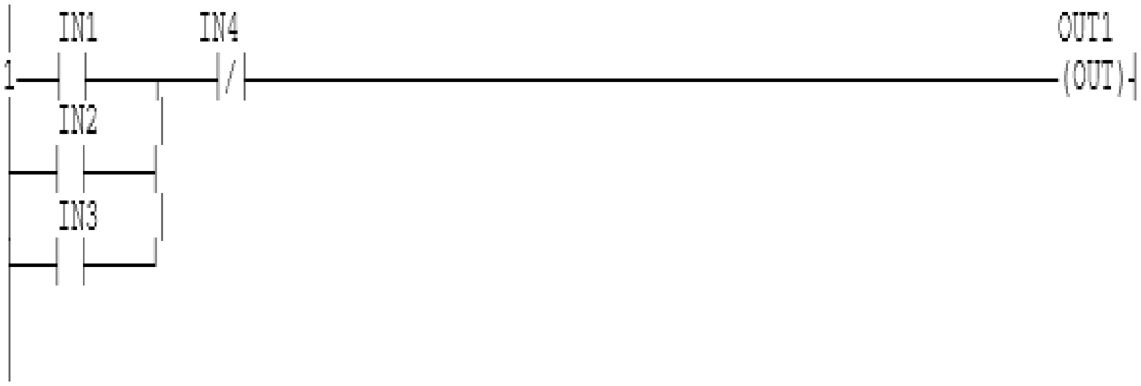
- OUTPUT OUT1 = Lights control relay coil CR1



- Any of three of the switches SWITCH1, SWITCH2, and SWITCH3, if turned ON can turn the lighting on
- The fourth switch SWITCH4 is a Master Control Switch. If this switch is in the ON position, the lights will be OFF

Boolean logic

CR1=(IN1 OR IN2 OR IN3) AND IN4



5. POST MCQ

1. Function Block Diagram (FBD) is a type of____________.

a) PLC Language

b).Block Diagram of a CPU module

c) Block Diagram of a PLC model

d) None of the above

2. The each line used in Ladder Language Programming is known as_______________.

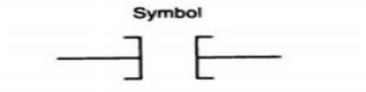
a) Ring

b) Wrong

c) Rung

d) None of the above

3. The symbol shown below in the ladder diagram --------------



a) can be thought of as a contact that is usually closed.
b) can be thought of as a contact that is usually opened.
c) is always a logic 0.
d) is always a logic 1.

4. A two input OR logic function implemented in ladder logic uses:

a)Two normally-closed contacts in series

b) Two normally-open contacts in series
c) Two normally-open contacts in parallel
d) Two normally-closed contacts in parallel

5.Which one of the following logic gate is universal logic gate

a) XOR
b) XNOR
c) NOR
d) All of the above

6. Normally closed contact also known as

a) Examine if open

b) Examine if closed.

c) Relay coil

d) None of the above

6. Conclusion

The basic programming of Programmable Logic Controller discussed and briefed

7. References

1. Gary Dunning, “Introduction Programmable Logic Controllers”, CENGAGE Learning, 3rd Ed., 2006.

2. John R. Hackworth, Frederick D. Hackworth Jr., “Programmable Logic Controllers”, Pearson, 2004.

3. Bolton, “Programmable Logic Controllers”, Elsevier, 4th Ed., 2006.

8. Assignment

1. Implement PLC program to control water level of the tank. One open tank is installed in the plant of which liquid level is to be controlled. When level reaches the Level Low, Outlet flow is blocked and inlet flow is allowed until high level is achieved. And when Level High is detected, outlet flow is allowed and inlet flow is blocked.
2. Implement the 4:1multiplexer using ladder logic diagram

3.The rung |--] [-----]/[-----( )--| would represent what Boolean equation?

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             X      Y      Z                  and draw the equivalent logic diagram using
gate
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