بسم الله الرحمن الرحيم

Benha University

Prof . Mohamed Ahmed Ebrahim

Benha University
Faculty of Engineering at Shoubra
Electrical Engineering Dept.

Industrial Controls (1)

By

Associate Prof. / Mohamed Ahmed Ebrahim Mohamed

E-mail: mohamedahmed_en@yahoo.com

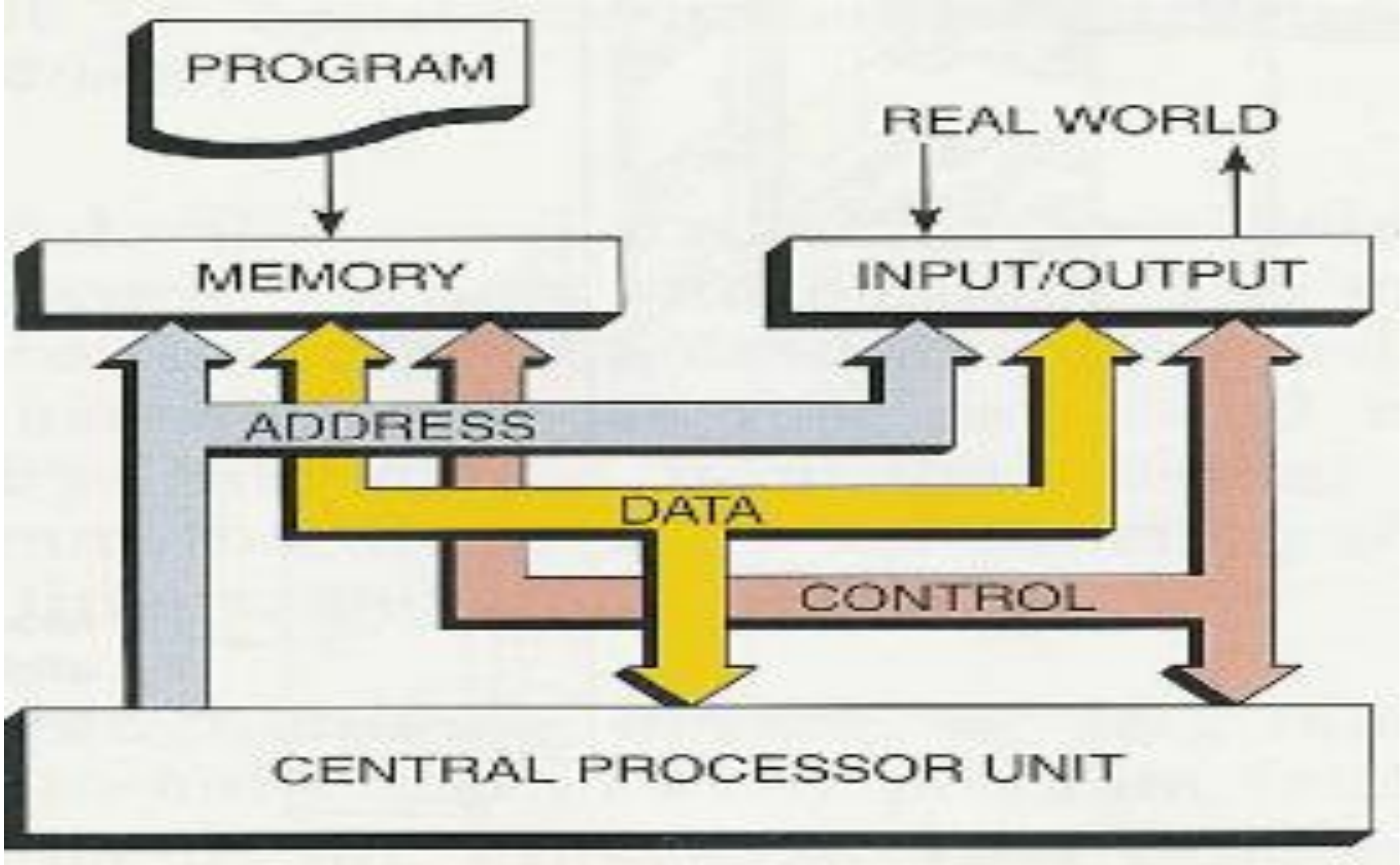
mohamed.mohamed@feng.bu.edu.eg

Web site: http://bu.edu.eg/staff/mohamedmohamed033

Lecture (5)

Basic design of a PLC

PLC Basic Architecture



Basic design of a PLC

- The term 'programmable logic controller' is defined as follows by **IEC 1131, Part 1**:

1. *PLC is a digitally operating electronic system, designed for use in an industrial environment, which uses a programmable memory for the internal storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting and arithmetic, to control, through digital or analog inputs and outputs, various types of machines or processes.*

2. *Both the PC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used' in all their intended functions.*

So we can say that programmable logic controller is therefore nothing more than a microcomputer, tailored specifically for certain control tasks.

The program of a PLC can be created in various ways:

- via assembler- type commands in 'statement list'
- in higher-level, problem-oriented languages such as structured text
- in the form of a flow chart such as represented by a sequential function chart
- in Europe, the use of function block diagrams based on function charts with graphic symbols for logic gates is widely used
- in America, the 'ladder diagram' is the preferred language by users

PLC Configuration

Depending on how the central control unit (CCU) is connected to the input and output modules, differentiation can be made between:

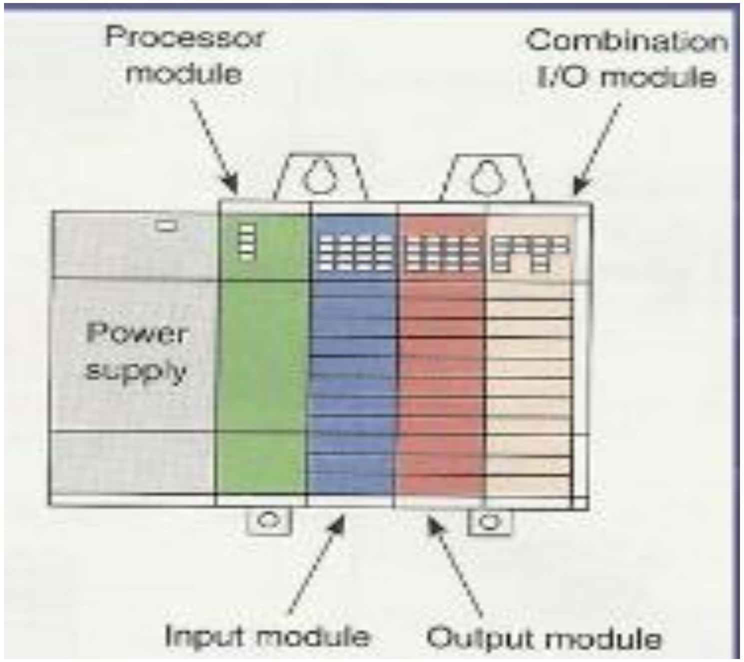
- compact PLCs (input module, central control unit and output module in one housing).
- modular PLCs.

1. Modular PLCs

- Modular PLCs may be configured individually.
- The modules required for the practical application - which can, for instance, include digital input/output modules, analogue modules, positioning and communication modules - are inserted in a rack, where individual modules are linked via a bus system. This type of design is also known as series technology.

Modular PLCs - Examples

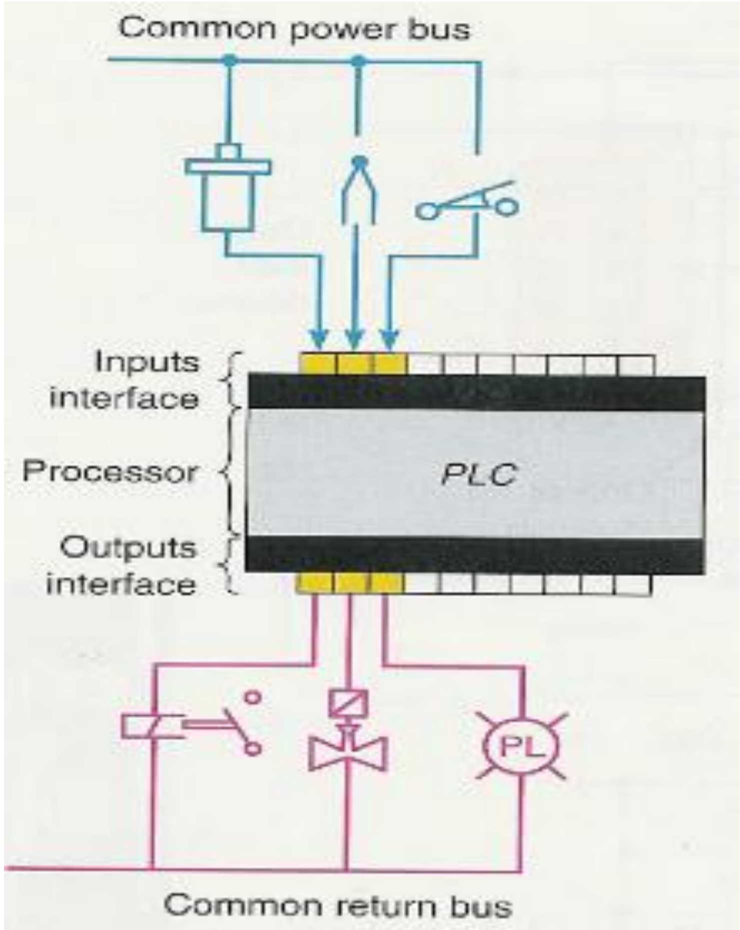
- Two examples of modular PLCs:
  1. New S7 -300 series by Siemens.
  2. Familiar modular PLC FPC405 FESTO.



Modular PLC – card format

- The card format PLC is a special type of modular PLC, developed during the last years of previous century.
- With this type, individual or a number of printed circuit board modules are in a standardised housing.
- The Festo FPC 405 is representative of this type of design.

2. Compact PLC - example



Compact Vs Modular PLC

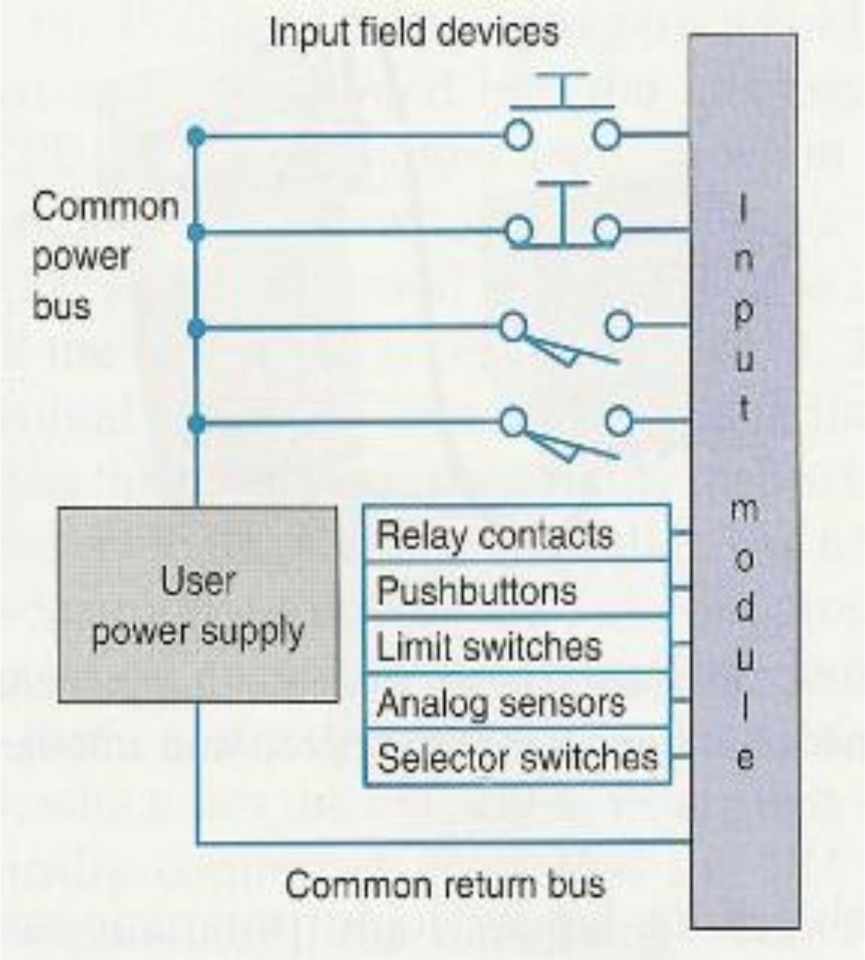
- A wide range of variants exists, particularly in the case of more recent PLCs.
- These include both modular as well as compact characteristics and important features such as space saving, flexibility and scope for expansion.

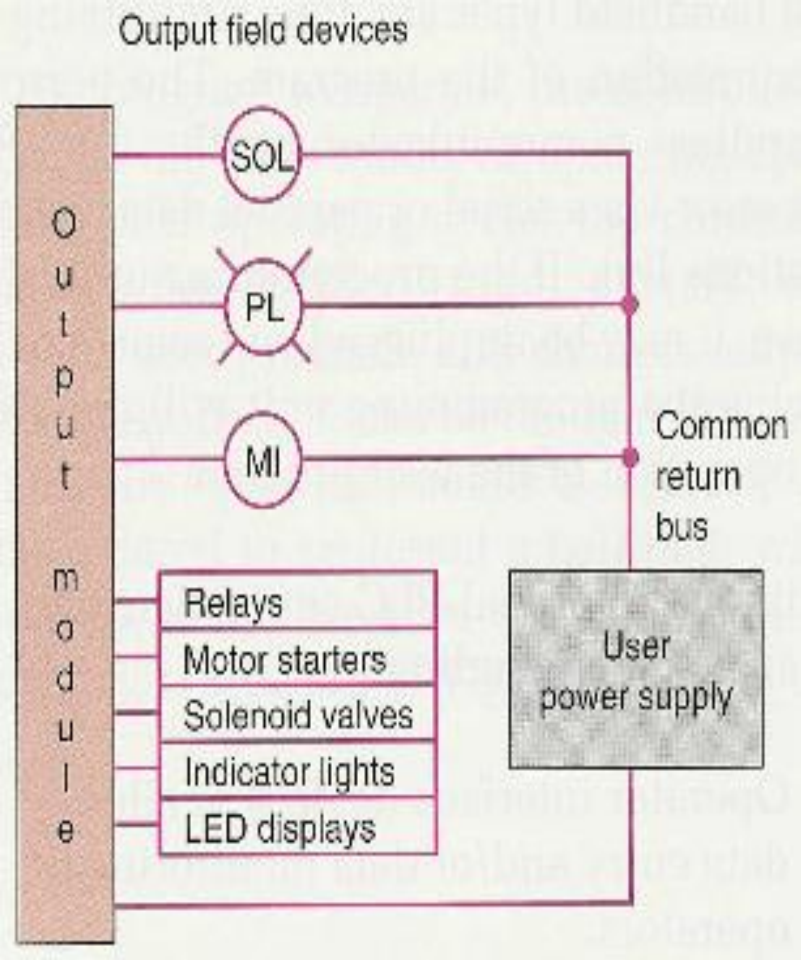
Hardware design for a PLC

The hardware design for a programmable logic controller is such that it is able to withstand typical industrial environments as regard:

- signal levels
- heat
- humidity
- fluctuations in current supply
- mechanical impact

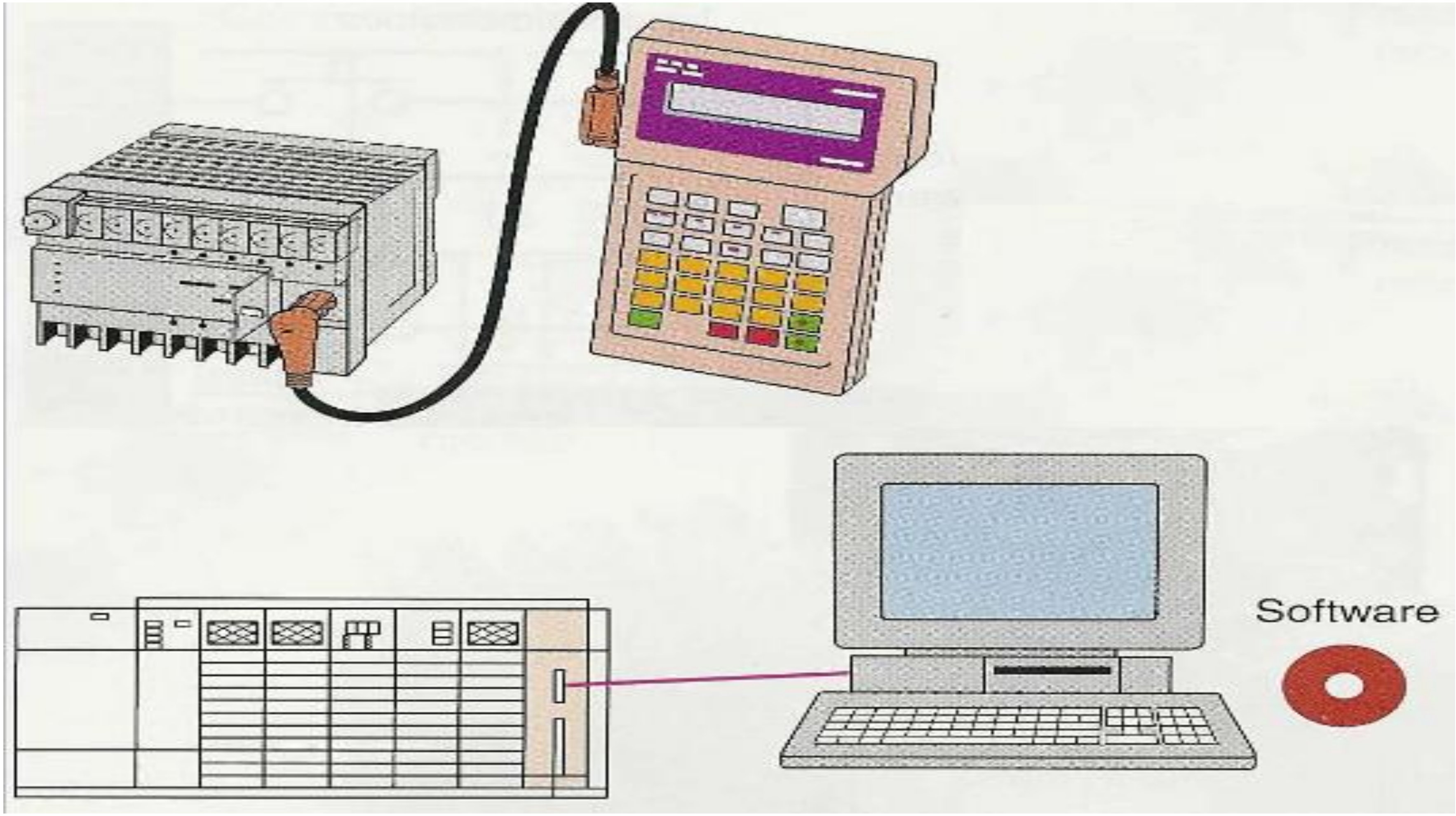
Input/output Modules





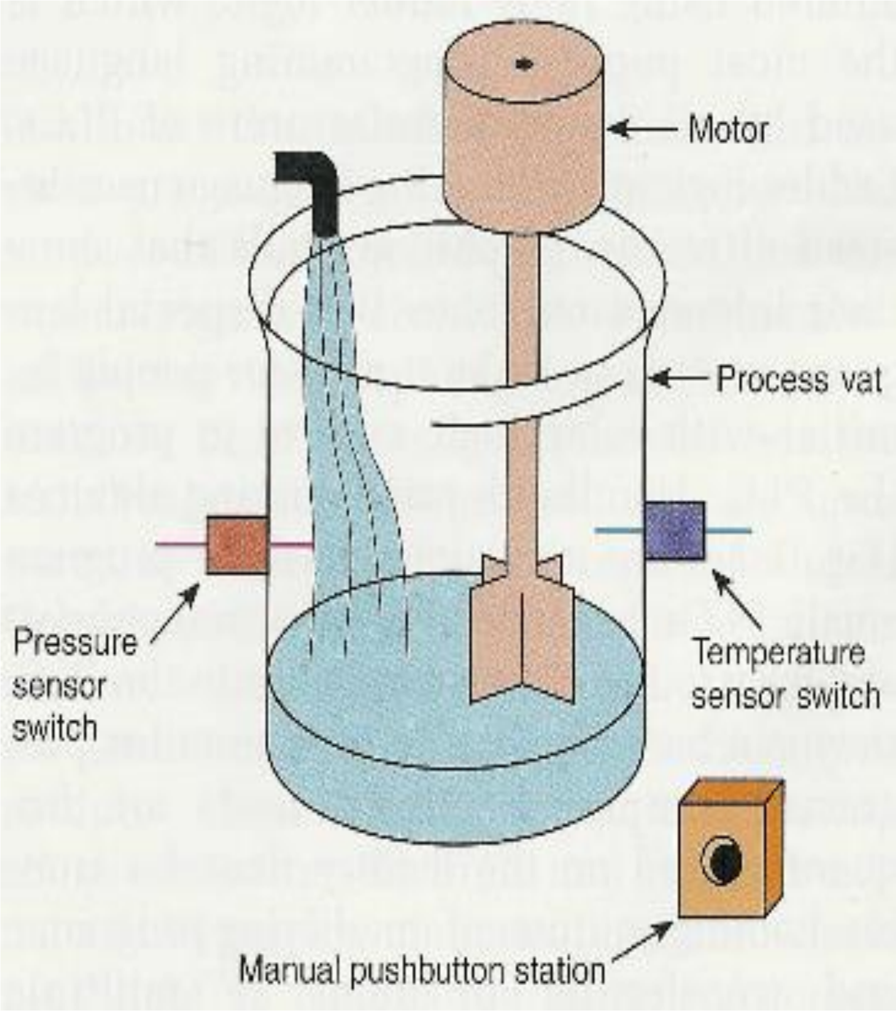
Prof. Mohamed Ahmed Ebrahim

Programming the PLC

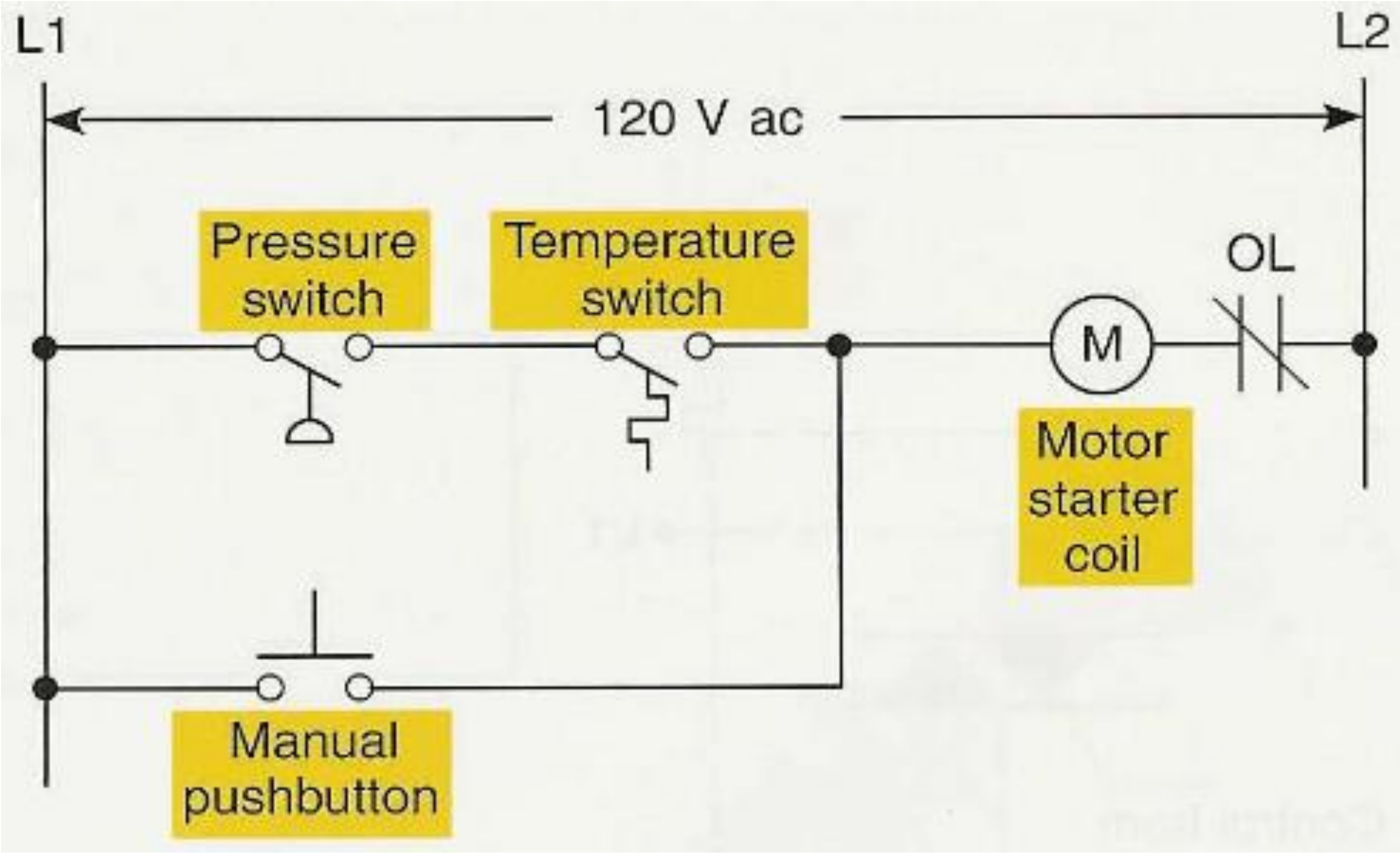


Principles of Operation

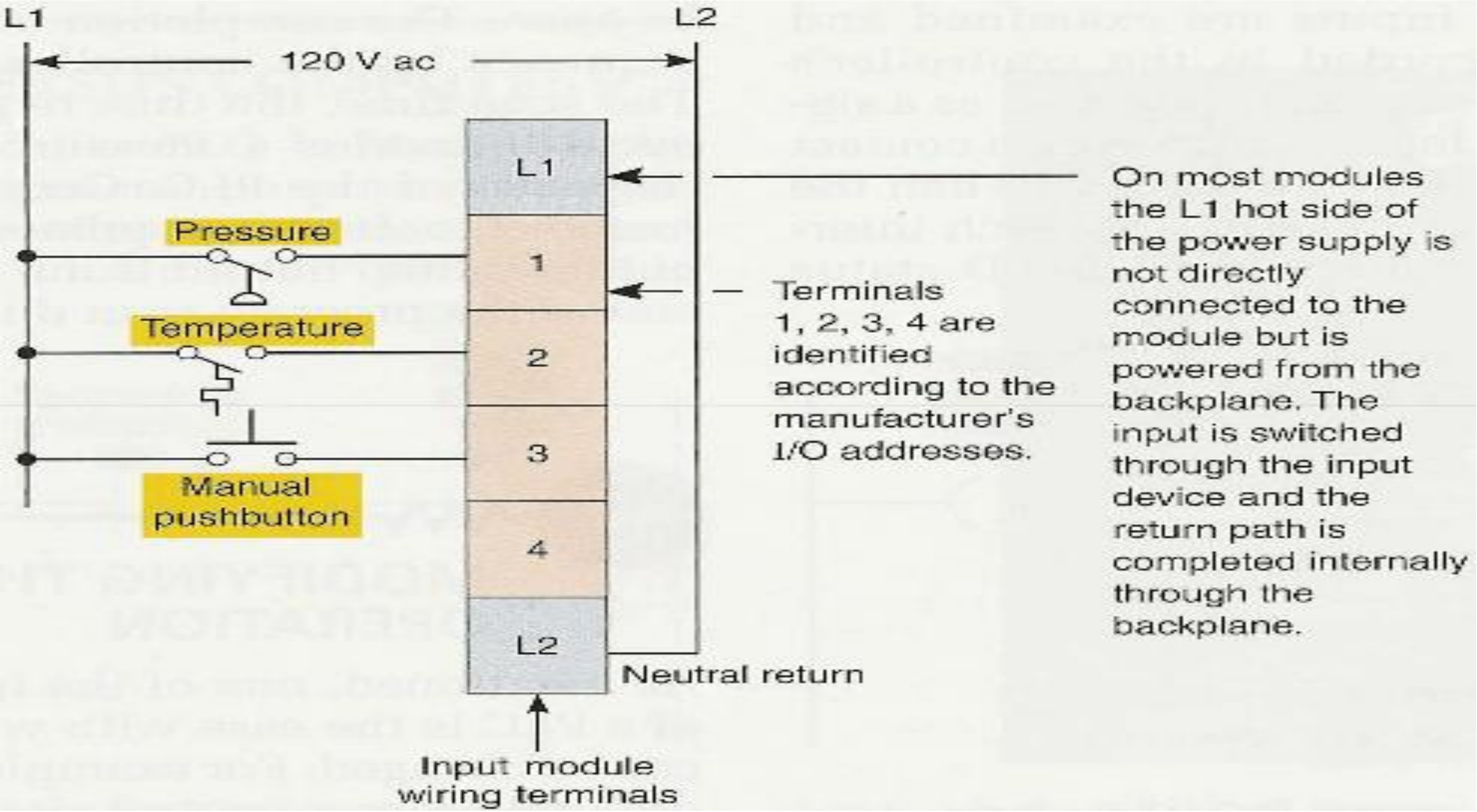
- To get an idea on how PLC operates lets consider the following simple process control problem.



Process Control Description

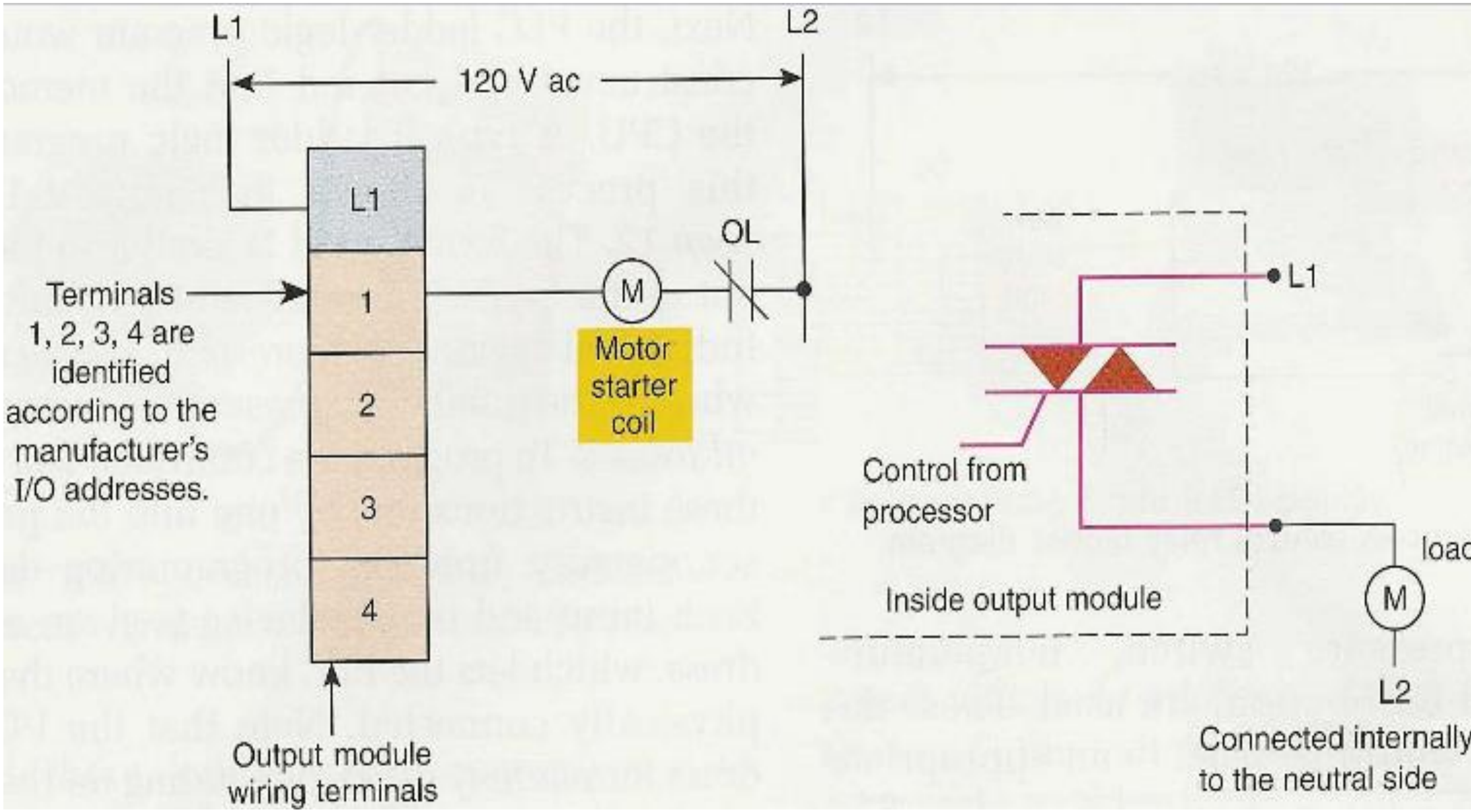


PLC Inputs Connection



Prof. Mohamed Ahmed Ebrahim

PLC Output Connections

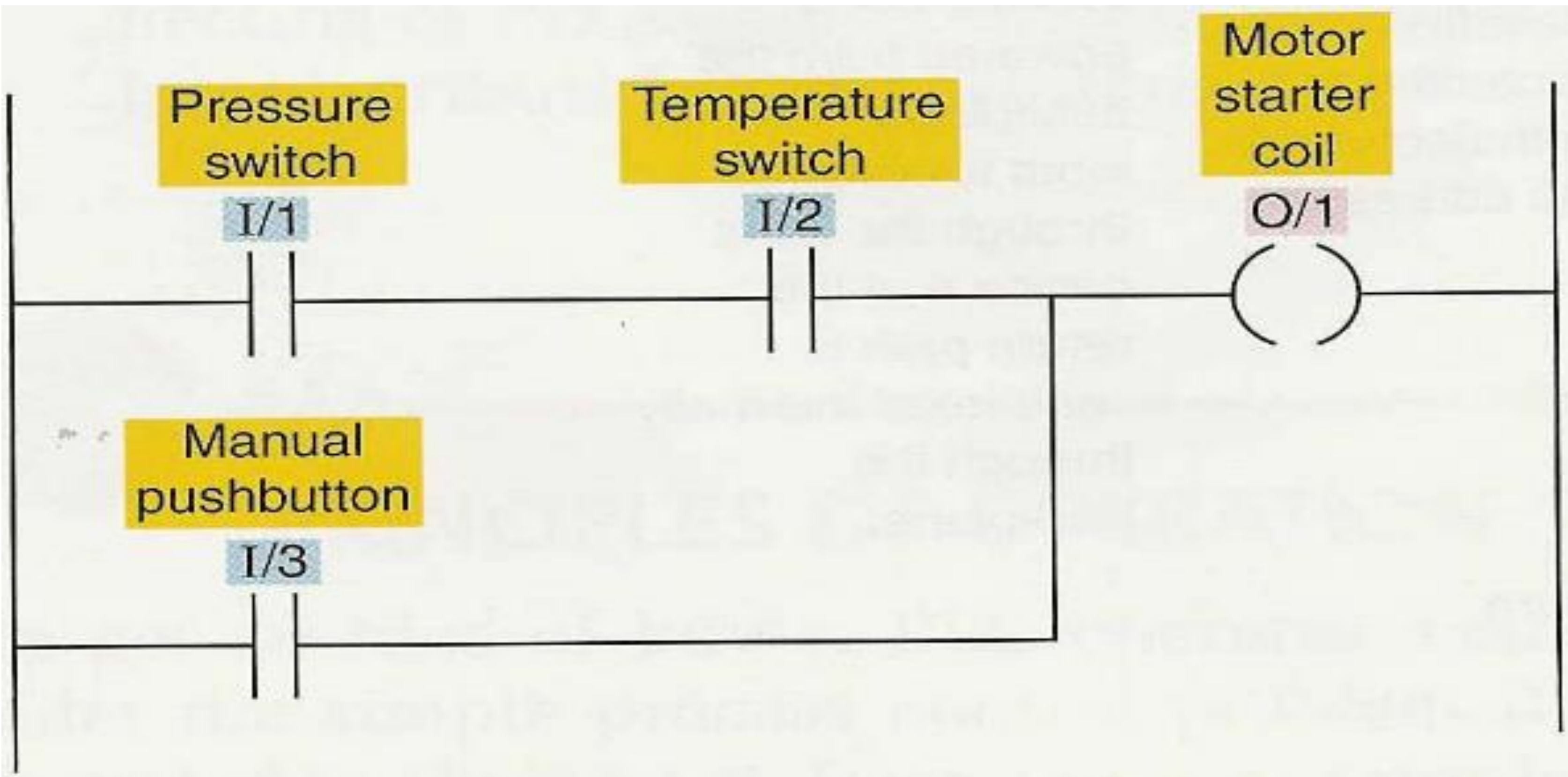


Prof. Mohamed Ahmed Ebrahim

Programming the PLC

1. To implement the described system using the PLC, a description in ladder logic should be provided.
2. Next, the ladder logic is complied and translated to basic instructions and down loaded to the internal memory.
3. During programming, the PLC should be in the <u>Terminal or Programming mode</u>.

Ladder Logic Program



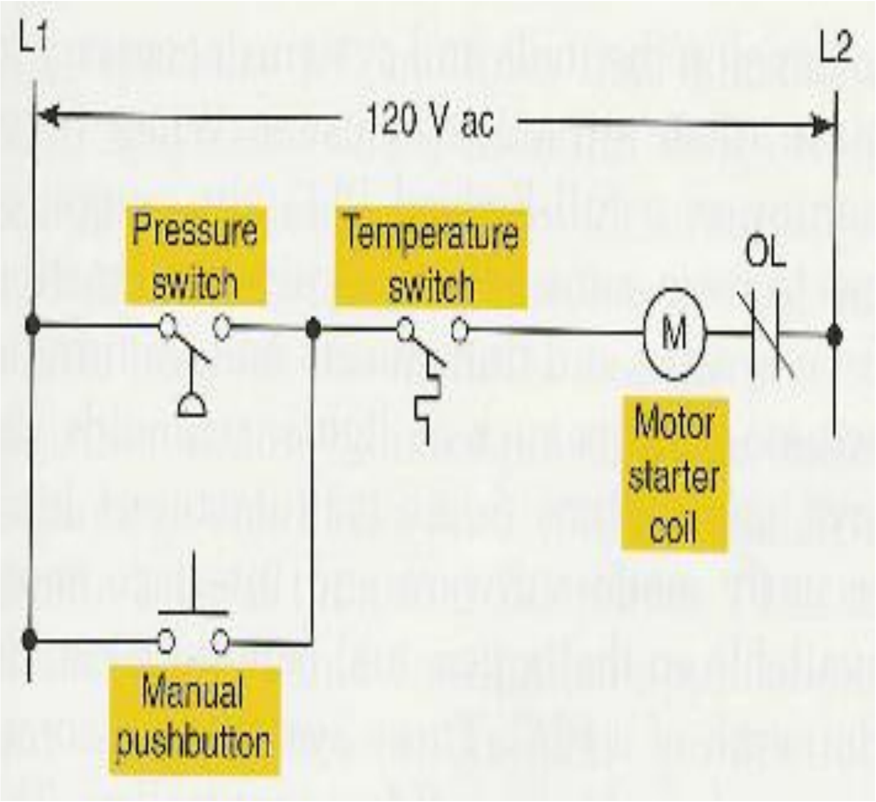
Running the Program

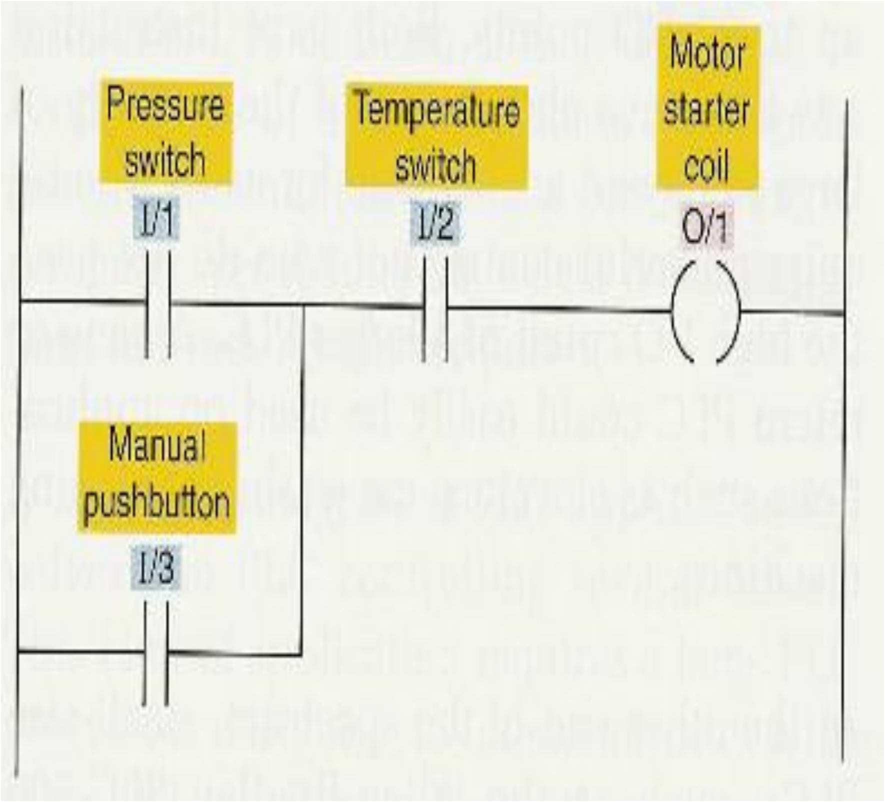
- For the program to operate the PLC should be put on the Run mode or Operating cycle.
- In the operating cycle, first the controller examines the inputs and their status is recorded in the PLC memory.
- Then, the ladder diagram is evaluated, and changes ladder diagram is evaluated, and changes are sent to the outputs accordingly.

Scan Time

- The completion of a cycle of the controller is called a Scan.
- The scan time needed to complete a full cycle by the controller gives the measure of execution for the PLC.
- Generally, outputs are updated in memory during the scan but the actual output is updated until the end of the program updated during the I/O scan.

Process Modification





Prof. Mohamed Ahmed Ebrahim

PLC Vs Computer

PLC

- Designed for extreme industrial environments.
- Can operate in high temperature and humidity.
- High immunity to noise.
- Integrated command interpreter(proprietary).

computer

- Designed mainly for data processing and calculation.
- Optimized for speed.
- Can't operate in extreme environments.
- Can be programmed in different languages.

The new PLC standard IEC 1131

Prof . Mohamed Ahmed Ebrahim

Previously PLC standards

- Previously valid PLC standards focussing mainly on PLC programming were generally geared to current state of the art technology in Europe at the end of the seventies.
- This took into account non-networked PLC systems, which primarily execute logic operations on binary signals.
- DIN 19 239, for example, specifies programming languages which possess the corresponding language commands for these applications.

Previously situation

- no equivalent, standardised language elements existed for the PLC developments and system expansions made in the eighties such as
  - processing of analogue signals
  - interconnection of intelligent modules
  - networked PLC systems etc.

Consequently, PLC systems by different manufacturers required entirely different programming.

International standard

- Since 1992, an international standard now exists for programmable logic controllers and associated peripheral devices (programming and diagnostic tools, testing equipment, human-to-machine (HMI) interfaces etc.).
- In this context, a device configured by the user and consisting of the above components is known as a PLC system.

The new IEC 1131 standard consists of six parts:

- Part 1: General information
- Part 2: Equipment requirements and tests
- Part 3: Programming languages
- Part 4: User guidelines (in preparation with IEC)
- Part 5: Messaging service specification (in preparation with IEC)
- Part 7: Fuzzy control programming

The purpose of the new standard

- to define and standardise
  - the design and functionality of a PLC
  - the languages required for programming

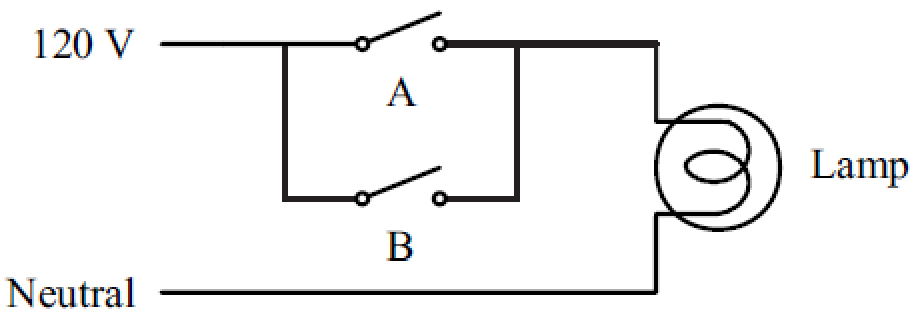
  to the extent where users were able to operate using different PLC systems without any particular difficulties

The simple Ladder Logic

Prof . Mohamed Ahmed Ebrahim

Simple ladder logic

- To introduce ladder logic programming simple switch circuits are converted to relay logic and then to PLC ladder logic.
- **Example(1):** OR Circuit. Two switches labeled A and B are wired in parallel controlling a lamp as shown in the Figure. Implement this function as PLC ladder logic where the two switches are separate inputs.



(a)

A	B	Lamp
off	off	off
off	on	on
on	off	on
on	on	on

(b)

Parallel switch circuit: *(a)* switch circuit; *(b)* truth table.

Solution.

- The switch circuit action is described as, “The lamp is on when switch A is on (closed) or switch B is on (closed).”
- The switches A and B are not connected to the lamp directly, but are connected to relay coils labeled AR and BR whose normally-open (NO) contacts control a relay coil, LR, whose contacts control the lamp.
- The switches, A and B, are the inputs to the circuit. When either switch A or B is closed, the corresponding relay coil AR or BR is energized, closing a contact and supplying power to the LR relay coil. The LR coil is energized, closing its contact and supplying power to the lamp.

Logic Gates
&
Memory Components

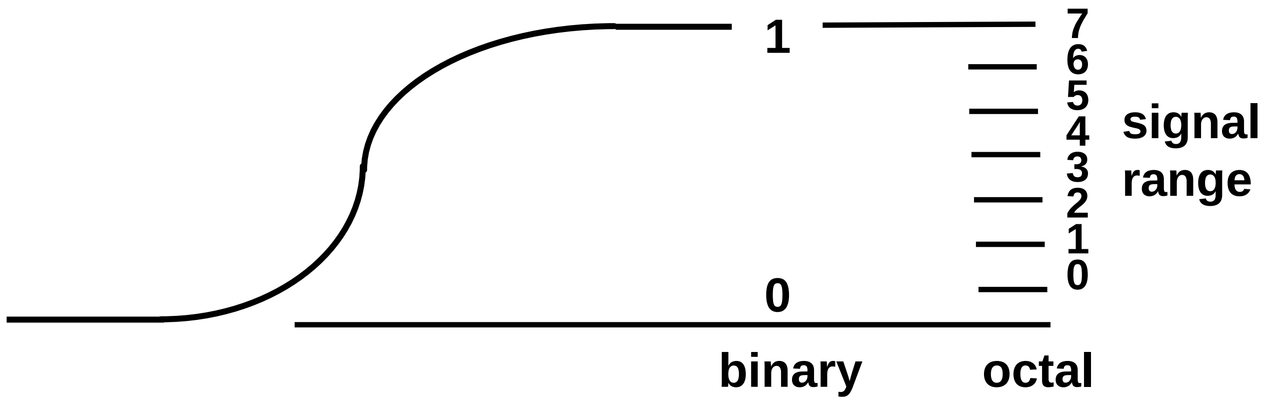
Prof . Mohamed Ahmed Ebrahim

Logic Gates

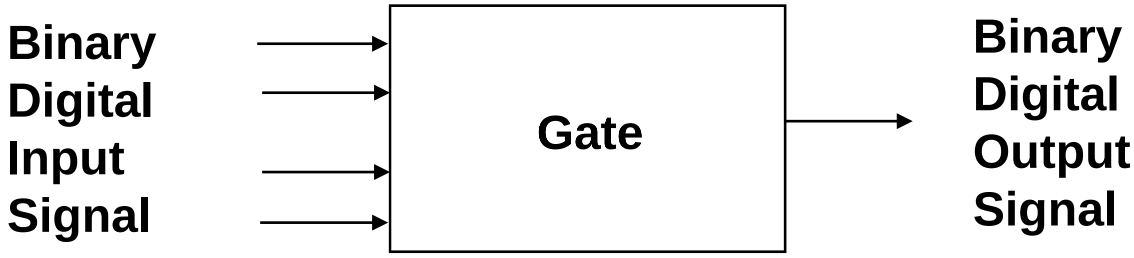
Digital Computers:

- Imply that the computer deals with digital information, i.e., it deals with the information that is represented by binary digits.
- Why BINARY ? instead of Decimal or other number system ?

Consider electronic signal



Basic Logic Block (Gate)



Types of Basic Logic Blocks:

1. Combinational Logic Block

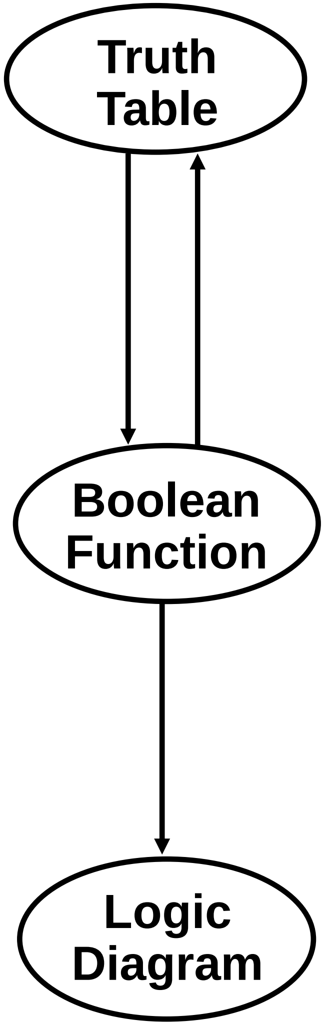
- Logic Blocks whose output logic value depends only on the input logic values.
- Sequential Logic Block Logic Blocks whose output logic value depends on the input values and the state (stored information) of the blocks.

Cont.

2. **Functions of Gates can be described by**

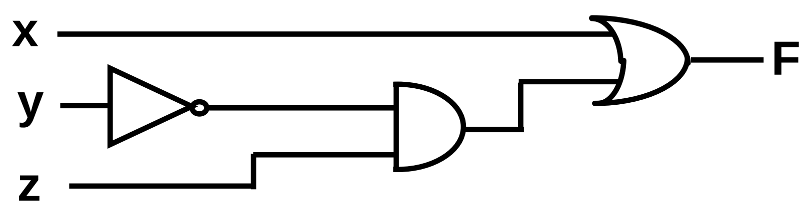
- Truth Table.
- Boolean Function.
- Karnaugh Map

Logic circuit design



x	y	z	F
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

$F = x + y'z$

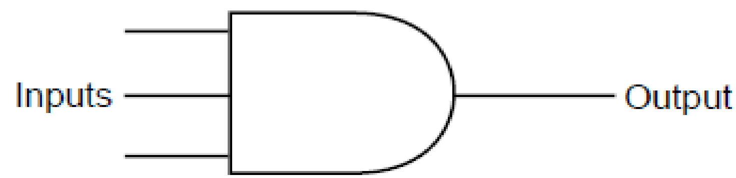


Combinational Gates

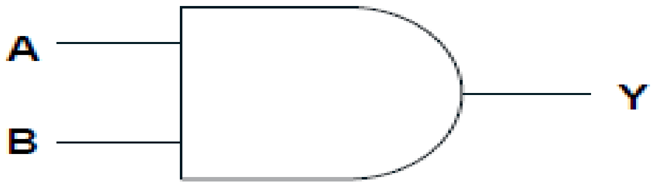
1. AND
2. OR
3. NOT
4. NAND
5. NOR
6. XOR
7. XNOR
8. Buffer

1. AND Gate

- The AND output is TRUE (1) only if all inputs are TRUE.
- An AND function can have an unlimited number of inputs, but it can have only one output.
- **Symbol for the AND function:**



- **truth table:**

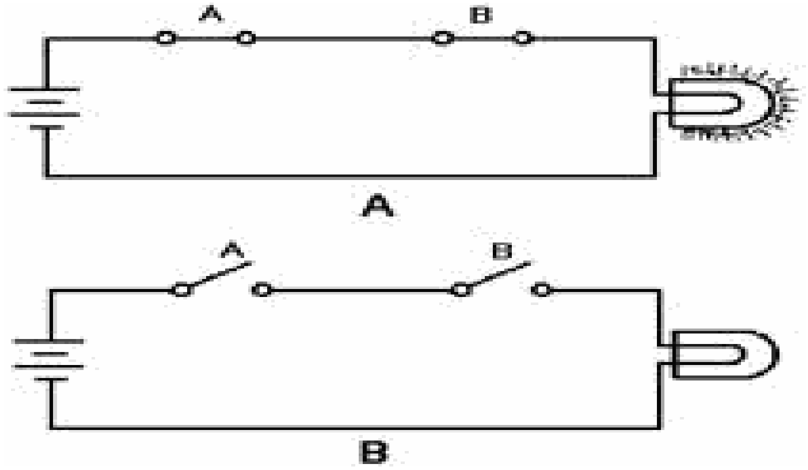


AND Truth Table		
Inputs		Output
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Two-input AND gate and its truth table.

Cont.

- **Electrical Circuit**



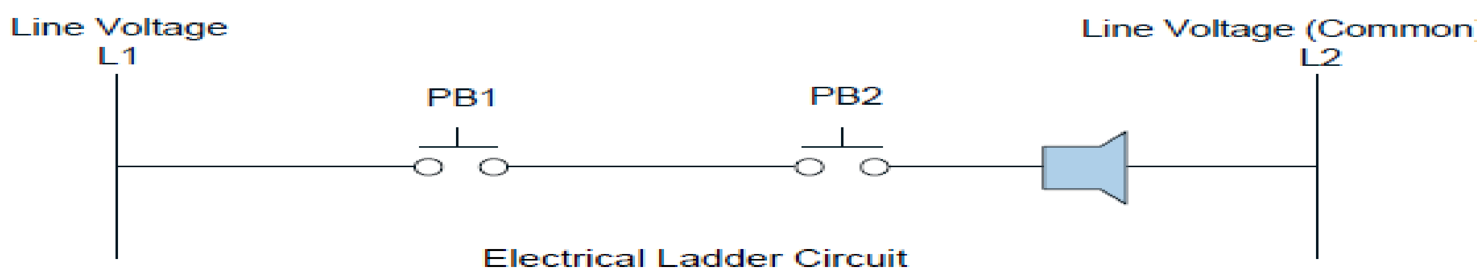
Example (1)

- Show the logic gate, truth table, and circuit representations for an alarm horn that will sound if its two inputs, push buttons PB1 and PB2, are 1 (ON or depressed) at the same time.

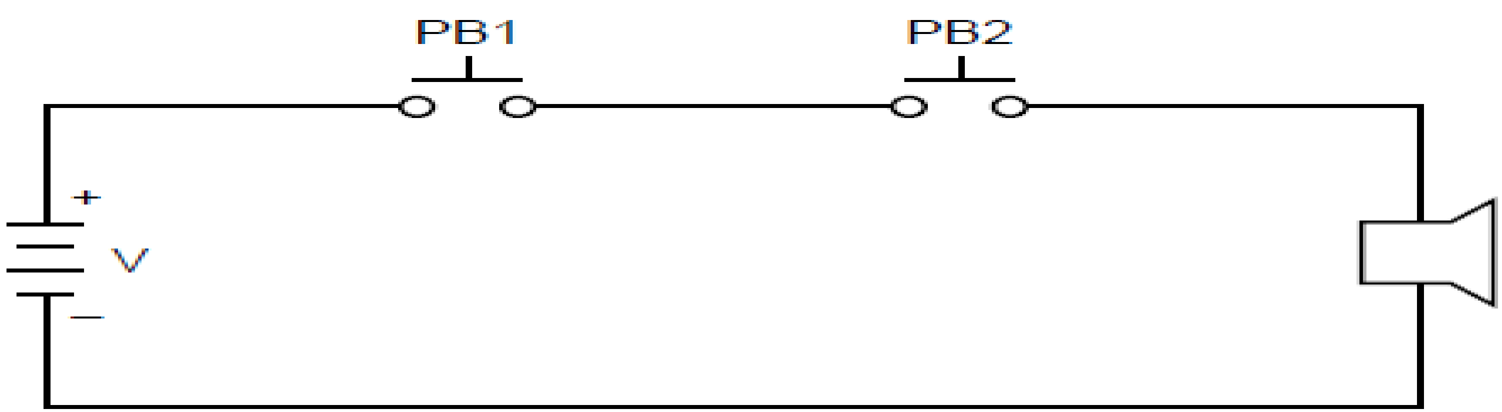
Solution (1)

Logic Representation

PB1	PB2	Alarm Horn
Not pushed (0)	Not pushed (0)	Silent (0)
Not pushed (0)	Pushed (1)	Silent (0)
Pushed (1)	Not pushed (0)	Silent (0)
Pushed (1)	Pushed (1)	Sounding (1)



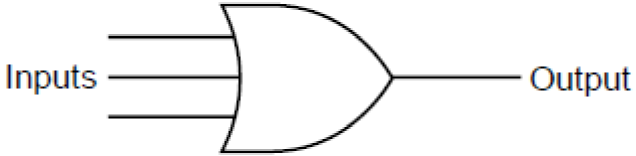
Electrical Ladder Circuit



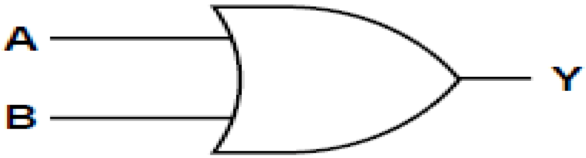
Electrical Circuit

2. OR Gate

- The OR output is TRUE (1) if one or more inputs are TRUE (1).
- can have an unlimited number of inputs but only one output.
- **Symbol for the OR function:**



- **truth table:**



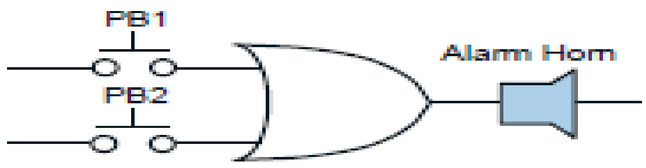
OR Truth Table		
Inputs		Output
A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Two-input OR gate and its truth table.

Example (2)

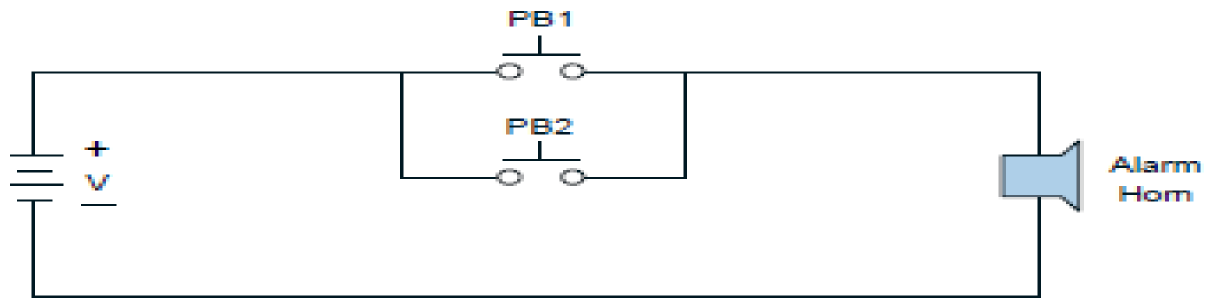
- Show the logic gate, truth table, and circuit representations for an alarm horn that will sound if either of its inputs, push button PB1 or PB2, is 1 (ON or depressed).

Solution (2)

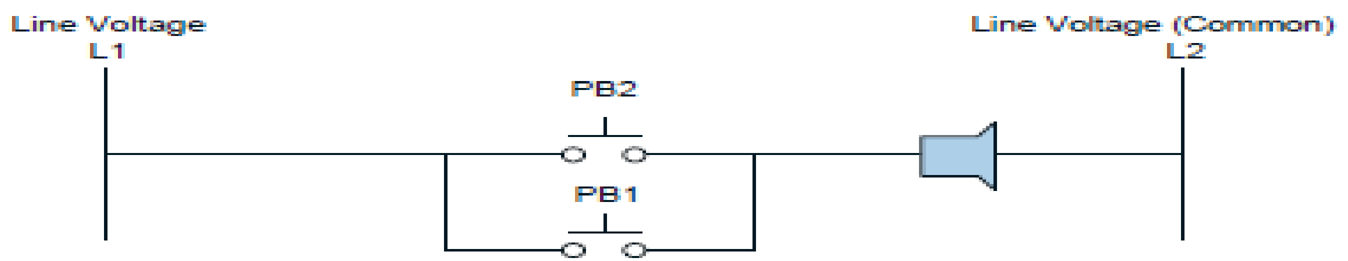


Logic Representation

PB1	PB2	Alarm Horn
Not pushed (0)	Not pushed (0)	Silent (0)
Not pushed (0)	Pushed (1)	Sounding (1)
Pushed (1)	Not pushed (0)	Sounding (1)
Pushed (1)	Pushed (1)	Sounding (1)



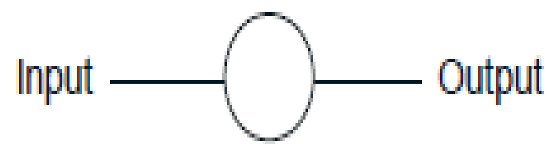
Electrical Circuit



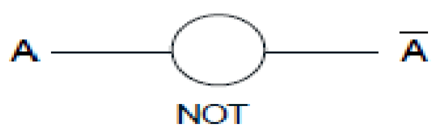
Electrical Ladder Circuit

3. NOT Gate

- The NOT output is TRUE (1) if the input is FALSE (0).Conversely, if the output is FALSE (0), the input is TRUE (1).
- The result of the NOT operation is always the inverse of the input; therefore, it is sometimes called an inverter.
- can have only one input.
- **Symbol for the NOT function:**



- **truth table:**



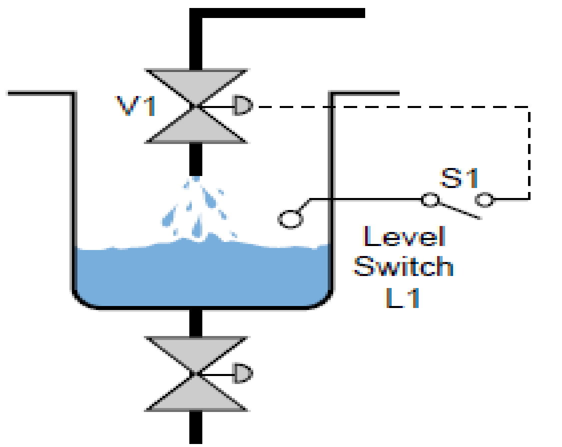
NOT Truth Table	
Input	**Output**
A	$\overline{A}$
0	1
1	0

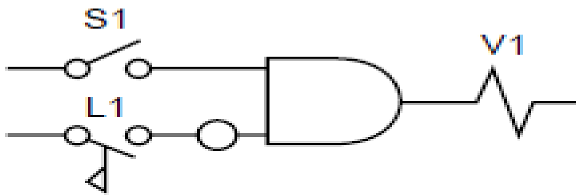
NOT gate and its truth table.

Example (3)

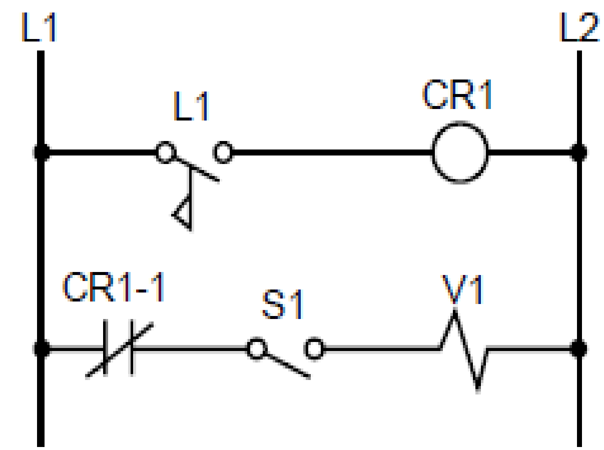
- Show the logic gate, truth table, and circuit representation for a solenoid valve (V1) that will be open (ON) if selector switch S1 is ON and if level switch L1 is NOT ON (liquid has not reached level).

Solution (3)





Logic Representation



Electrical Ladder Circuit

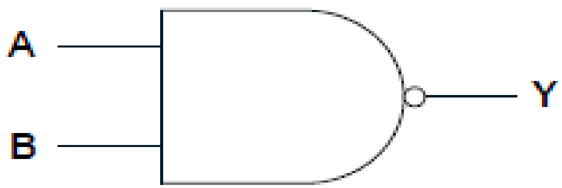
S1	L1	($\overline{L1}$)	V1
0	0	1	0
0	1	0	0
1	0	1	1
1	1	0	0

Truth Table

4. NAND Gate

- A negated AND gate is called a **NAND** gate.

- **logic symbol and truth table:**

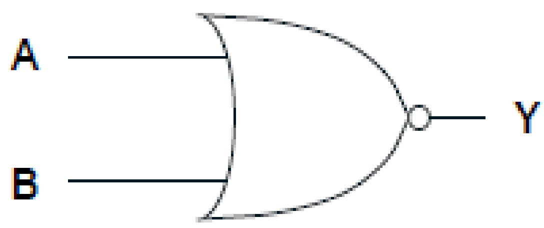


Two-input NAND gate and its truth table.

NAND Truth Table		
Inputs		Output
A	B	Y
0	0	1
0	1	1
1	0	1
1	1	0

5. NOR Gate

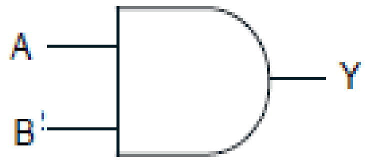
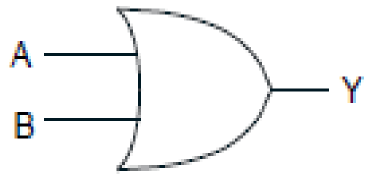
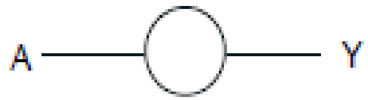
- NOT symbol is placed at the output of an OR gate. The normal output is negated, and the function is referred to as a NOR gate.
- **logic symbol and truth table:**



Two-input NOR gate and its truth table.

NOR Truth Table		
Inputs		Output
A	B	Y
0	0	1
0	1	0
1	0	0
1	1	0

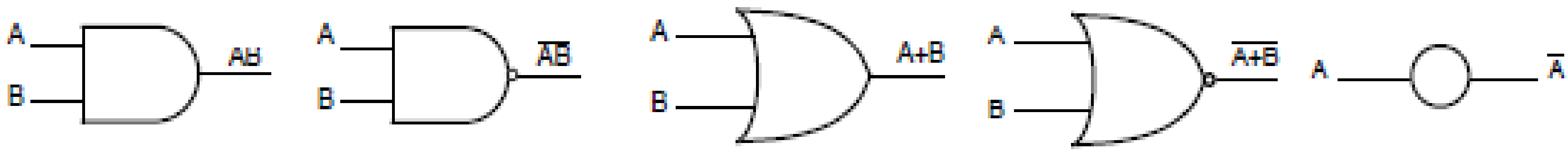
Principles of Boolean Algebra and Logic

Logical Symbol	Logical Statement	Boolean Equation
	Y is 1 if A AND B are 1	$Y = A \cdot B$ or $Y = AB$
	Y is 1 if A OR B is 1	$Y = A + B$
	Y is 1 if A is 0 Y is 0 if A is 1	$Y = \overline{A}$

Boolean algebra as related to the AND, OR, and NOT functions.

Logic operations using Boolean algebra

1. Basic Gates. Basic logic gates implement simple logic functions. Each logic function is expressed in terms of a truth table and its Boolean expression.



A	B	AB
0	0	0
0	1	0
1	0	0
1	1	1

AND

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

NAND

A	B	A + B
0	0	0
0	1	1
1	0	1
1	1	1

OR

A	B	$\overline{A + B}$
0	0	1
0	1	0
1	0	0
1	1	0

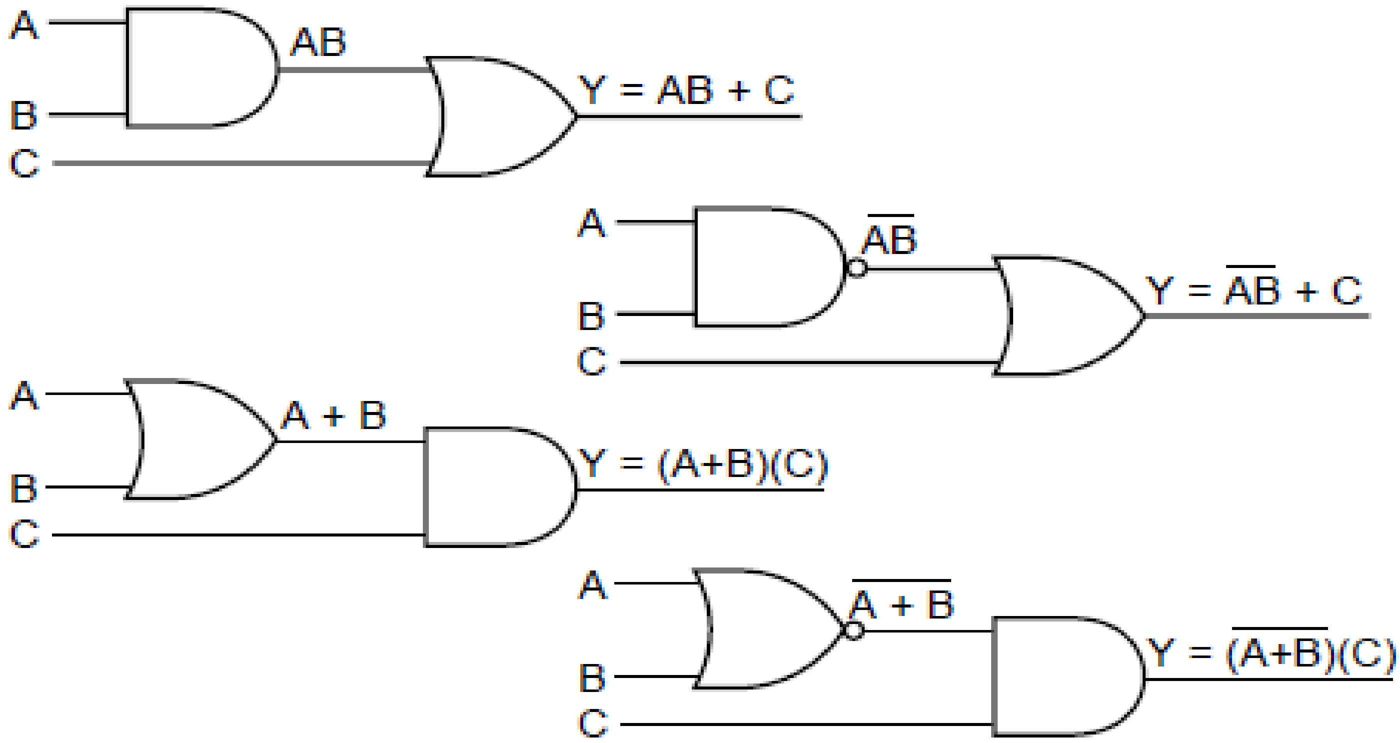
NOR

A	$\overline{A}$
0	1
1	0

NOT

Cont.

2. Combined Gates. Any combination of control functions can be expressed in Boolean terms using three simple operators: (•), (+), and (¯).



Prof. Mohamed Ahmed Ebrahim

Cont.

3. Boolean Algebra Rules. Control logic functions can vary from simple to very complex combinations of input variables. However simple or complex the functions may be, they satisfy the following rules. These rules are a result of a simple combination of basic truth tables and may be used to simplify logic circuits.

Commutative Laws

$$A + B = B + A$$

$$AB = BA$$

Associative Laws

$$A + (B + C) = (A + B) + C$$

$$A(BC) = (AB)C$$

De Morgan's Laws

$$\overline{(A + B)} = \overline{AB}$$

$$\overline{(AB)} = \overline{A} + \overline{B}$$

$$\overline{\overline{A}} = A, \ \overline{1} = 0, \ \overline{0} = 1$$

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

$$AB + AC + B\overline{C} = AC + B\overline{C}$$

Distributive Laws

$$A(B + C) = AB + AC$$

$$A + BC = (A + B)(A + C)$$

Law of Absorption

$$A(A + B) = A + AB = A$$

The Memory System

&

Components

Prof . Mohamed Ahmed Ebrahim

Memory Sections

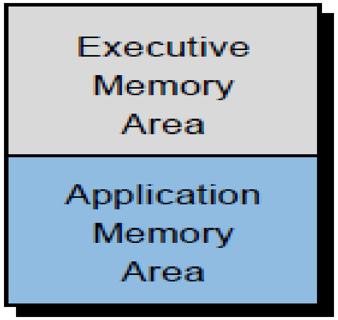
- The total memory system in a PLC is actually composed of two different memories:

1. **the executive memory.**

- The executive memory is a collection of permanently stored programs that are considered part of the PLC itself.

2. **the application memory.**

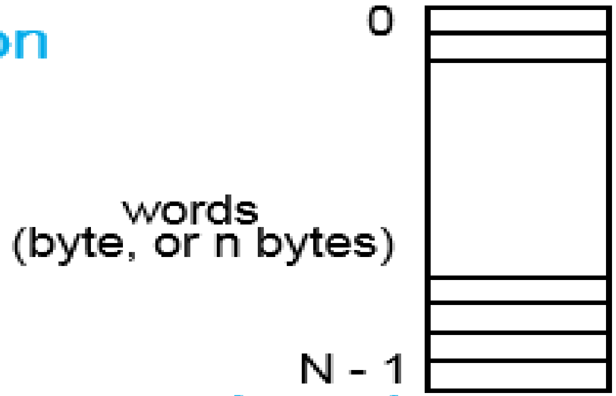
- The application memory provides a storage area for the user-programmed instructions that form the application program.



Simplified block diagram of the total PLC memory system.

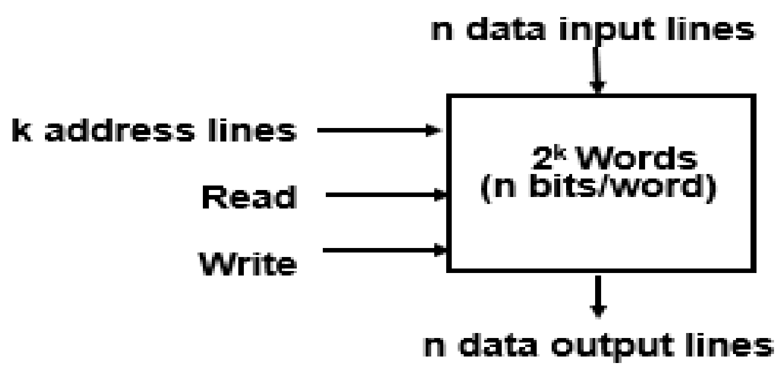
Memory Types

Logical Organization



Random Access Memory (RAM)

- Each word has a unique address
- Access to a word requires the same time independent of the location of the word
- Organization

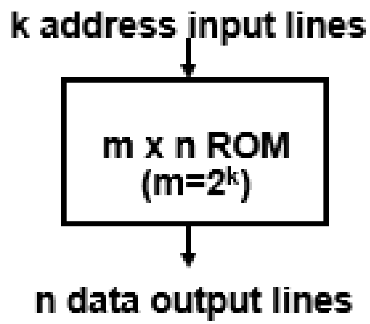


Prof. Mohamed Ahmed Ebrahim

READ ONLY MEMORY(ROM)

Characteristics

- Perform read operation only, write operation is not possible
- Information stored in a ROM is made permanent during production, and cannot be changed
- Organization



Information on the data output line depends only on the information on the address input lines.

--> Combinational Logic Circuit

X_0=A'B' + B'C
X_1=A'B'C + A'BC'
X_2=BC + AB'C'
X_3=A'BC' + AB'
X_4=AB

Canonical minterms

X_0=A'B'C' + A'B'C + AB'C
X_1=A'B'C + A'BC'
X_2=A'BC + AB'C' + ABC
X_3=A'BC' + AB'C' + AB'C
X_4=ABC' + ABC

address	Output				
ABC	X_0	X_1	X_2	X_3	X_4
000	1	0	0	0	0
001	1	1	0	0	0
010	0	1	0	1	0
011	0	0	1	0	0
100	0	0	1	1	0
101	1	0	0	1	0
110	0	0	0	0	1
111	0	0	1	0	1

Prof . Mohamed Ahmed Ebrahim

Types of ROM

1. **ROM**

- Store information (function) during production.
- Mask is used in the production process.
- Unalterable.
- Low cost for large quantity production used in the final products.

2. **PROM (Programmable ROM)**

- Store info electrically using PROM programmer at the user's site.
- Unalterable.
- Higher cost than ROM.
- used in the system development phase.
- Can be used in small quantity system

Cont.

2. **EPROM (Erasable PROM)**

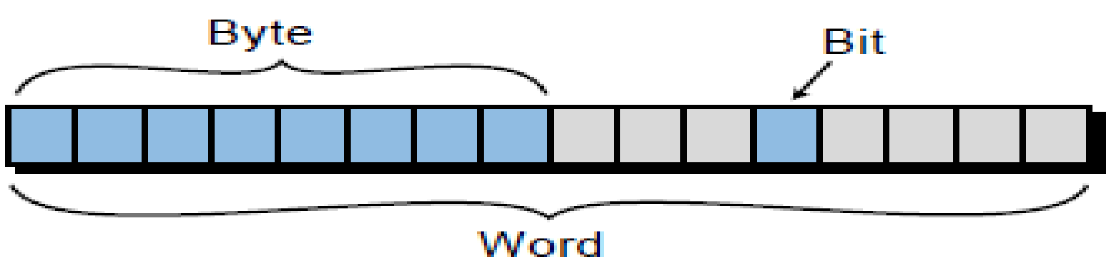
- Store info electrically using PROM programmer at the user's site.
- Stored info is erasable (alterable) using UV light (electrically in some devices) and rewriteable.
- Higher cost than PROM but reusable (used in the system development phase).
- Not used in the system production due to eras ability.

Memory Structure and Capacity

- PLC memories can be thought of as large, two-dimensional arrays of single unit storage cells, each storing a single piece of information in the form of **1 or 0** (binary numbering format).
- each cell can store only one binary digit and bit is the acronym for "binary digit," each cell is called a bit.
- A bit is considered to be ON if the stored information is 1(voltage present) and OFF if the stored information is 0 (voltage absent).

Cont.

- A group of bits handled simultaneously is called a byte.
- Although byte size is normally eight bits, this size can vary depending on the specific controller.
- The third and final structural information unit used within a PLC is a word.
- words are usually one byte or more in length



Units of PLC memory: bits, bytes, and words.

Thank You

For Your Attention

Mohamed Ahmed Ebrahim