Industrial Automation (ICE 3252)

Programmable Logic Controller

Bipin Krishna
Assistant Professor (Sr.)
ICE Department
Manipal Institute of Technology
MAHE, Karnataka, India

Understanding the Title

Industry

Systematic Economic Activity that could be related to *Manufacture* */Service/ Trade.*

Industrial Automation ICE 3252

Understanding the Title

Automation

"Auto"(self) and "Matos"(moving)

"move by itself"

Automation is a set of technologies that results in operation of machines
and systems without significant human intervention and achieves performance
superior to manual operation

Control System..

- Control is a set of technologies that achieves desired patterns of variations of operational parameters and sequences for machines and systems by providing the input signals necessary.

- Automation Systems may include Control Systems but the reverse is not true.

- Control Systems may be parts of Automation Systems.

- The main function of control systems is to ensure that outputs follow the set points.

- Automation Systems may have much more functionality, such as computing set points for control systems, monitoring system performance, plant startup or shutdown, job and equipment scheduling etc.

Role of automation in industry

- Manufacturing processes, basically, produce finished product from raw/unfinished material using energy, manpower and equipment and infrastructure.

- Since an industry is essentially a "systematic economic activity", the fundamental objective of any industry is to make profit.

- Roughly speaking, Profit = (Price/unit − Cost/unit) x Production Volume

- So profit can be maximized by producing good quality products, which may sell at higher price, in larger volumes with less production cost and time.

A Historical Background

- Manual Control

  - Pneumatic Control

    - Hard wired logic control

      - Electronic control using logic gates

        - Programmable logic controller

Industrial Automation ICE 3252

Manual Control

All the actions related to process control are taken by the operators.

Drawbacks

- Likely human errors and consequently its effect on quality of final product.
- The production, safety, energy consumption and usage of raw material are all subject to the correctness and accuracy of human action.

Industrial Automation ICE 3252

Pneumatic Control

Industrial automation, with its machine and process control, had its origin in the 1920s with the advent of "*Pneumatic Controllers*".

Actions were controlled by a simple manipulation of pneumatic valves, which in turn were controlled by relays and switches.

Drawbacks

- Bulky and Complex System
- Involves lot of rework to implement control logic
- Longer project time.

Hard wired logic control

The contactor and Relays together with hardware timers and counters were used in achieving the desired level of automation.

Drawbacks

- Bulky panels
- Complex wiring
- Longer project time
- Difficult maintenance and troubleshooting

Electronic Control using Logic Gates

In 1960s with the advent of electronics, the logic gates started replacing the relays and auxiliary contactors in the control circuits.

The hardware timers & counters were replaced by electronic Timers.

Advantages

- Reduced space requirements
- Energy savings
- Less maintenance & greater reliability .

Drawbacks

- Changes in control logic not possible
- More project time

Programmable Logic Controllers

In 1970s with the coming of microprocessors and associated peripheral chips, the whole process of control and automation underwent a radical change.

Instead of achieving the desired control or automation through physical wiring of control devices, in PLC it is achieved through a program or say software.

The programmable controllers have in recent years experienced an unprecedented growth as universal element in Industrial Automation.

It can be effectively used in applications ranging from simple control like replacing small number of relays to complex automation problems .

Introduction of PLC

- Microprocessor: It is a digital integrated circuit which carries out necessary digital functions to process the information obtained from measurement system.

- Microcomputer: It uses microprocessor as its central processing unit and contains all functions of a computer.

- Programmable Logic Controller (PLC): It is used to control the operations of electro-mechanical devices especially in tough and hazardous industrial environments.

Cont..

"The programmable logic controller is defined as a digital electronic device that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic words to control machines and processes.

Definition : It is a solid state device ,which can performs a sequential and a discrete logic for industrial or factory Environment.
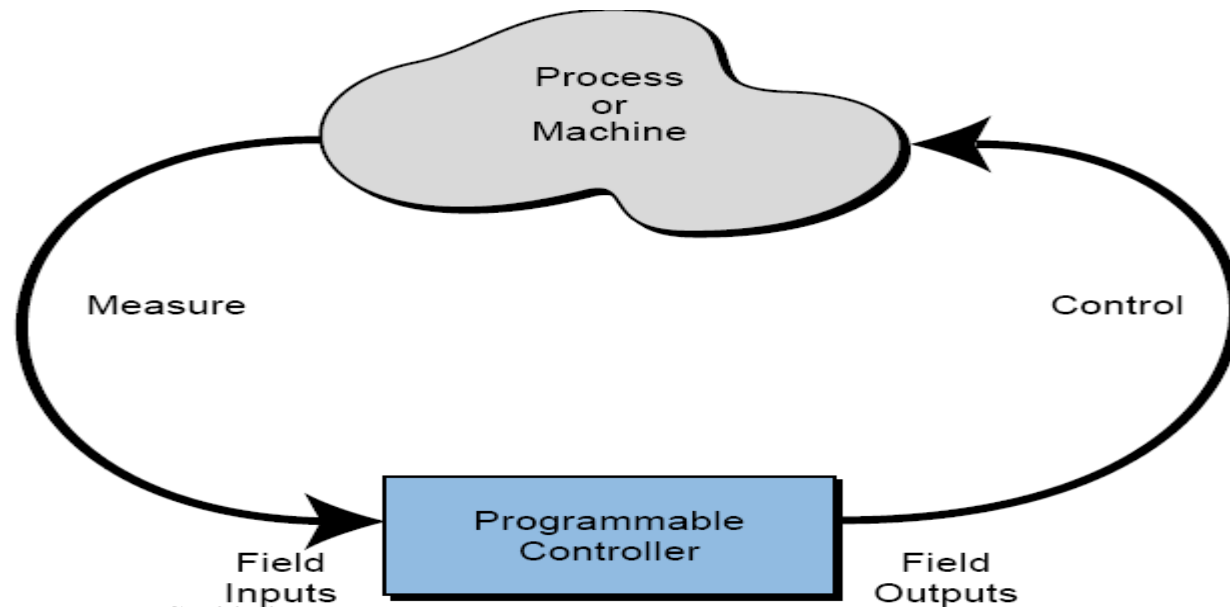
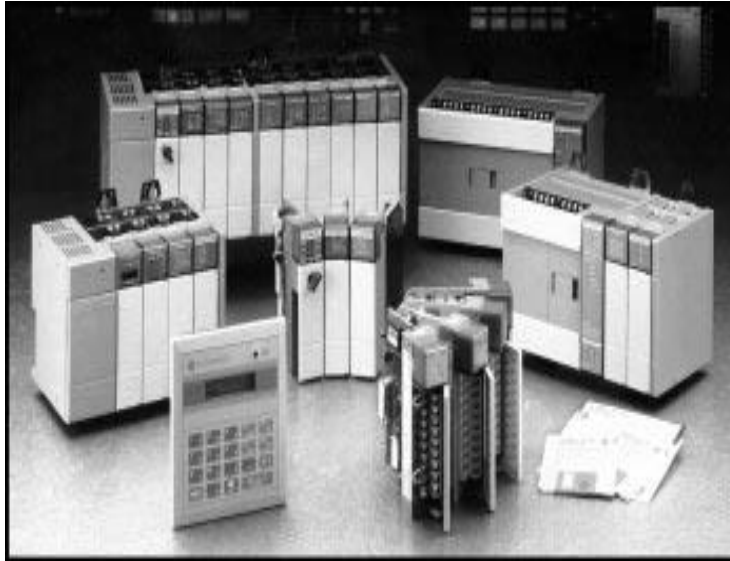# Programmable Logic Controllers

Sequential logic solver

PID Calculations.

Advanced Subroutines

BIT Operations.

Data Transfer.

Text Handling.

EXAMPLE S OF PLC MODULES

Industrial Automation ICE 3252

Why PLCs

Reduced space

Energy saving

Ease of maintenance

Economical

Greater life & reliability

Tremendous flexibility

Faster Response Time.

Shorter project time

Easier storage, archiving and documentation

Industrial Automation ICE 3252

Industrial Automation ICE 3252
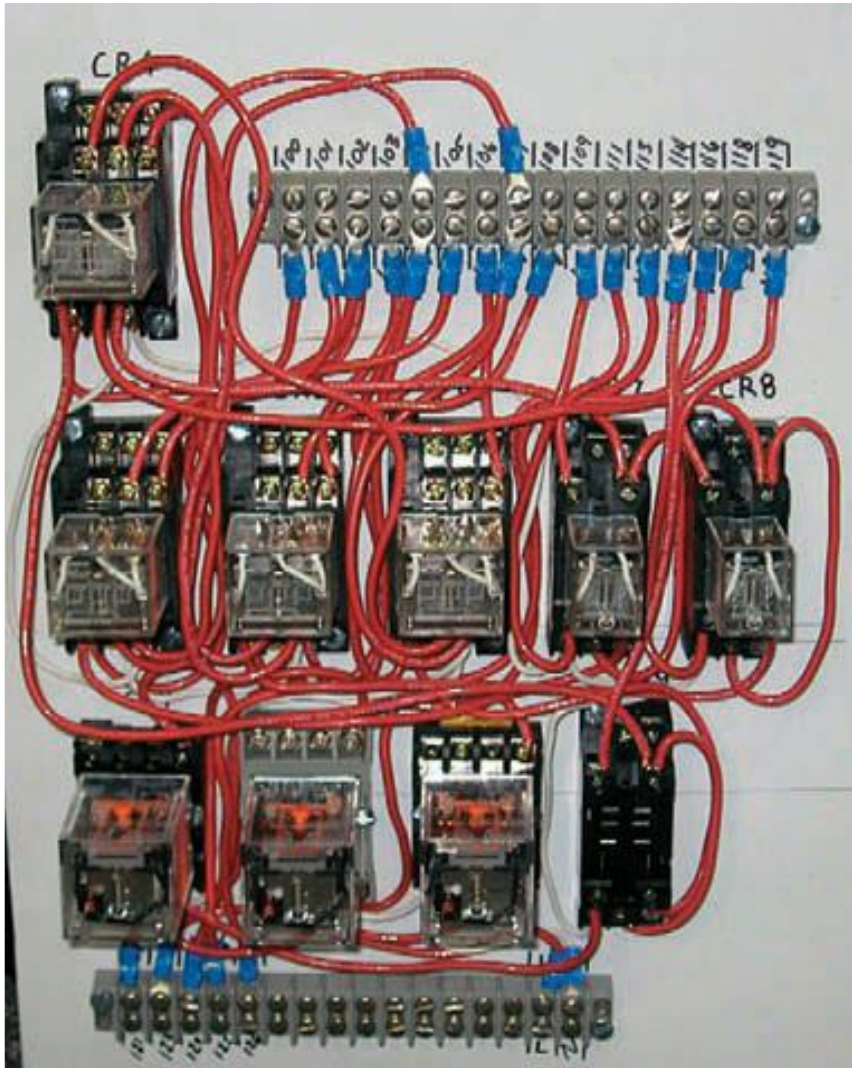
Parts of PLC (Basic Components of a PLC System)

There are **five basic components** in a PLC system :

- The PLC processor, or controller. (CPU)

- I/O (Input /Output) modules.

- Chassis or backplane.

- Power supply.

- Programming software that runs in a PC and A network interface(communication).

In General PLC contains following parts

Power supply
Internal power supply,
Buffering of remanent data via battery

CPU unit
CPU, System-Software (Firmware),
Program memory
(User program)

Communication unit
Field bus interface,
Connection of HMIs,
Cross communication with other controllers

Unit for In- and Outputs
Sensor connection
(switches, initiators, light curtains,
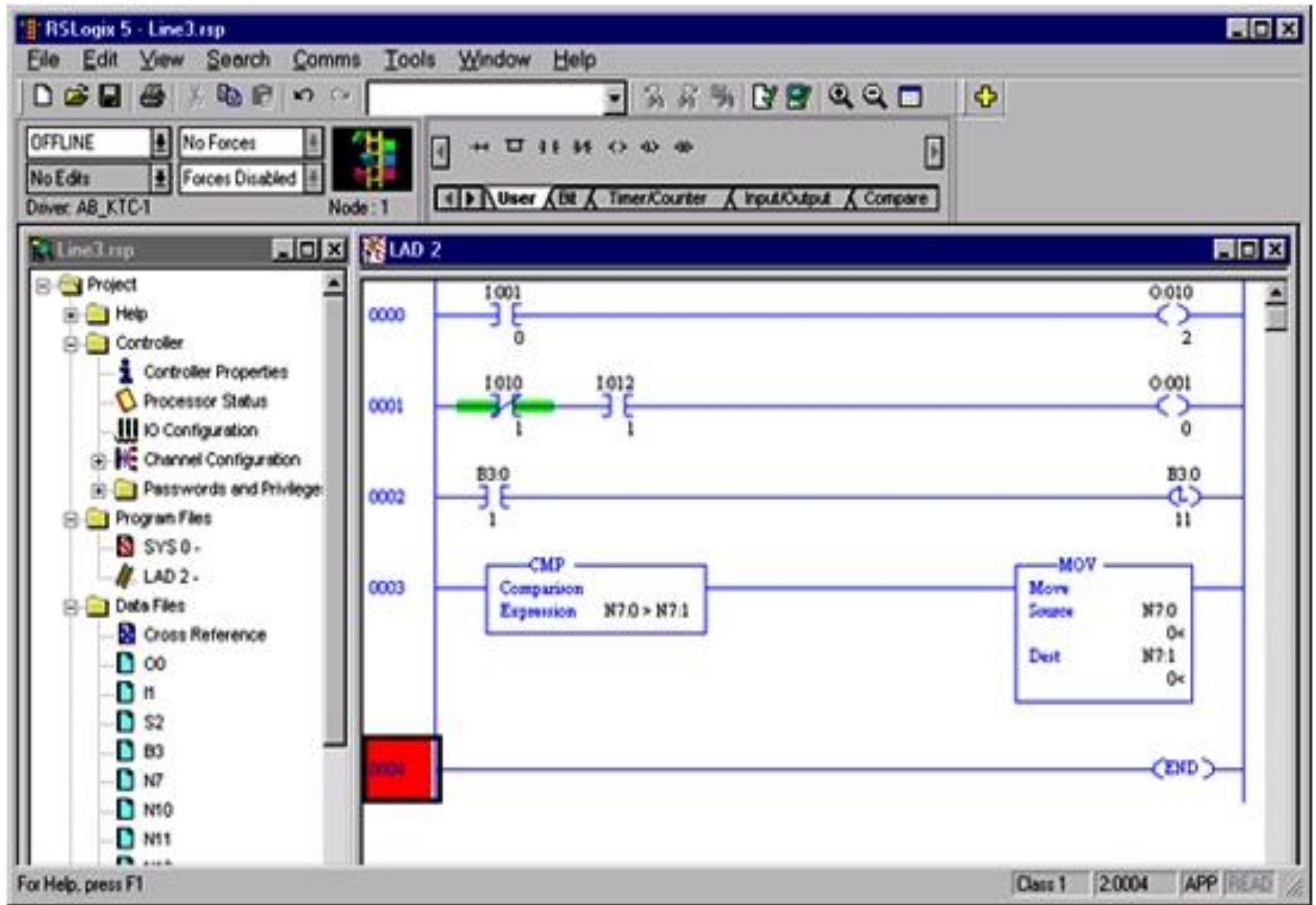temperature sensors, …)
Actuator connection
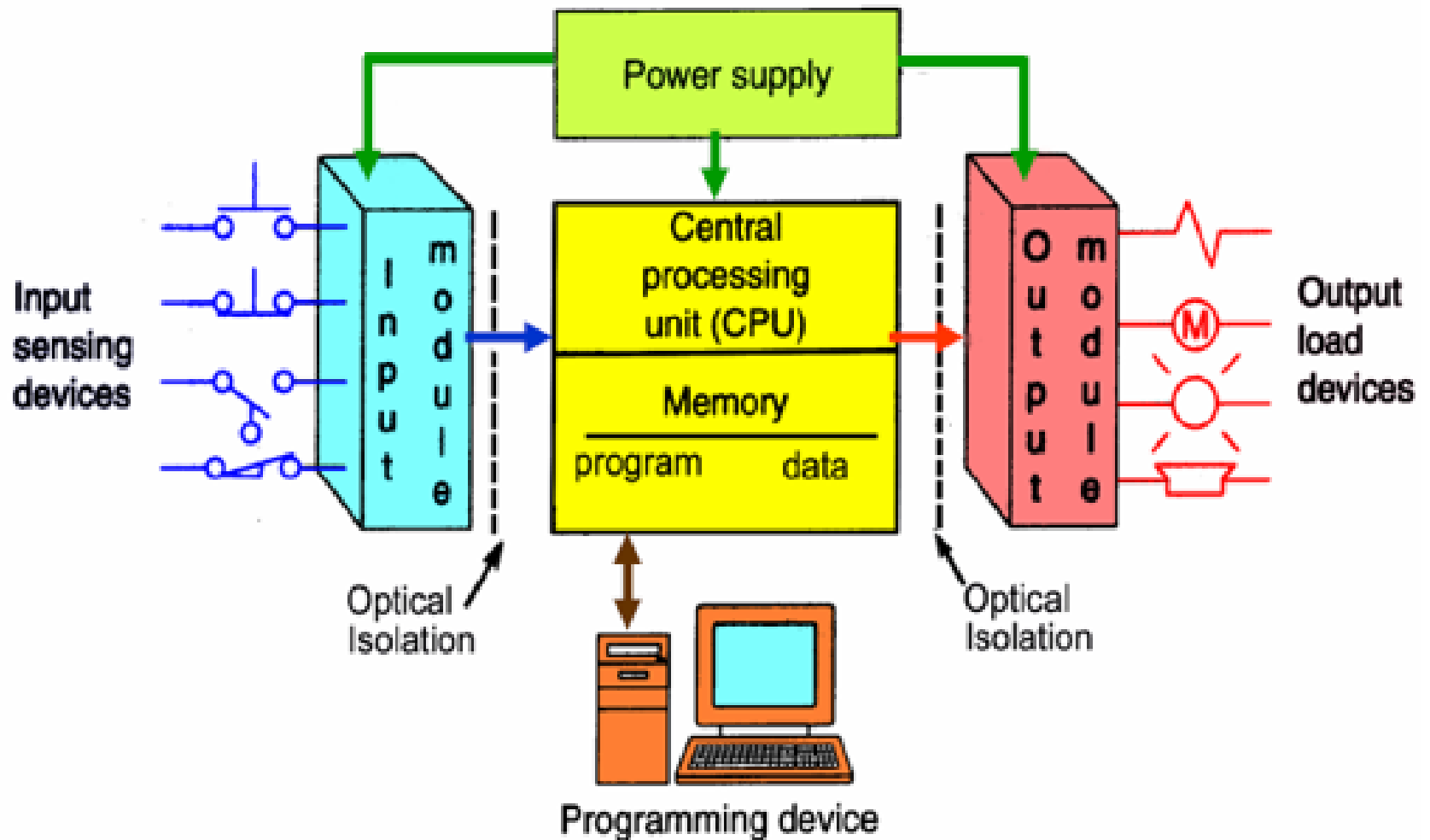(valves, lamps, motors, contactors …)
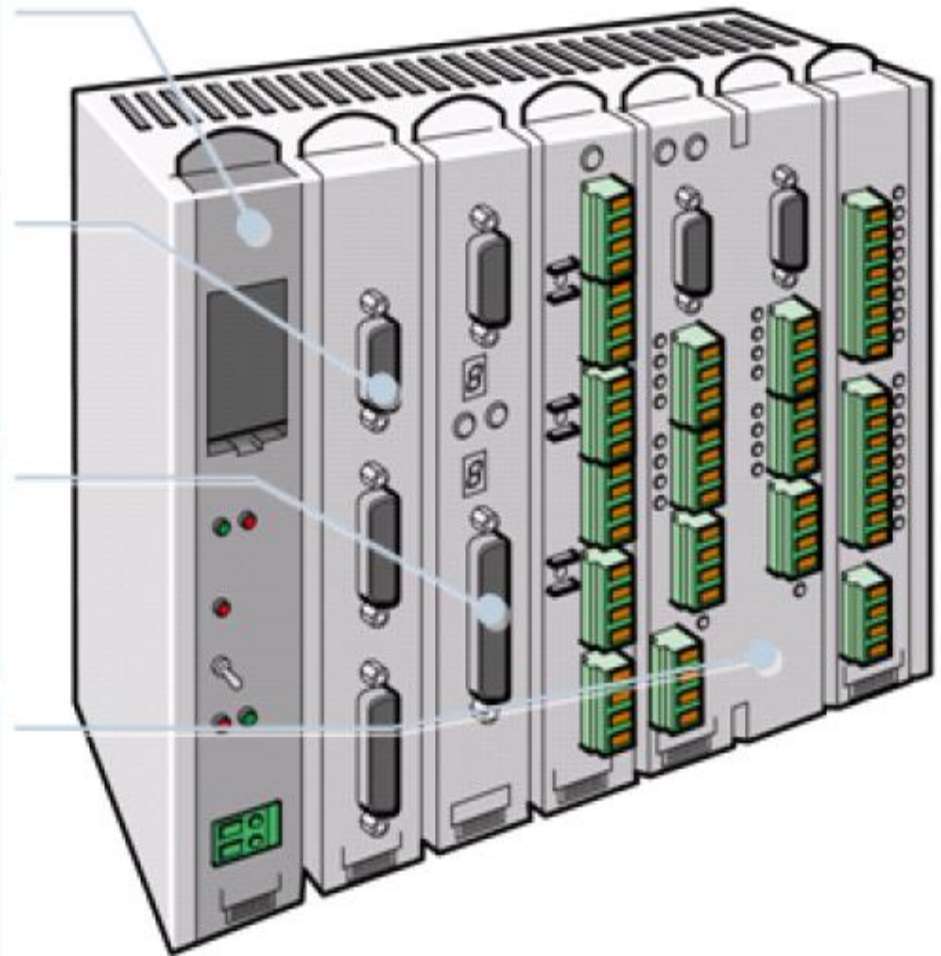
PLC Size

- The criteria used in categorizing PLCs include functionality, number of inputs and outputs, cost, and physical size of these, the *I/O count* is the most important factor.

- The *nano* is the smallest size with less than 15 I/O points.

- The micro types (15 to 128 I/O points),

- Medium types (128 to 512 I/Opoints), and

- Large types (over 512 I/O points).

Cont…

Input ports

PLC

Output ports

Industrial Automation ICE 3252   **An Industrial PLC**

Industrial Automation ICE 3252
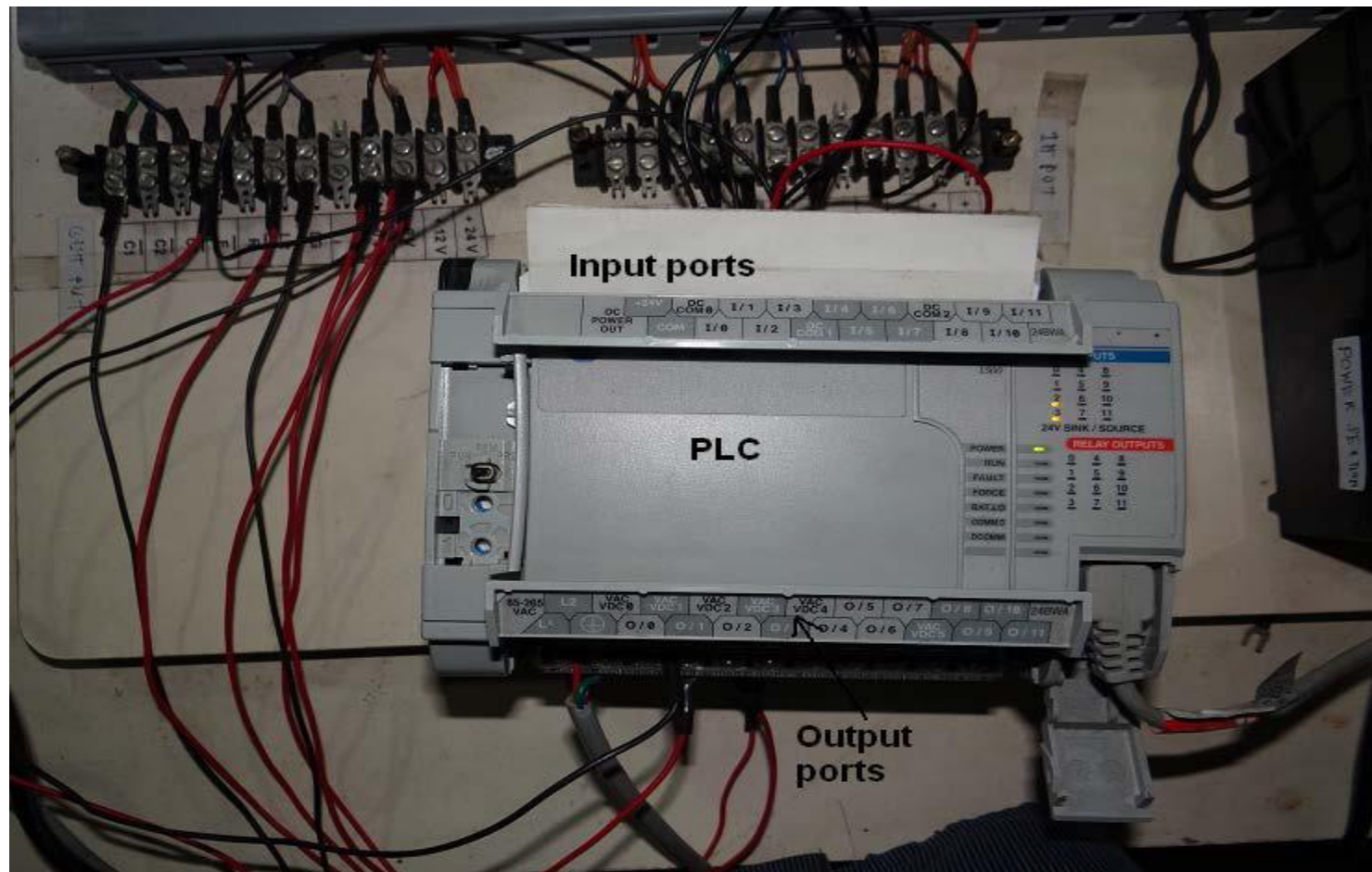
PLC Hardware

PLC Architecture

- An *open architecture* design allows the system to be connected easily to devices and programs made by other manufacturers.

- A *closed architecture* or *proprietary* system, is one whose design makes it more difficult to connect devices and programs made by other manufacturers.

  NOTE: When working with PLC systems that are proprietary in nature you must be sure that any generic hardware or software you use is compatible with your particular PLC.

Internal architecture of PLC
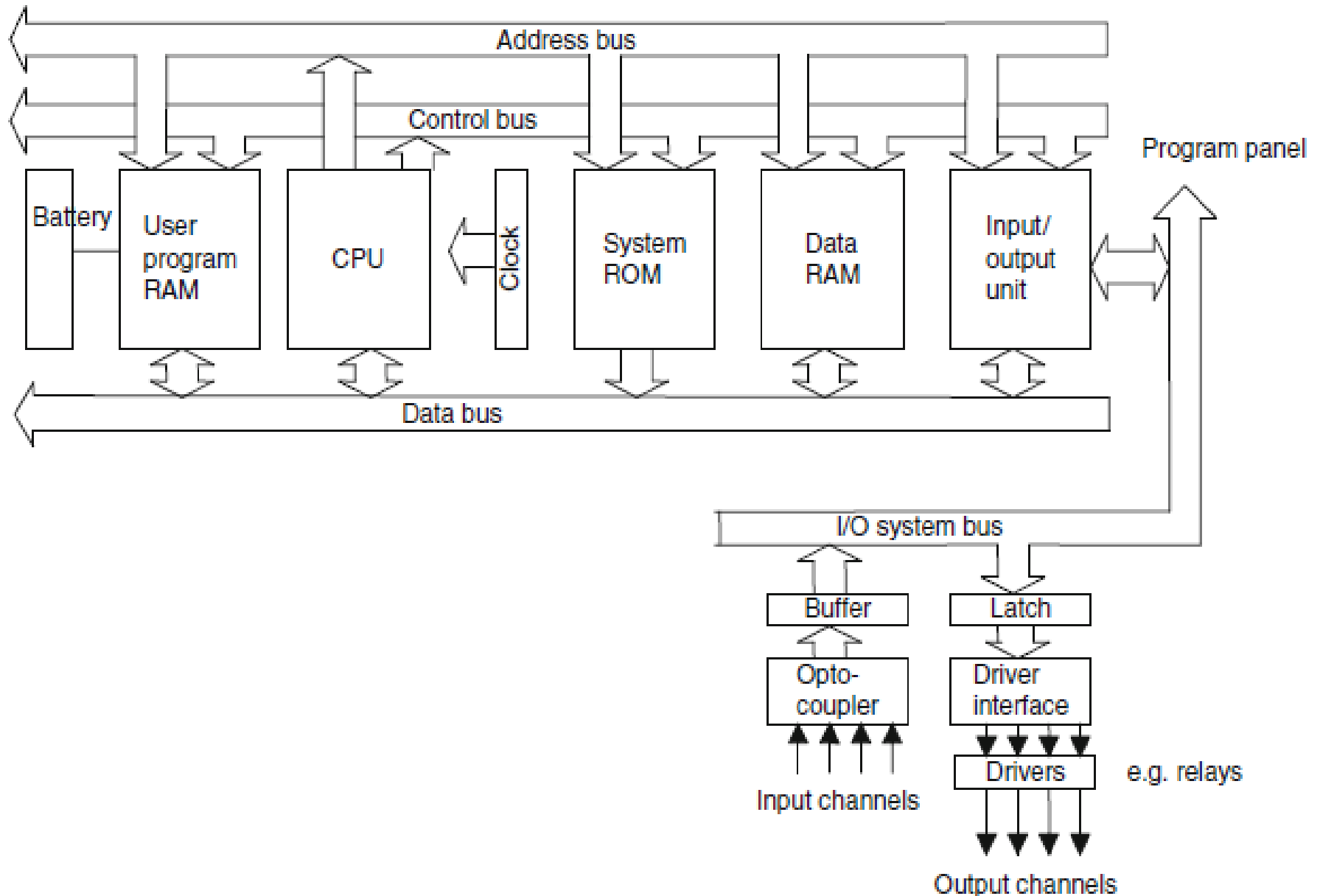
The Buses

The system has four buses:

➢Data bus

➢Address bus

➢Control bus

➢System bus

- The buses are the paths used for communication within the PLC.

- The information is transmitted in binary form, i.e. as a group of *bits, a bit* being a binary digit of 1 or 0, i.e. on/off states.

- The term *word is used for* the group of bits constituting some information. Thus an 8-bit word might be the binary number 00100110. Each of the bits is communicated simultaneously along its own parallel wire.

Cont..

- The data bus carries the data used in the processing done by the CPU

- The address bus is used to carry the addresses of memory locations. So that each word can be located in memory, every memory location is given a unique address

- The control bus carries the signals used by the CPU for control, such as to inform memory devices whether they are to receive data from an input or output data and to carry timing signals used to synchronize actions.

- The system bus is used for communications between the input/output ports and the input/ output unit.

Processor (CPU)

- Is the brain of the PLC

- Consists of microprocessor for logic implementation and for controlling the communications among the modules.

- Stores the control program and data in its memory.

- Reads the status of connected input devices.

- Executes the control program.
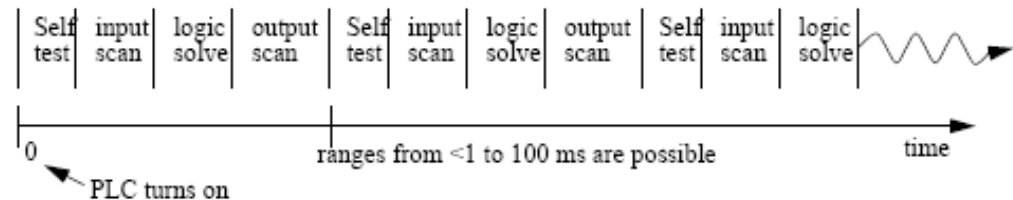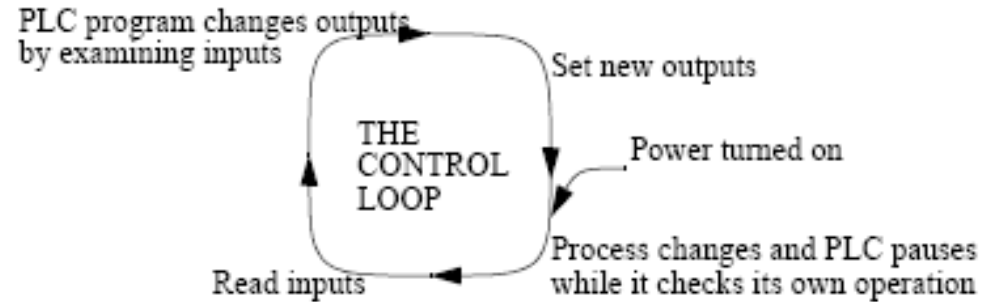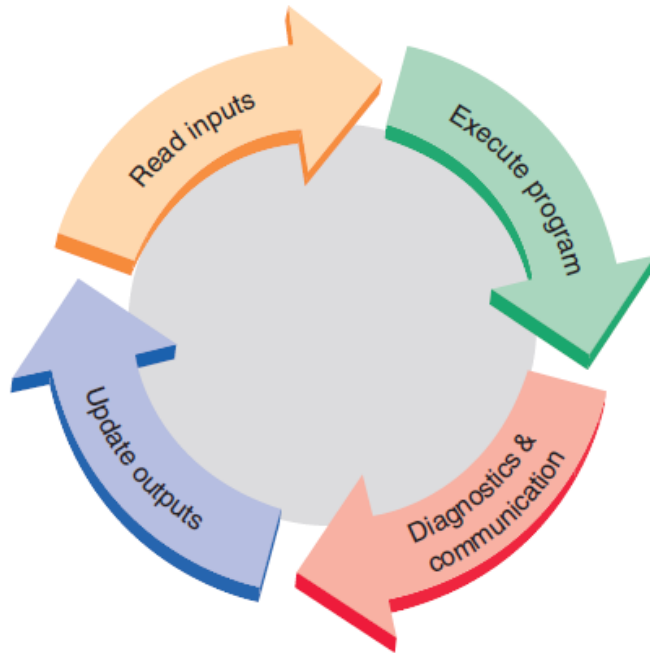

Power supply

Processor Module
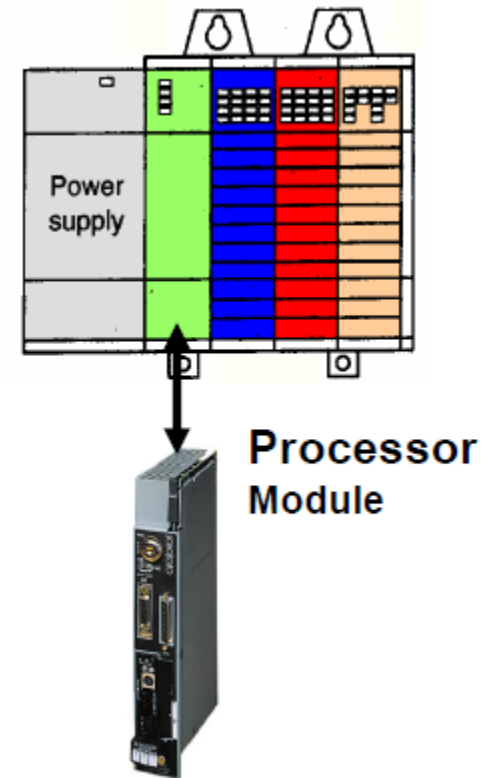
Processor, Controller, or CPU

- Commands outputs devices to change state based on program execution.

    - For example : Turn a light on, start a fan, adjust a speed, or temperature.

- Comes in various physical forms.

Industrial Automation ICE 3252
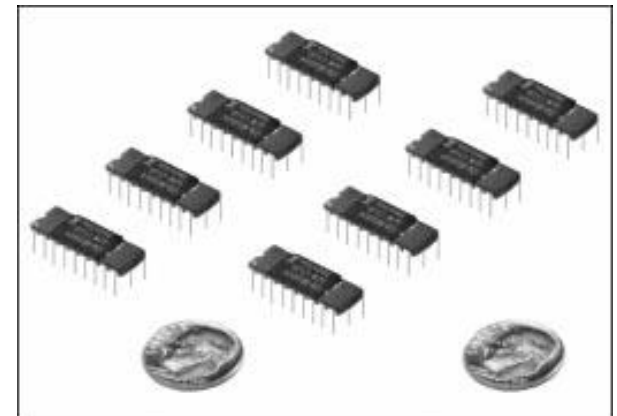
Typical PLC scan cycle

- When the inputs to the PLC are scanned the physical input values are copied into memory.
- When the outputs to a PLC are scanned they are copied from memory to the physical outputs.
- When the ladder logic is scanned it uses the values in memory, not the actual input or output values.

Industrial Automation ICE 3252
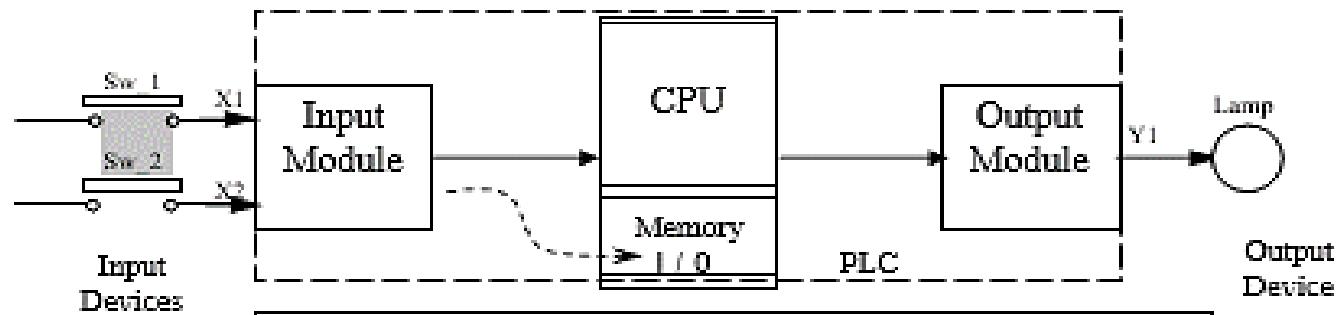
1. **Input Scan**: check status from input devices, update I/O memory
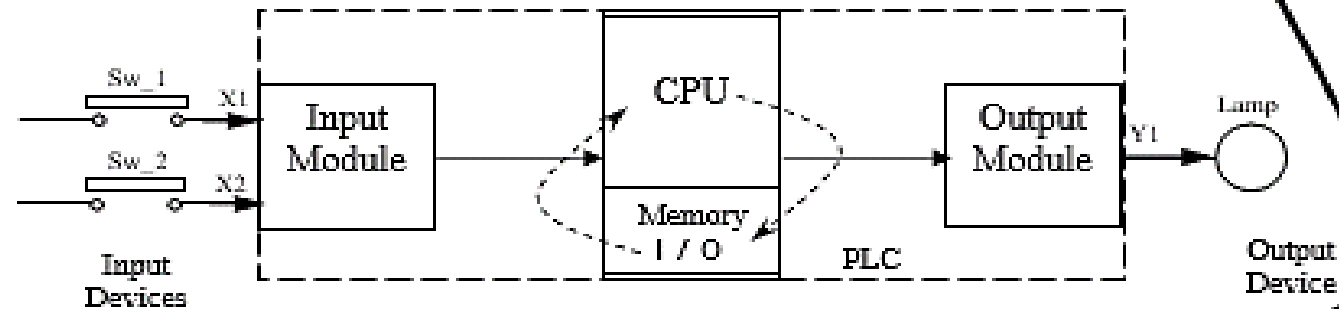
2. **Program Scan**: execute program, update result into I/O memory
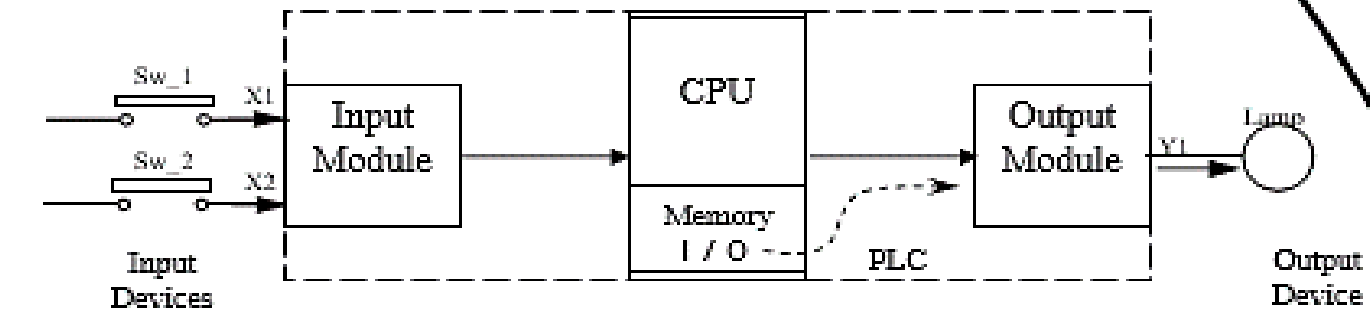
3. **Output Scan**: transfer status of I/O memory to output module

Memory Types

ROM (Read Only Memory): is designed to permanently store a fixed program that is not alterable under ordinary circumstances

RAM (Random Access Memory):is designed so that information can be written into or read from the memory storage area. Random-access memory does not retain its contents if power is lost; therefore, it is a volatile type of memory.
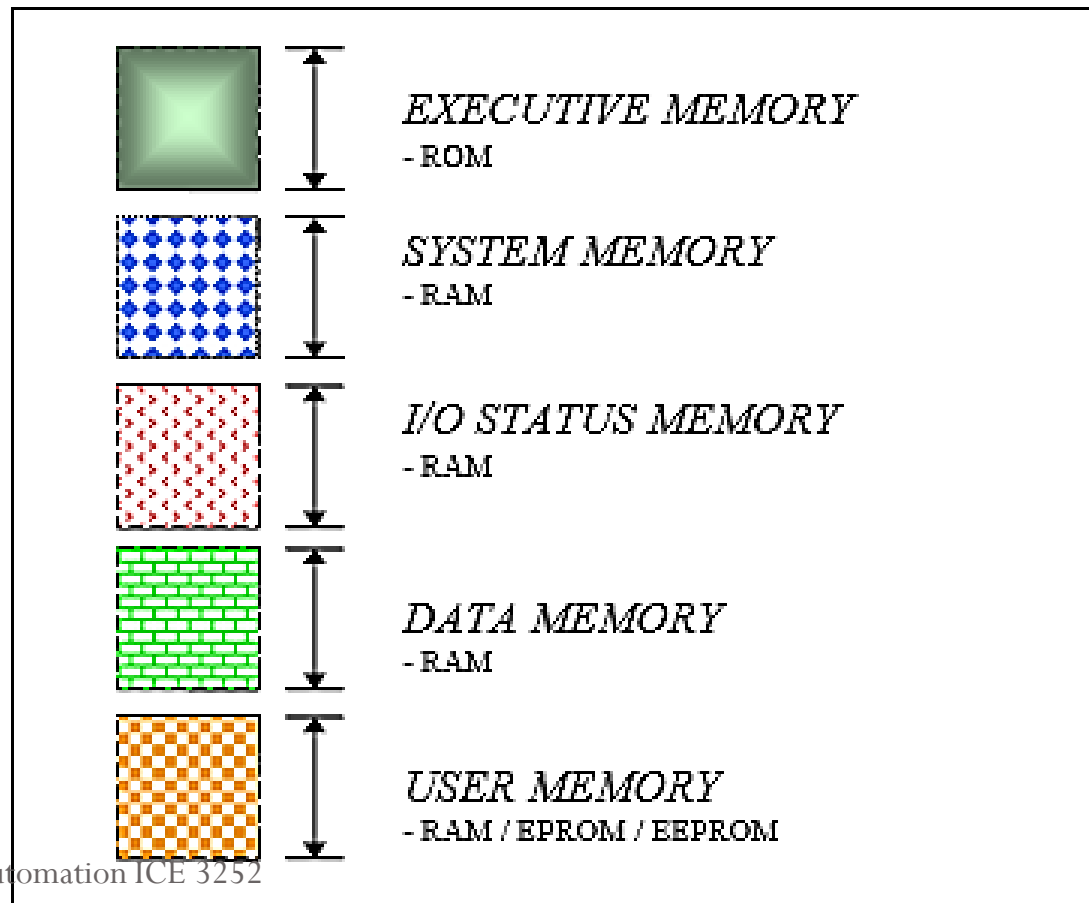
PROM (Programmable ROM): is a special type of ROM because it can be programmed.

EPROM (Erasable PROM): : is a specially designed PROM that can be reprogrammed after being entirely erased by an ultraviolet (UV) light source.

EEPROM-Electrically erasable PROM: Several of today's small and medium-size controllers use EEPROM as the only memory within the system. It provides permanent storage for the program and can be easily changed with the use of a programming device (e.g., a PC) or a manual programming unit.

PLC Memory

- All PLC memories can be subdivided into at least five major areas. A typical memory utilization map for a PLC is depicted in the following figure.

EXECUTIVE MEMORY
- ROM

SYSTEM MEMORY
- RAM

I/O STATUS MEMORY
- RAM

DATA MEMORY
- RAM

USER MEMORY
- RAM / EPROM / EEPROM

Executive Memory

- The operating system or executive memory for the PLC is always in ROM

- Once programmed and developed by the manufacturer, it rarely needs changing.

- It is the one that actually does the scanning in a PLC.

- The operating system is a special machine language program that runs the PLC.

- It instructs the microprocessor to read each user instruction, helps the microprocessor to interpret user programmed symbols and instructions,

- Keeps track of all the I/O status, and is responsible for maintaining/monitoring the current status of the health of the system and all its components.

Industrial Automation ICE 3252

System memory

- This memory is allotted for system administration.

- Normally this area is allotted for use of the operating system only and is not available to the user for programming.

- It might be assumed of as a scratch pad for the operating system to doodle on as necessary.

Industrial Automation ICE 3252

I/O Status Memory

- Another portion of RAM is allocated for the storage of current I/O status.

- Every single input/output module has been assigned to it a particular location within the input/output image table.

- The location within the input and output image tables are identified by addresses, each location has its own unique address.

- During the execution, the status of input modules used are read from the input image table (not directly from the input module itself).

- Various output device status generated during the execution of user program are stored in the output image table

Data Memory

- Whenever timers, counters, mathematics and process parameters are required, an area of memory must be set aside for data storage.

Industrial Automation ICE 3252

User Program Memory

- The final area of memory in a PLC is allocated to the storage of the user program. It is this memory area that the executive program instructs the microprocessor to examine or 'scan' to find the user instructions.

- In the majority PLCs, the internal data storage and user program areas are located in RAM.

Industrial Automation ICE 3252

Power Supply :

A power supply is needed to provide power to the PLC and any other modules. Power supplies come in various forms :

- Power supply modules that fit into one of the slots in a chassis.

- External power supplies that mount to the outside of a chassis.

- Stand alone power supplies that connect to the PLC or I/O through a power cable.

- Embedded power supplies that come as part of the PLC block.

Industrial Automation ICE 3252

Industrial Automation ICE 3252
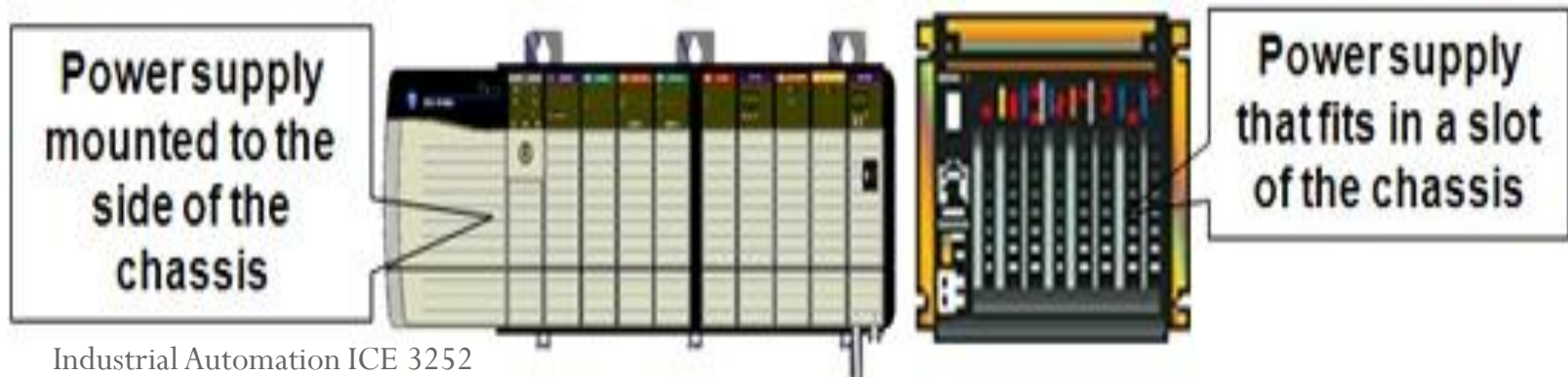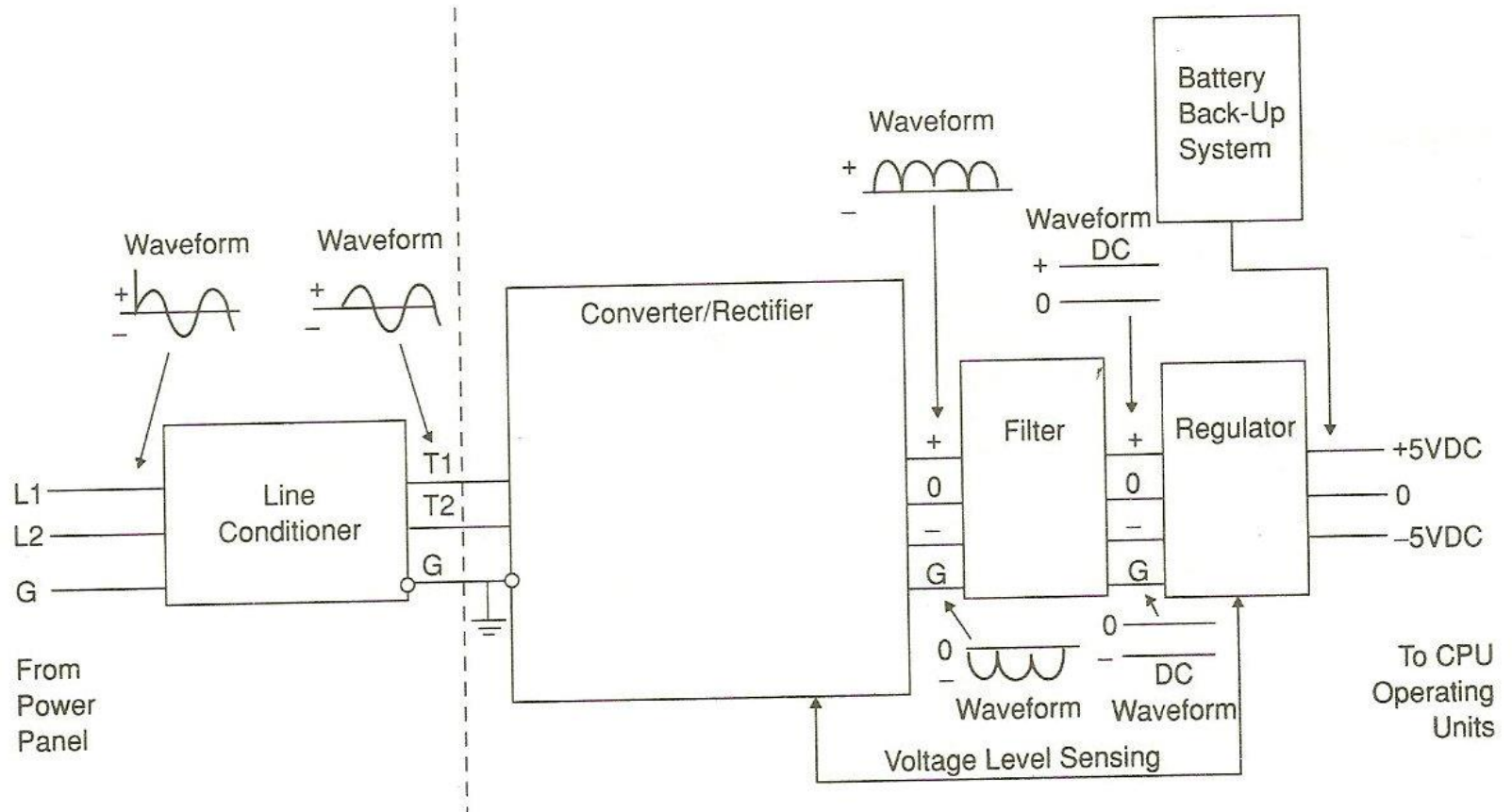
The function of the power supply is to provide the DC power to operate the PLC. It is supplied by single-phase 120 or 240 VAC line power that powers the PLC system.

The Power Supply is a module located in the PLC system module rack. The DC power (voltage and current) it provides power to the other modules in the rack, such as the CPU, Co-processor Modules, and I/O Modules.

The line power provided to the PLC system also powers the I/O Field Devices in micro PLCs. The PLC system is protected against PLC module or field device malfunctions. The Fuse in Figure provides this protection. In large PLC systems, it does not power the field devices.
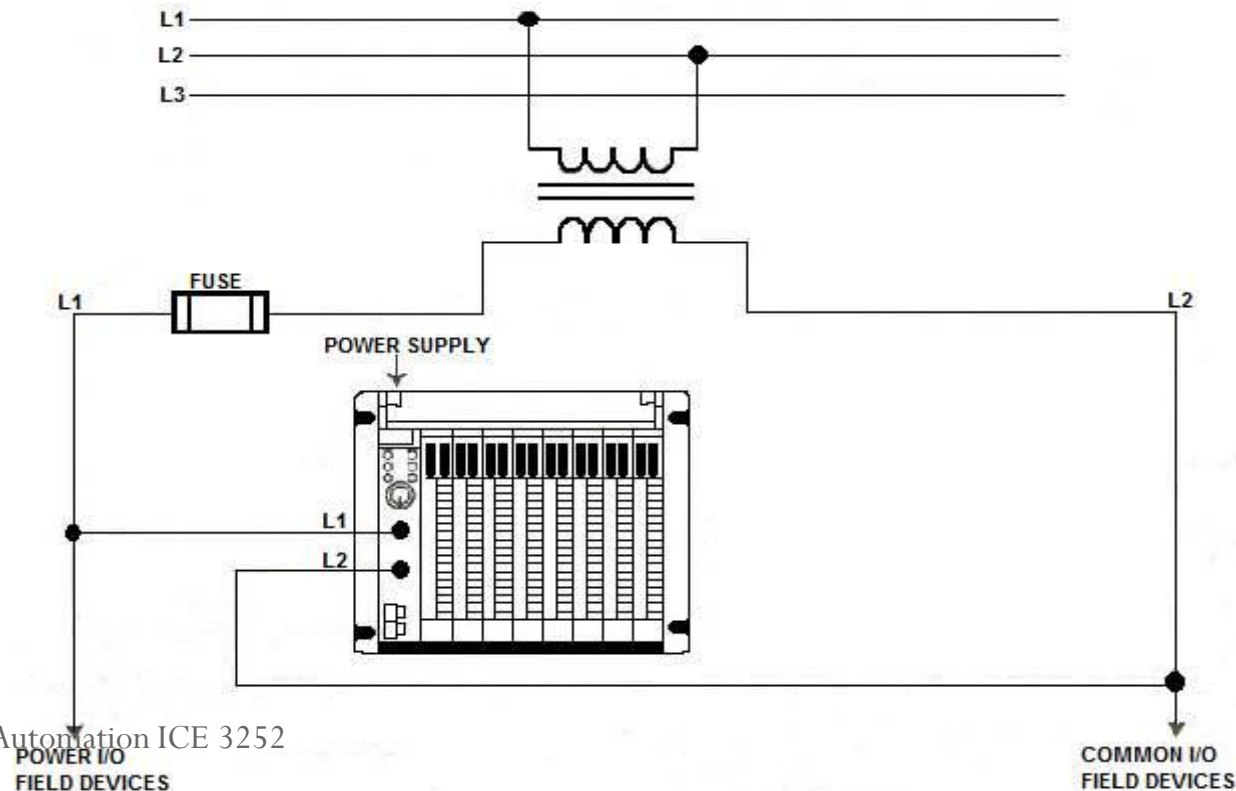
Chassis/Backplane /Rack:

All PLCs need some method of communicating between the controller, I/O and communications modules. Here are three ways used to accomplish this communications between the various components that make up the PLC system.

Modules are installed in the **same chassis** as the PLC and communicate over the chassis backplane.

Modules are designed to **"plug" into** each other. The interconnecting plugs form a backplane there is no chassis.

Modules are **built into** the PLC and modules come together in one physical block. The backplane in this case is transparent to the user.

A backplane chassis based system. You can see the backplane in the area where the modules are not inserted. The modules have connectors that plug into the black connectors on the backplane. All of the connectors on the backplane are connected together electrically.
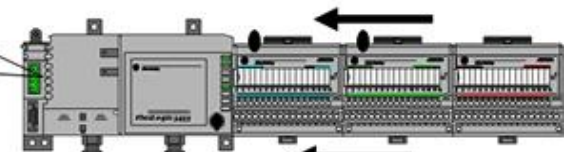

Backplane connector

Example of a modular based PLC. The PLC slides into the **chassis along with** other modules
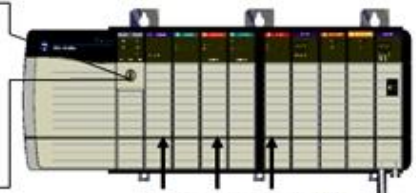
Slide modules into available slots

Example of a PLC that **plugs into** adjacent modules to form a backplane with no chassis required

Each module plugs into the one to the left

Connections for the built in I/O

Example of a PLC with the modules **built in**. Comes as one block

PLC Rack or Chassis

Industrial Automation ICE 3252
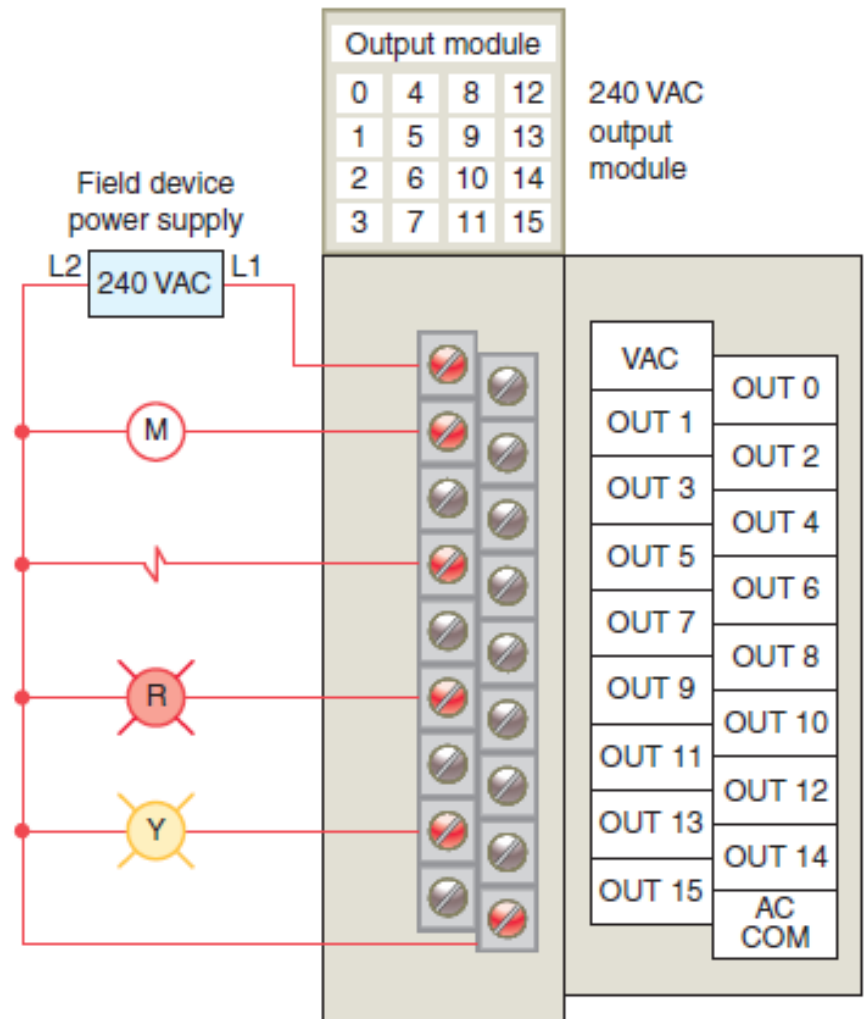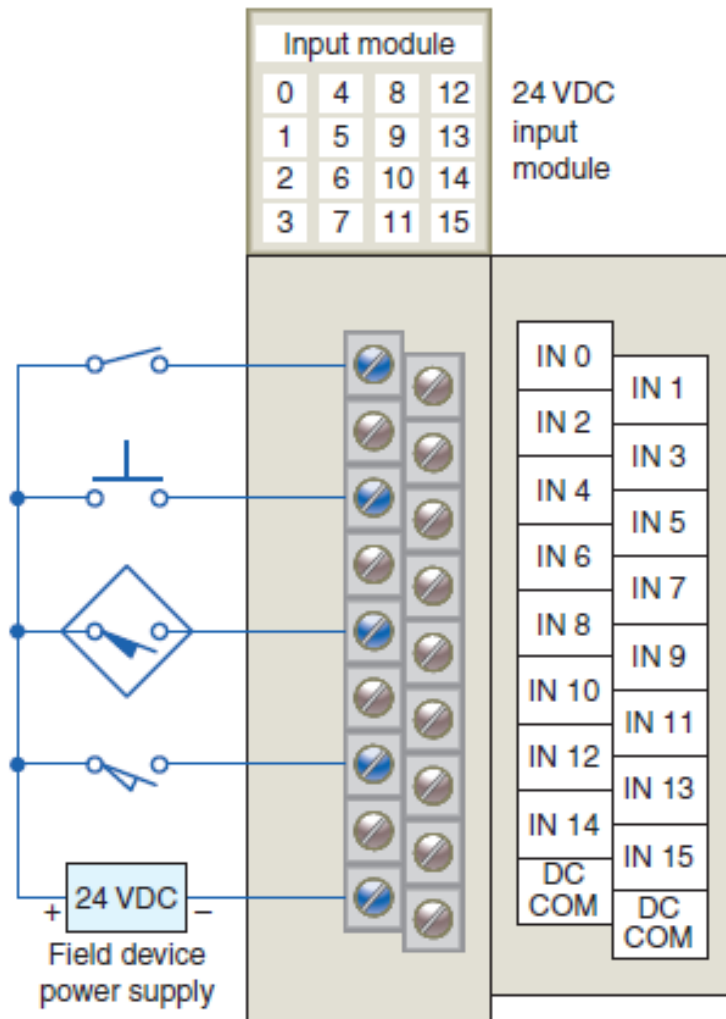
I/O Modules :

- Physically connect to field devices.

- It forms the interface by which input field devices are connected to the controller.

- Input modules convert electrical signals coming in from input field devices such as pushbuttons, to electrical signals that the PLC can understand.

- Input modules convert many different types of electrical signals such as 24VDC ,10VDC, or 4-20mA, to signals which the controller can understand.

- Output modules take information coming from the PLC and convert it to electrical signals the output field devices can understand, such as a motor starter, or a hydraulic solenoid valve. I/O comes in various forms.
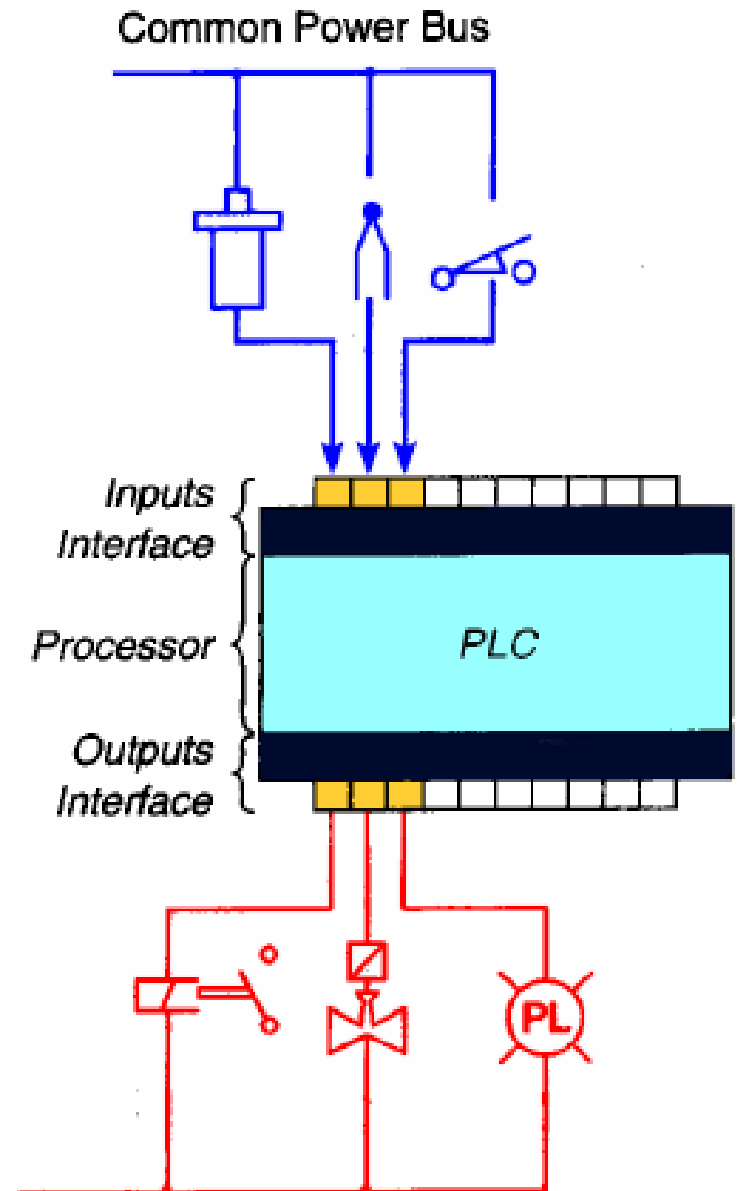
Industrial Automation ICE 3252

I/O modules

Typical PLC I/O system connection
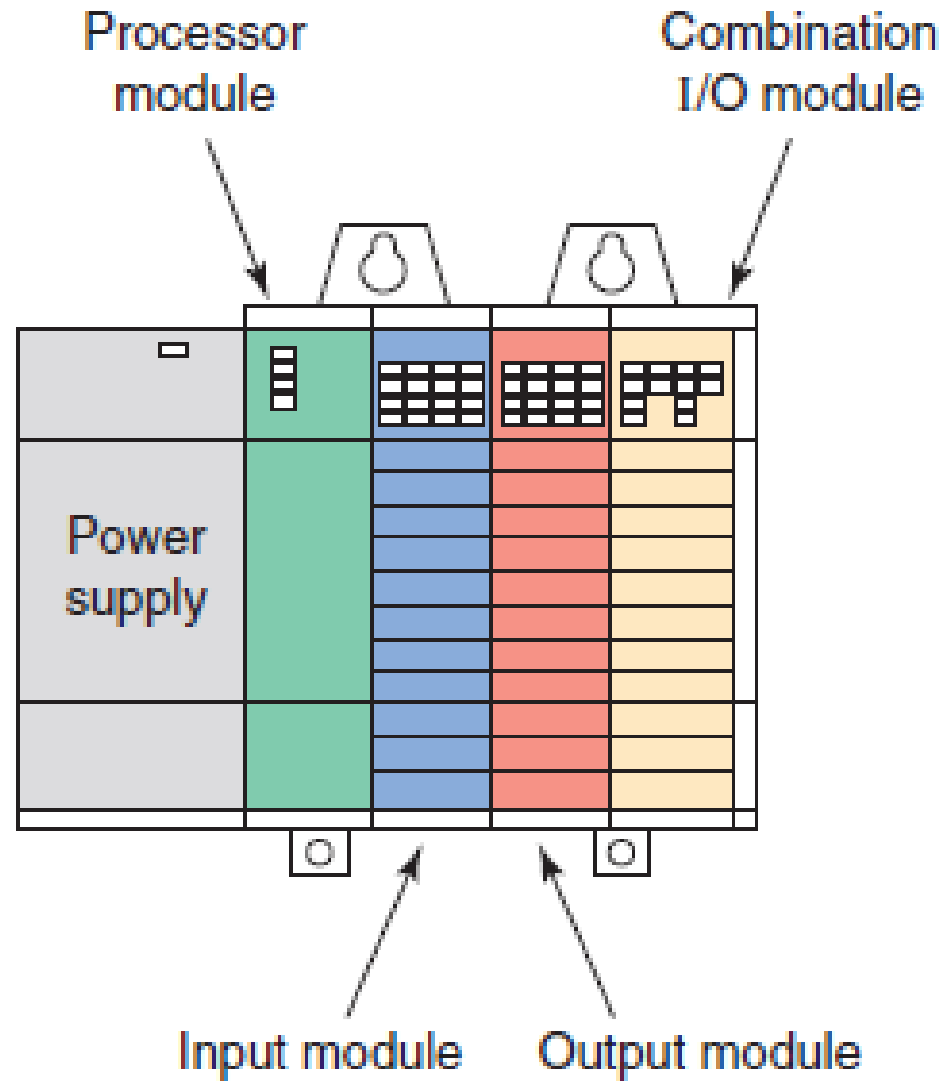
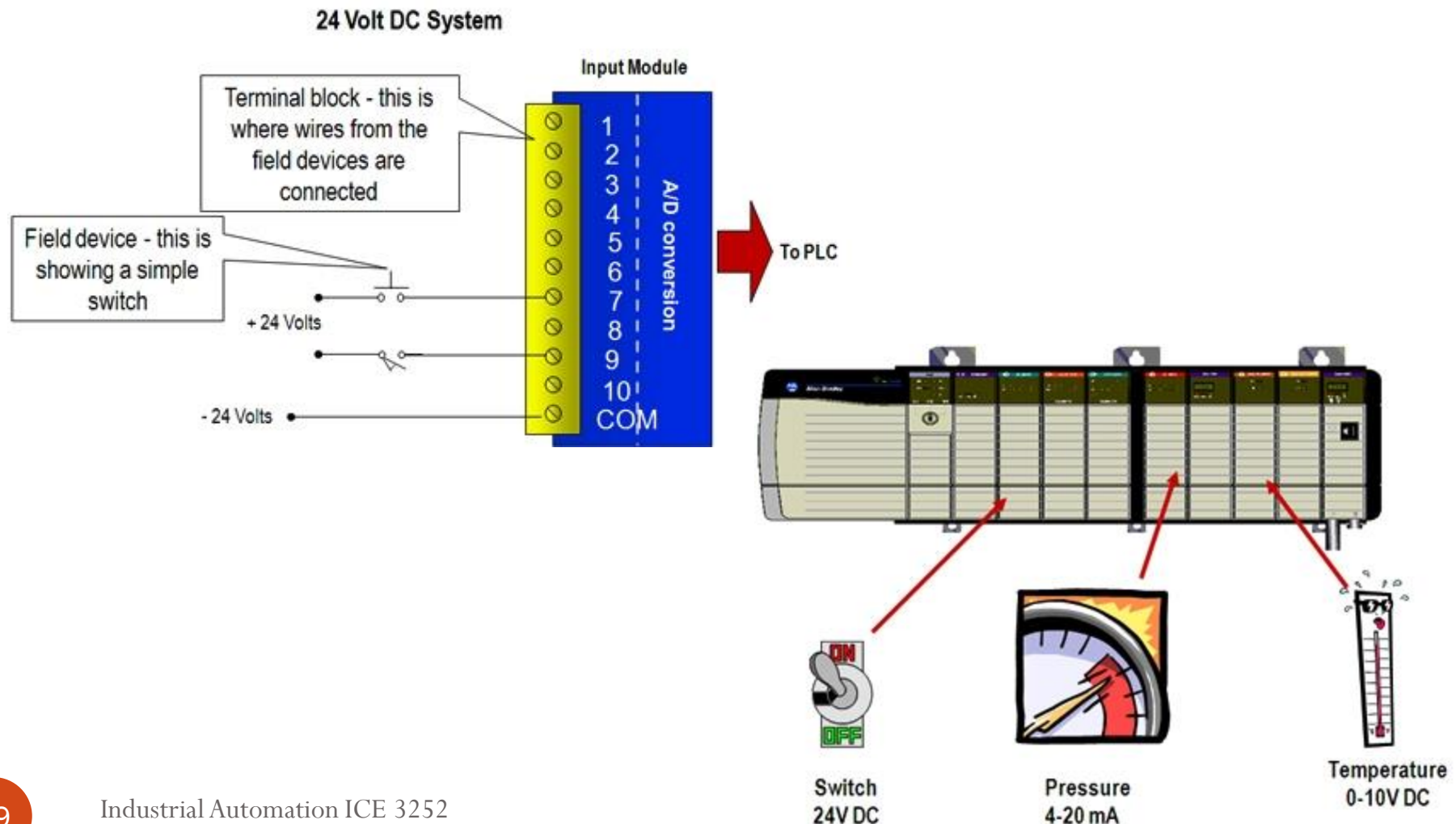Industrial Automation ICE 3252

I/O Configurations

Fixed I/O

• Is typical of small PLCs

• Comes in one package, with no separate removable units.

• The processor and I/O are packaged together.

• Lower in cost – but lacks flexibility.

Common Power Bus

Inputs Interface

Processor — PLC

Outputs Interface

PL

Industrial Automation ICE 3252

Modular I/O

Processor module

Combination I/O module

Power supply

Input module

Output module
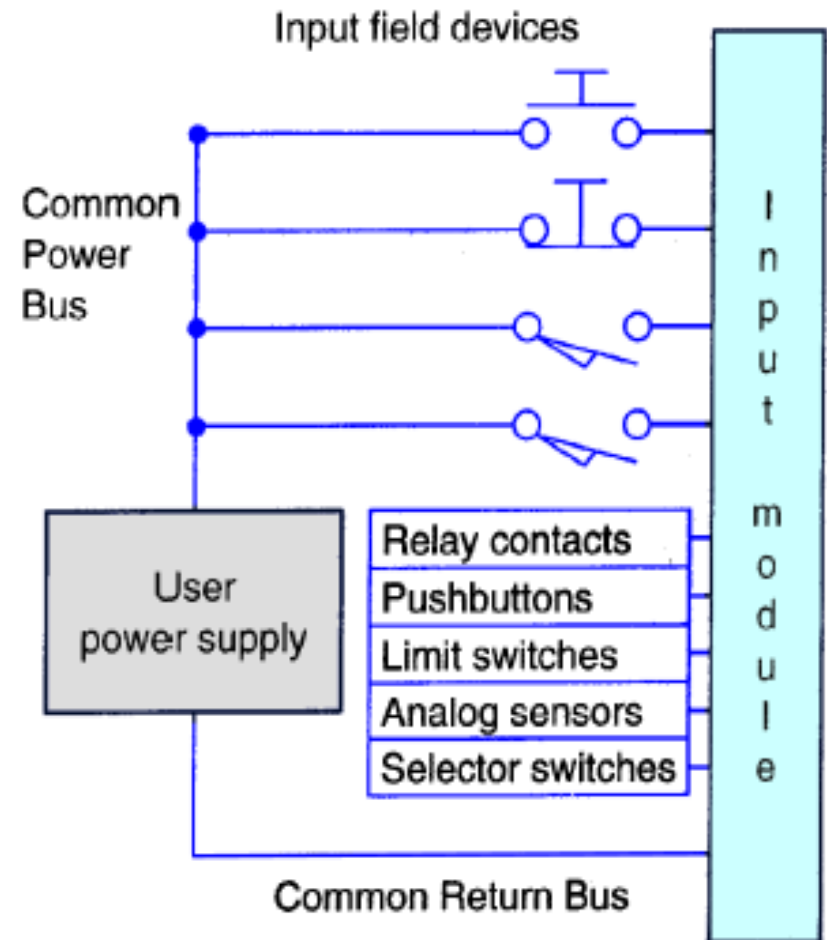
Industrial Automation ICE 3252

Input modules convert real world voltage and currents to signals the PLC can understand. Since there are different types of input devices, there is a wide variety of input modules available, including both digital and analog modules.

24 Volt DC System

Input Module

Terminal block - this is where wires from the field devices are connected

Field device - this is showing a simple switch

+ 24 Volts

- 24 Volts

1
2
3
4
5
6
7
8
9
10
COM

A/D conversion

To PLC

Switch
24V DC

Pressure
4-20 mA

Temperature
0-10V DC

I/O Section

Input Module

• Forms the interface by which input field devices are connected to the controller.

• The terms "field" and "real world" are used to distinguish actual external devices that exist and must be physically wired into the system.

Input field devices

Common Power Bus

User power supply

Relay contacts
Pushbuttons
Limit switches
Analog sensors
Selector switches

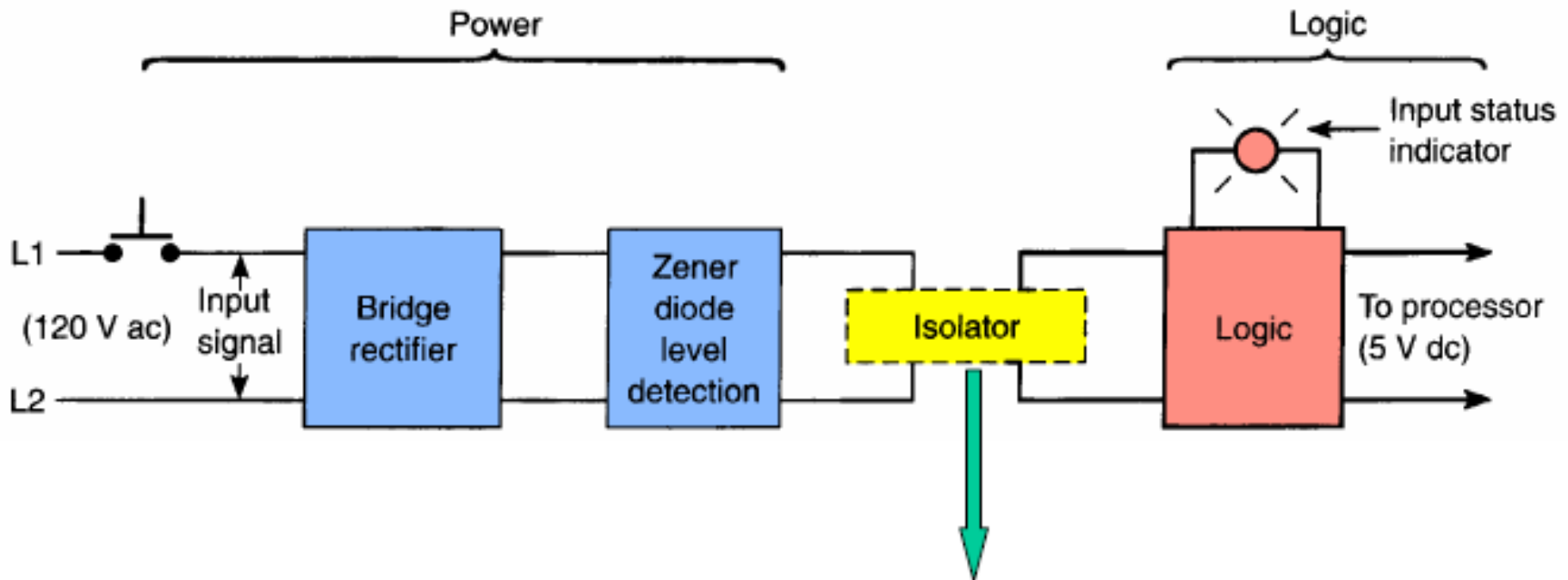Input module

Common Return Bus

- **Discrete Modules :**

    • Devices that are either **on or off**, such as a **pushbutton**, get wired to **discrete** modules. Discrete modules come in a variety of types, such as 24VDC, 48VDC or110vac, 120VAC.

- **Analog Modules :**

    • Devices that have a **number** associated with them, such as a **temperature sensor**, get wired to **analog** modules. Analog modules come in a variety of types, such as 4 to 20 mA or 0 to 10 VDC.
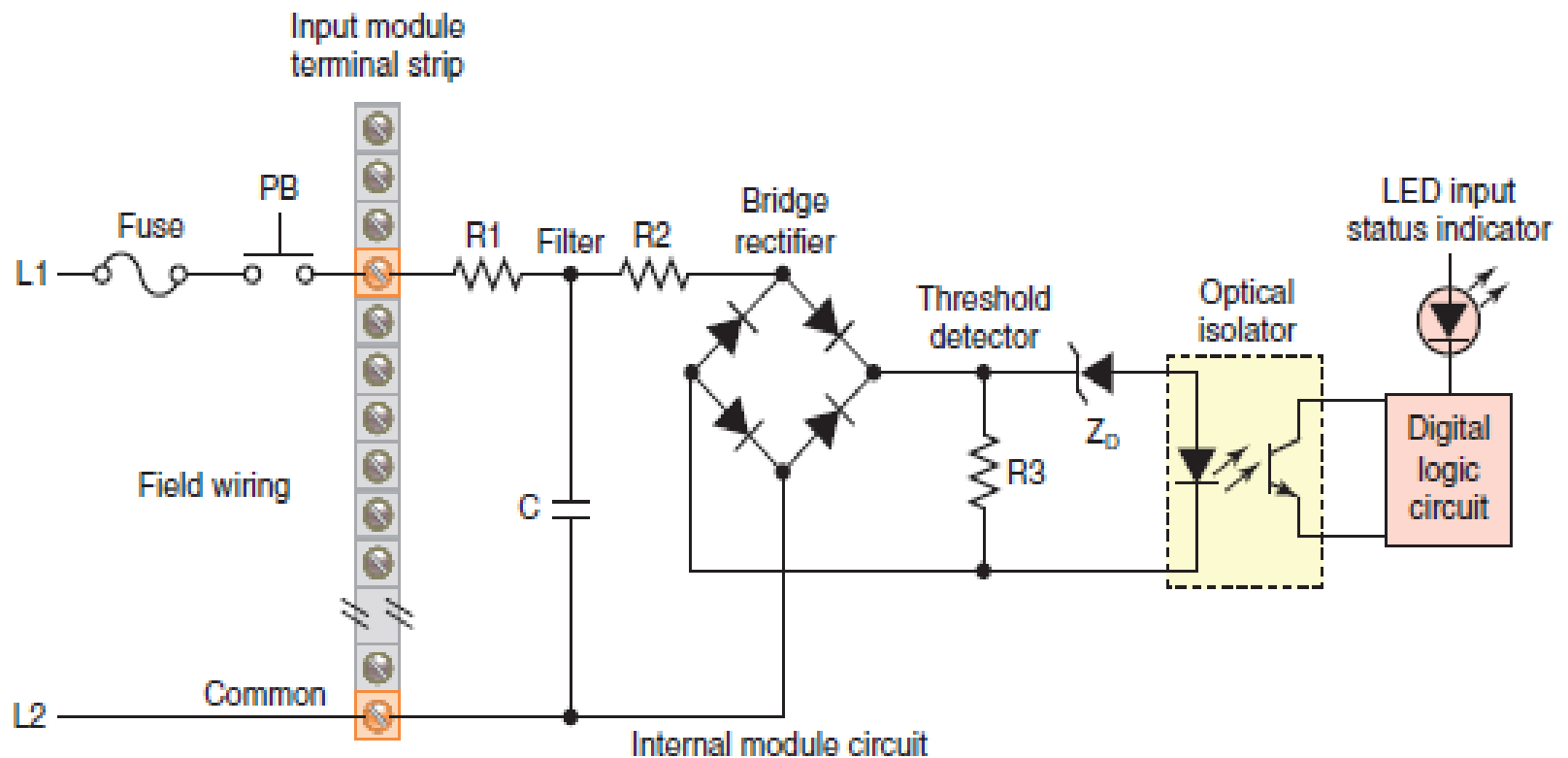
Industrial Automation ICE 3252

AC Discrete Input Module

The input circuit is composed of two basic sections: the power section and the logic section.

The power and logic sections are normally coupled together with a circuit, which electrically separates the two.

Industrial Automation ICE 3252

Cont..

Input module terminal strip

LED input status indicator

Bridge rectifier

Threshold detector

Optical isolator

Fuse   PB

L1

R1   Filter   R2

Field wiring

C

Z_D

R3

Digital logic circuit
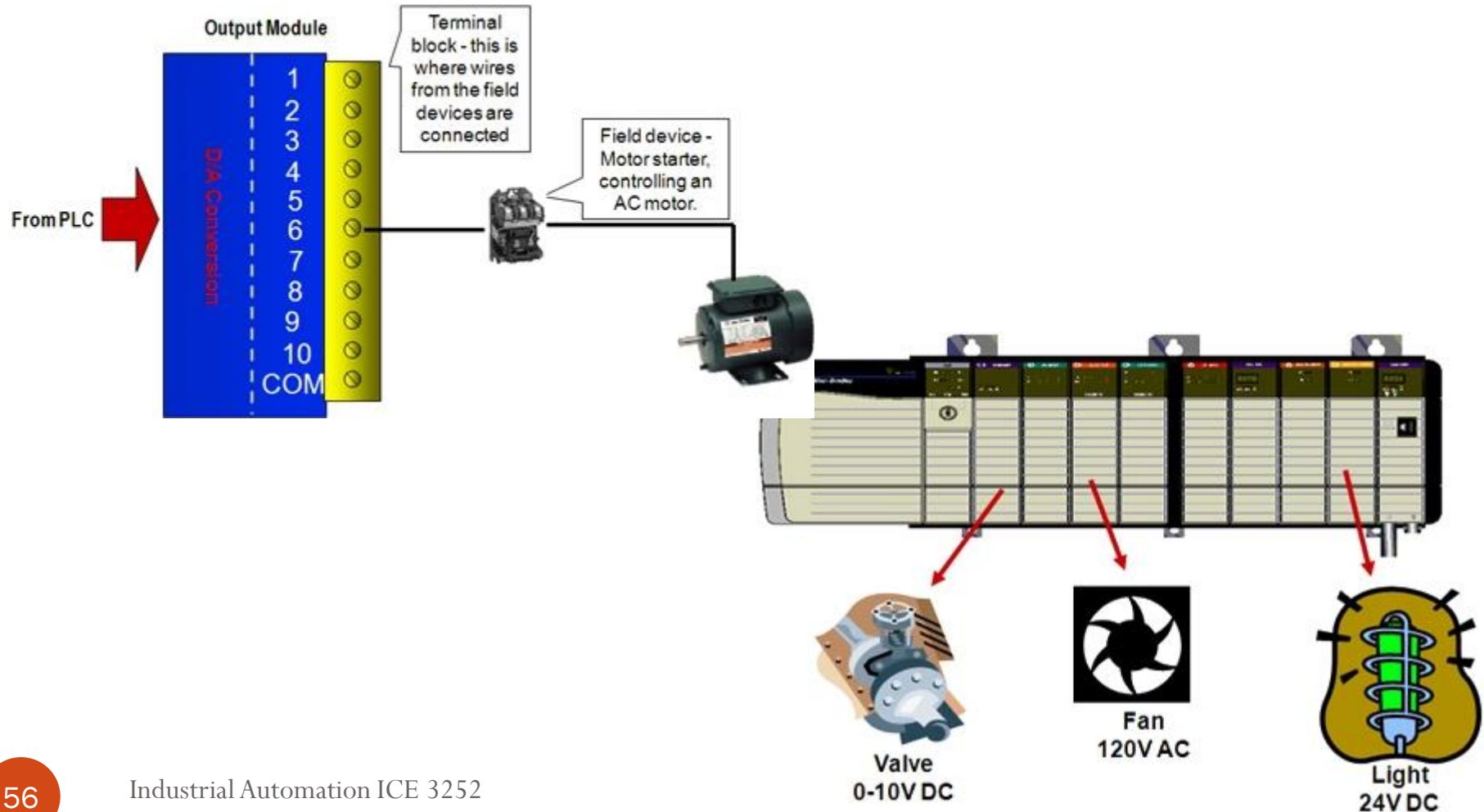
L2

Common

Internal module circuit

- **Discrete input modules perform four tasks in the PLC control system.**

- They:

- Sense when a signal is received from a field device.

- 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.

Output Modules

output module Physically connect to the output devices

- Output modules interface directly to devices such as motor starters and lights.

- Output modules take digital signals from the PLC and convert them to electrical signals such as 24VDC and 4 to 20mA that field devices can understand.
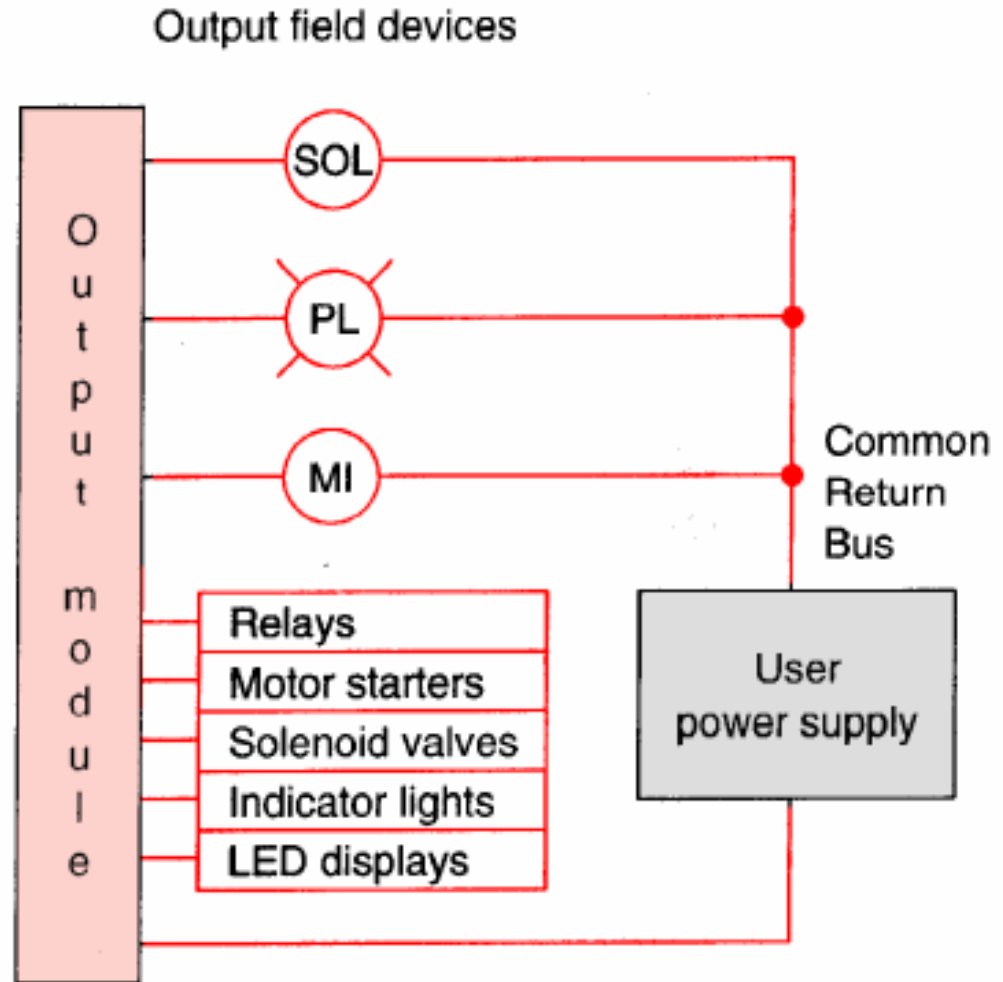
Output modules take a signal from a PLC and convert it to a signal that a field device needs to operate. Since there are different types of output devices, there is a wide variety of output cards available, including both digital and analog cards.

Output Module

Terminal block - this is where wires from the field devices are connected

Field device - Motor starter, controlling an AC motor.

From PLC

D/A Conversion

1
2
3
4
5
6
7
8
9
10
COM

Valve
0-10V DC

Fan
120V AC

Light
24V DC

I/O Section

Output Module

- Forms the interface by which output field devices are connected to the controller.

- PLCs employ an optical isolator which uses light to electrically isolate the internal components from the input and output terminals.

Output field devices

Output module

- SOL
- PL
- MI
- Relays
- Motor starters
- Solenoid valves
- Indicator lights
- LED displays

Common Return Bus

User power supply

Industrial Automation ICE 3252

Discrete/analog Output Modules

- Used to turn real-world output deices either on or off
- Can be used to control any two state device
- Available in AC and DC versions
- Available in various voltage ranges and current capabilities

- Examples of Discrete Devices Controlled by
  - ☐ Indicator Lamps, Alarm Lamps
  - ☐ Motor Starters, , Electric Valves, Electric Fans
  - ☐ Control Relays, Heater Relay

Common voltage ratings

Input Interfaces	Output Interfaces
12 V ac/dc	12-48 V ac
24 V ac/dc	120 V ac
48 V ac/dc	230 V ac
120 V ac/dc	120 V ac
230 V ac/dc	230 V dc
5 V dc (TTL level)	5 V dc (TTL level)
	24 V dc

AC Discrete Output Module

The output circuit is composed of two basic sections: the power section and the logic section, coupled by an isolation circuit.
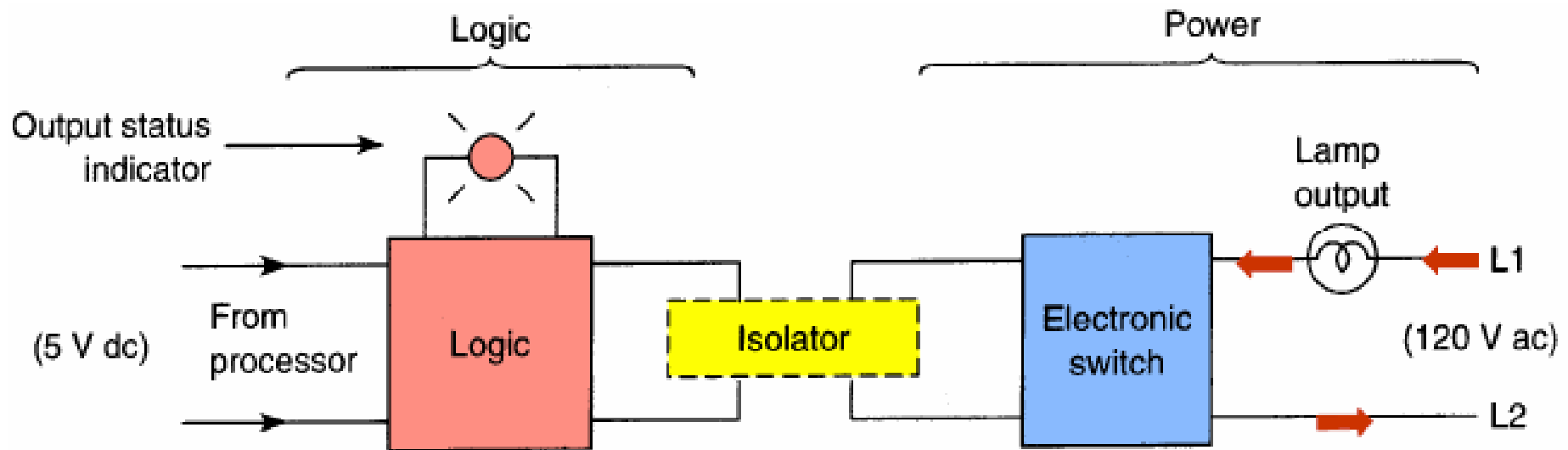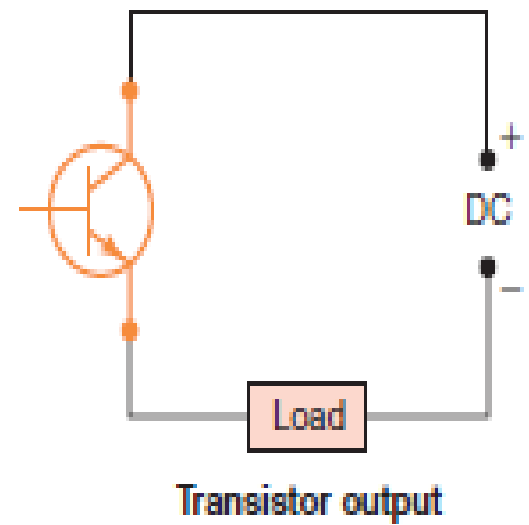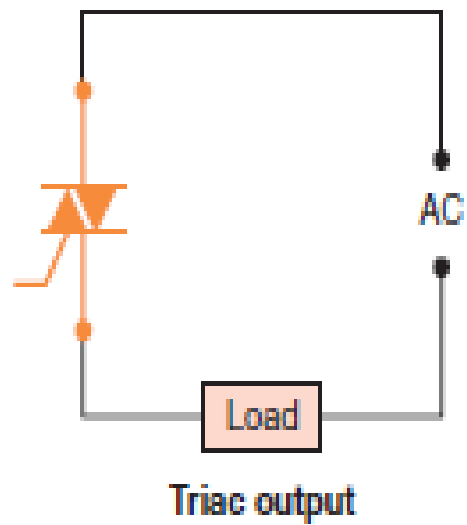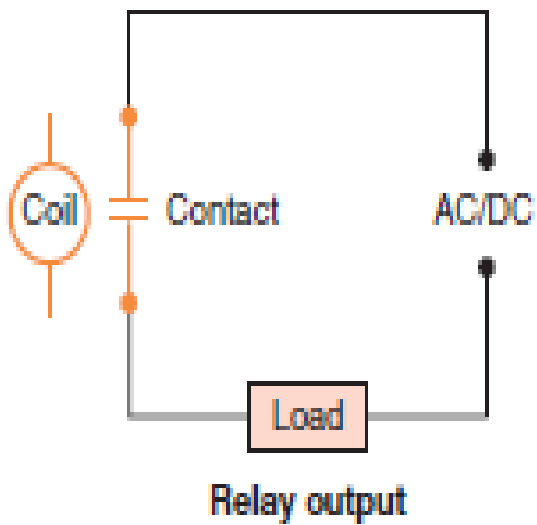

The output interface can be though of as a simple electronic switch to which power is applied to control the output device.

Cont...

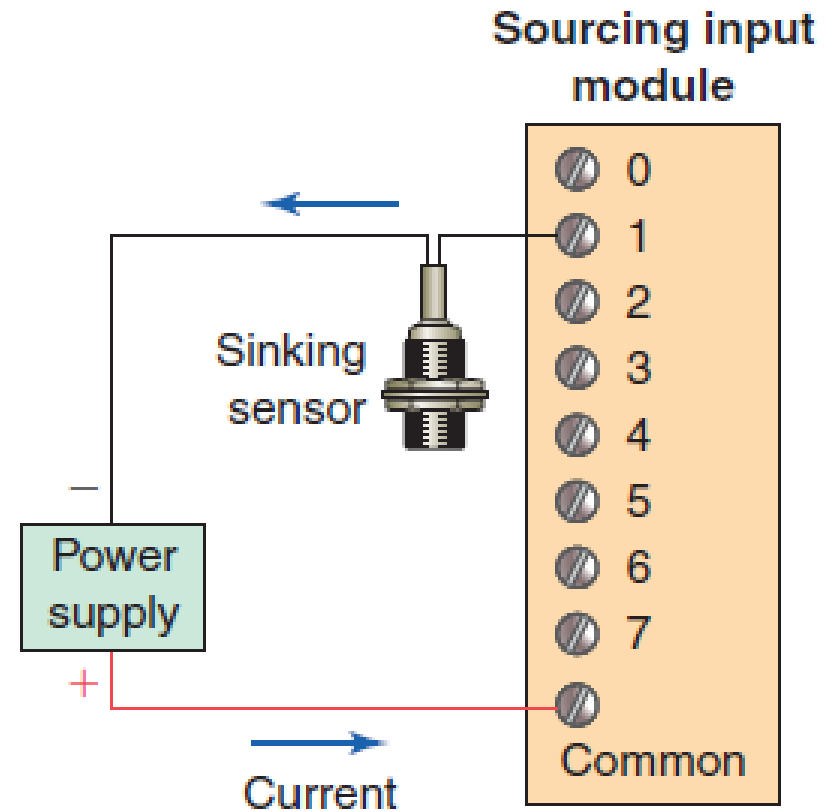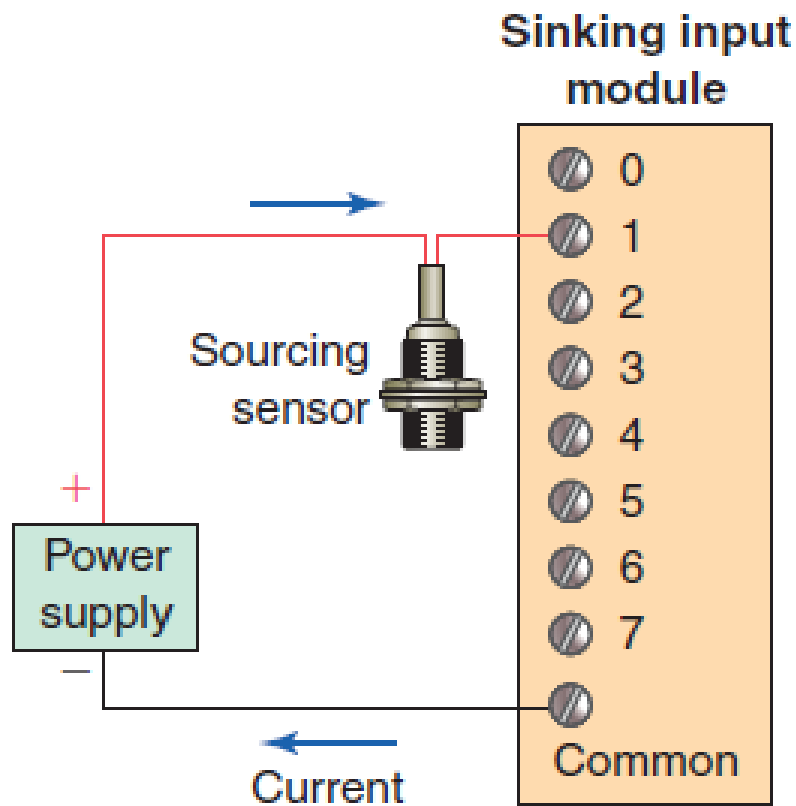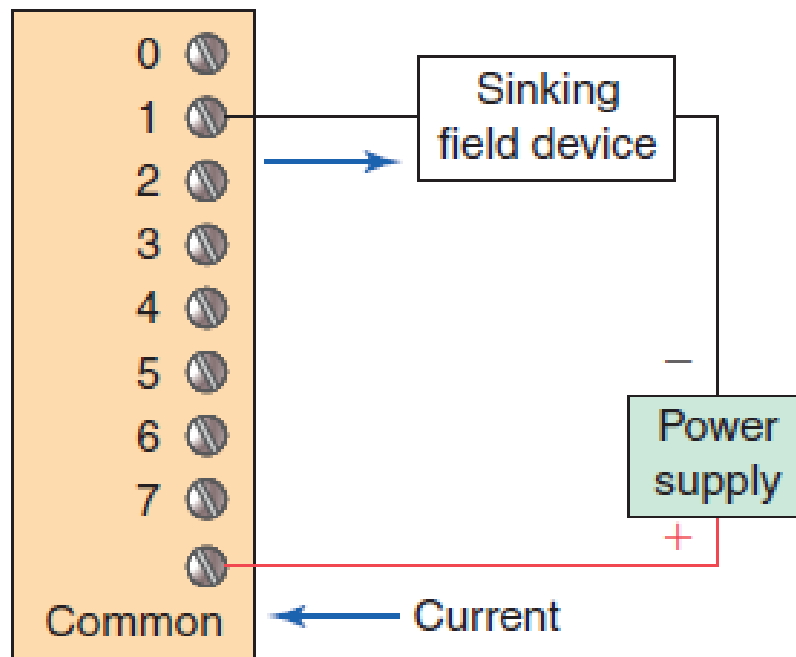LED output status indicator

Optical isolator

Triac switch

Output module terminal strip

L1

Fuse

Digital logic circuit

Field wiring

Internal module circuit

Load

L2

Industrial Automation ICE 3252

Switching elements

Relay output

Triac output

Transistor output

Industrial Automation ICE 3252
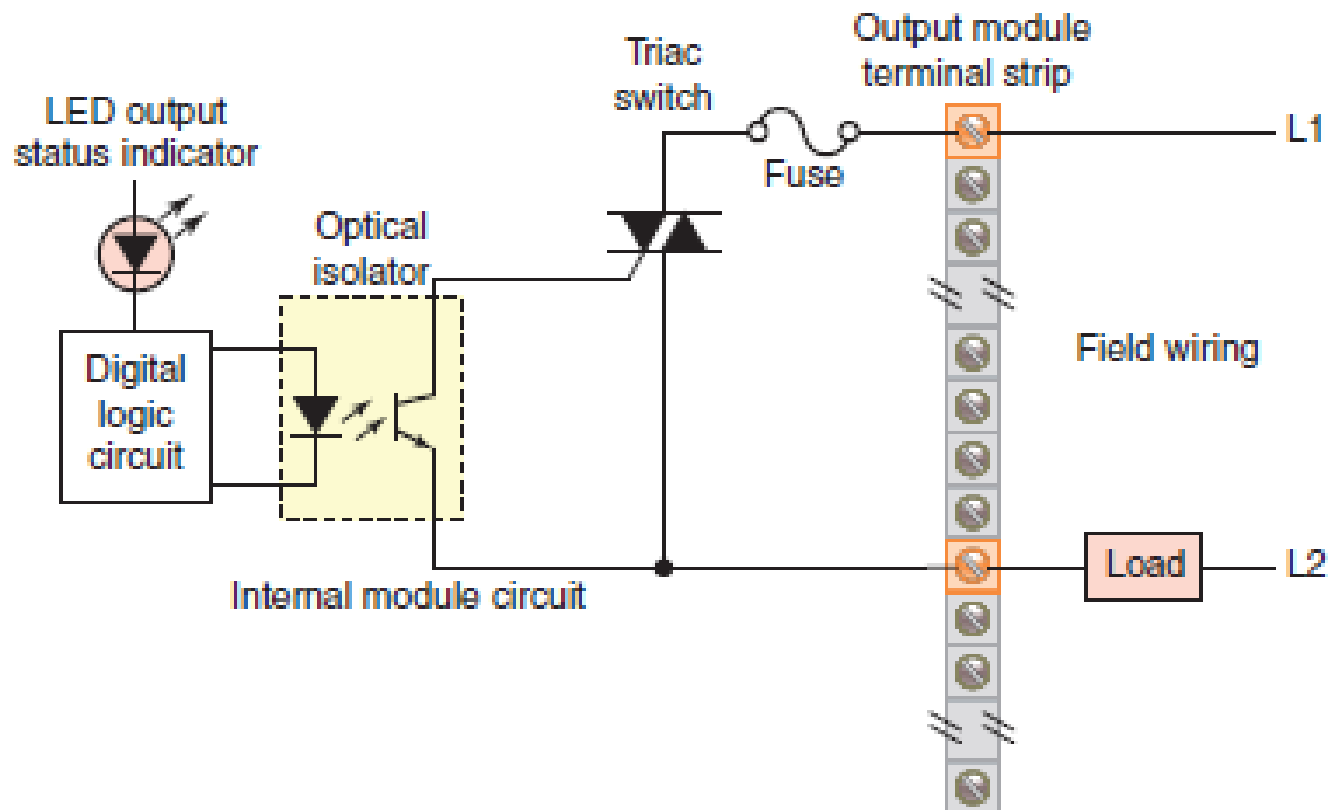
Sinking and sourcing inputs

Industrial Automation ICE 3252

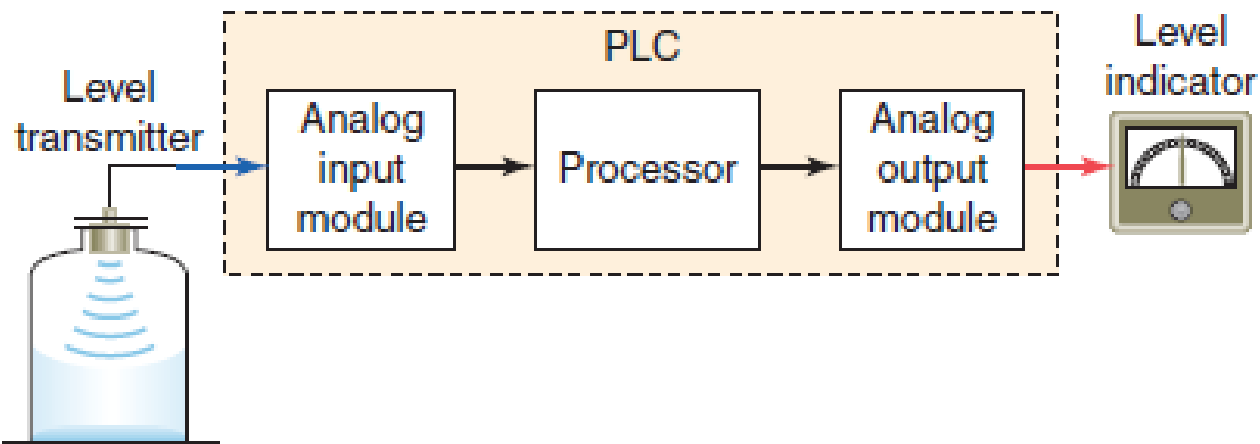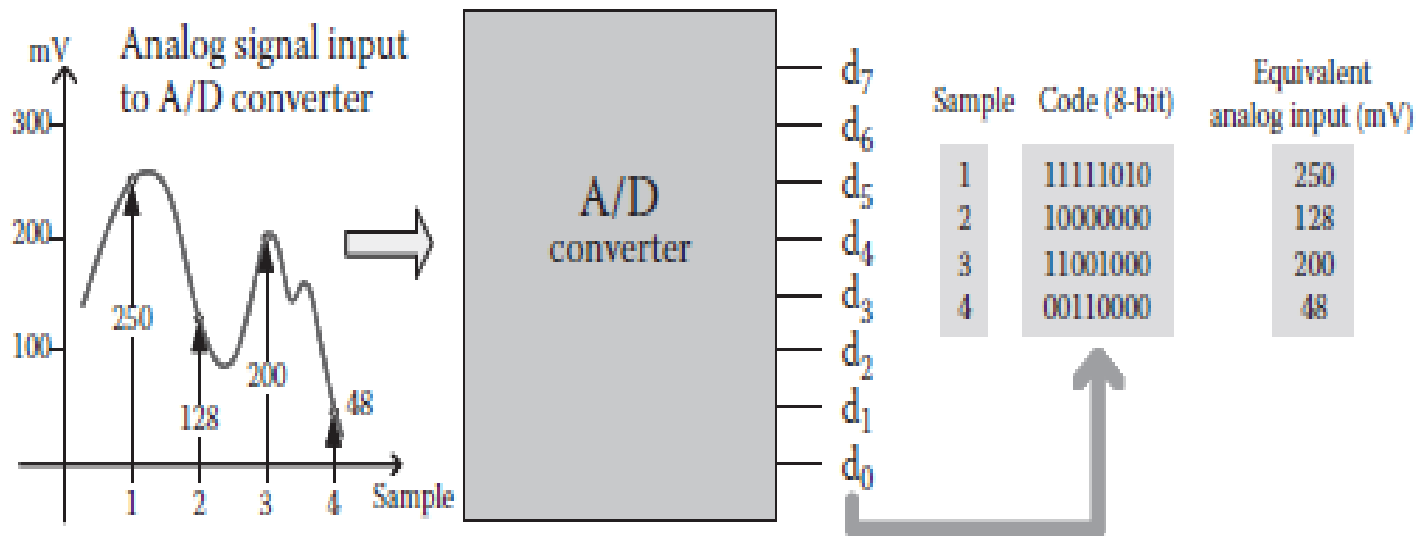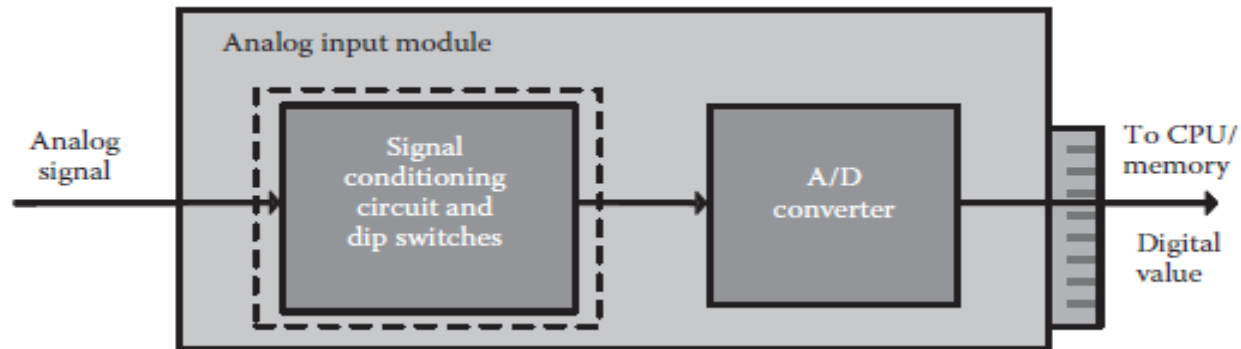# Sinking and sourcing outputs
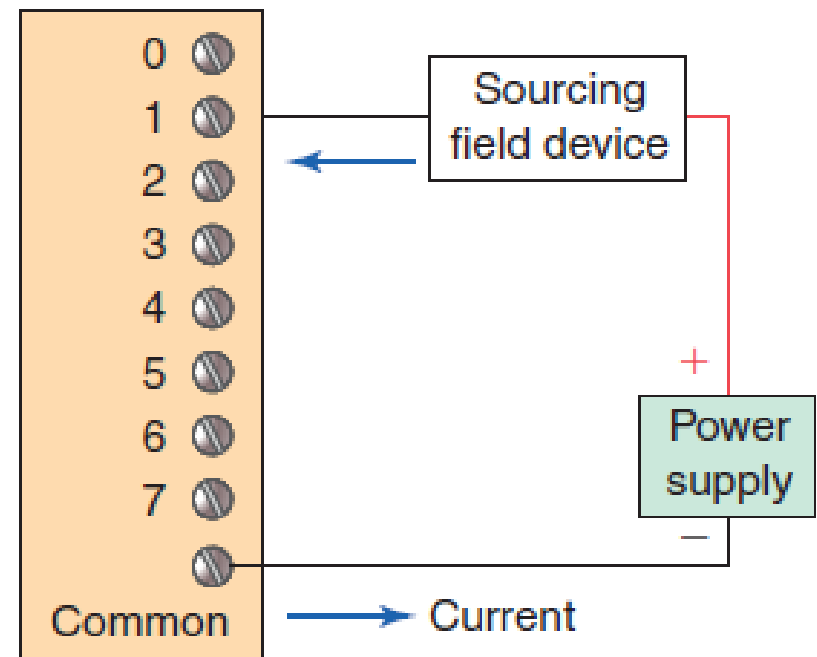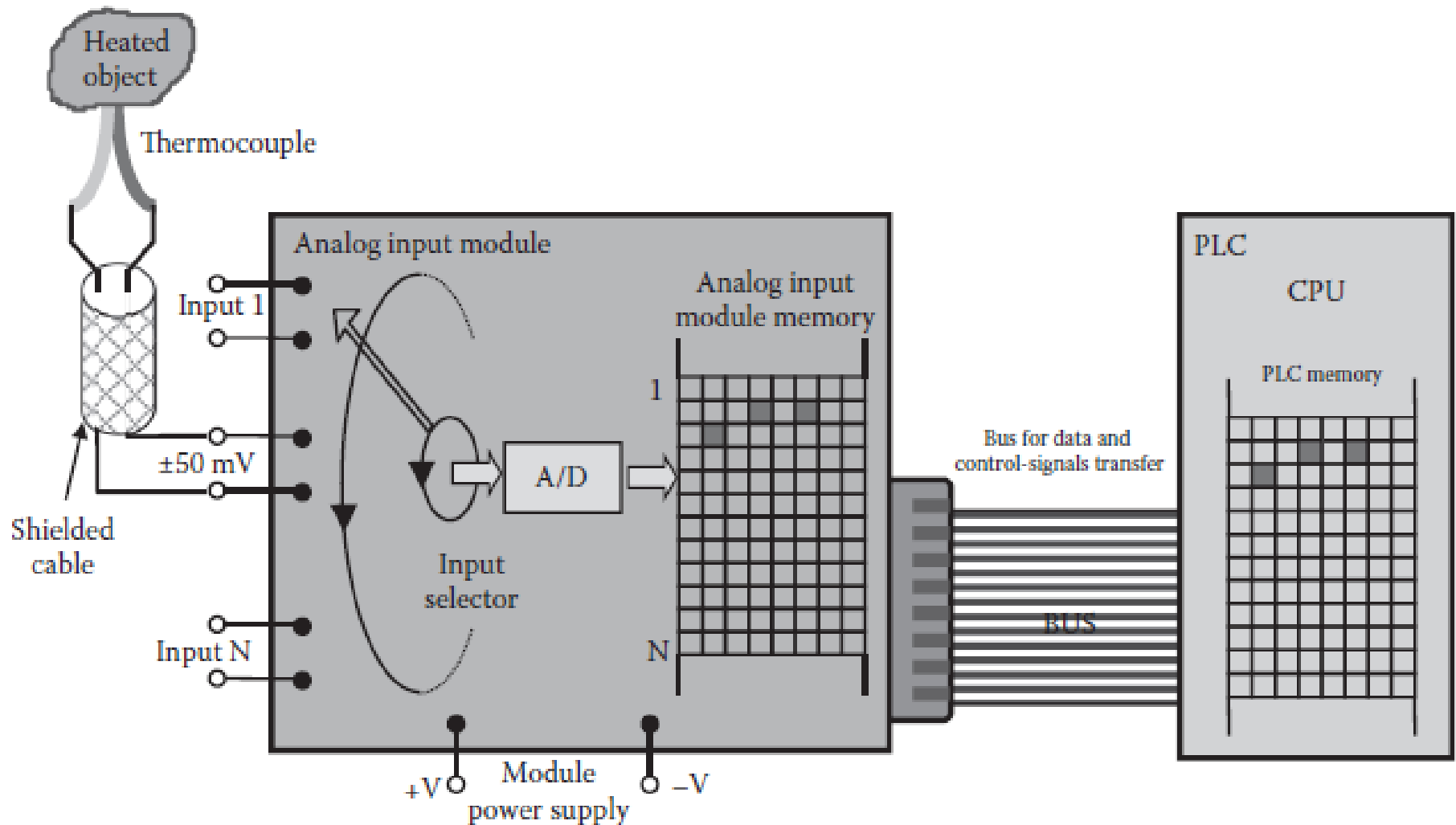
Analog I/O Module

- Typical analog inputs and outputs vary from 0 to 20 milliamps, 4 to 20 milliamps, or 0 to 10 volts.

- Analog input modules normally have multiple input channels that allow 4, 8, or 16 devices to be interface to the PLC.

- The two basic types of analog input modules are *voltage* sensing and *current* sensing.

Industrial Automation ICE 3232

Analog input module

Analog input module

Analog signal → Signal conditioning circuit and dip switches → A/D converter → To CPU/memory Digital value

mV — Analog signal input to A/D converter

A/D converter — d_7, d_6, d_5, d_4, d_3, d_2, d_1, d_0

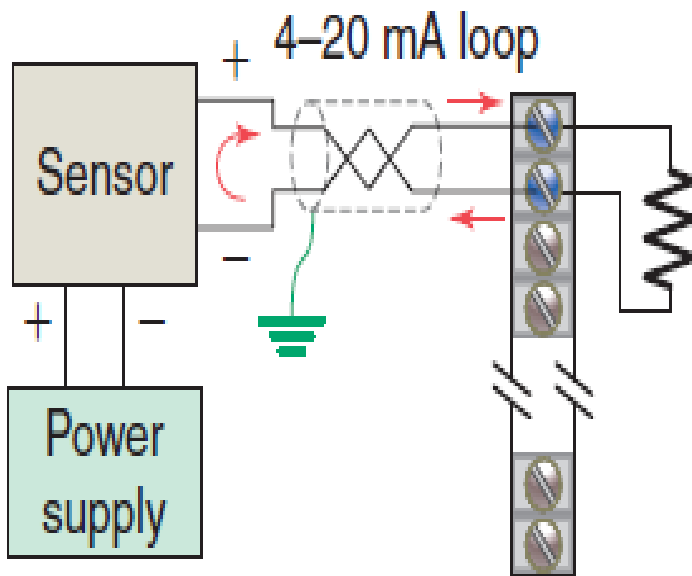| Sample	Code (8-bit)	Equivalent analog input (mV)
1	11111010	250
2	10000000	128
3	11001000	200
4	00110000	48

Analog input module

Sensor and analog module supplied power

Sensor supplied power

Module supplied power

4–20 mA loop

Programming Device

PC with appropriate software
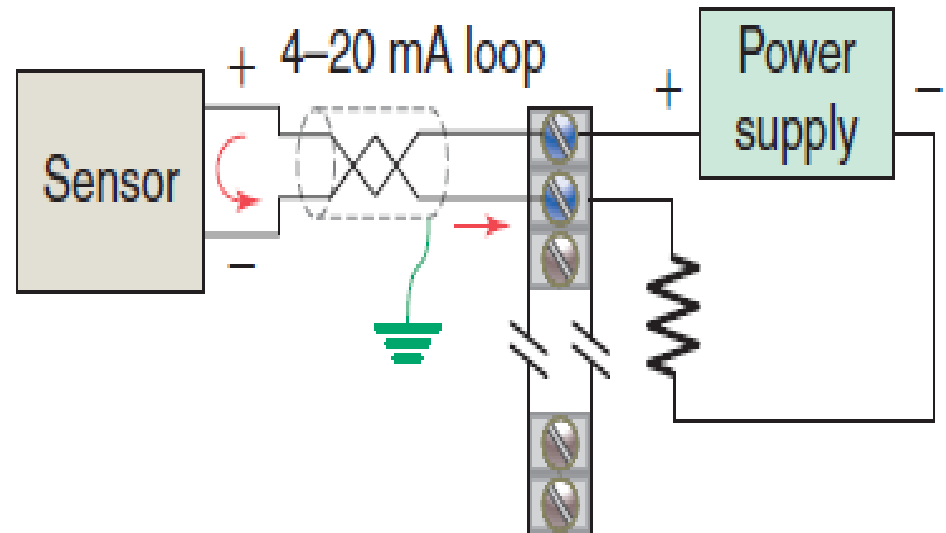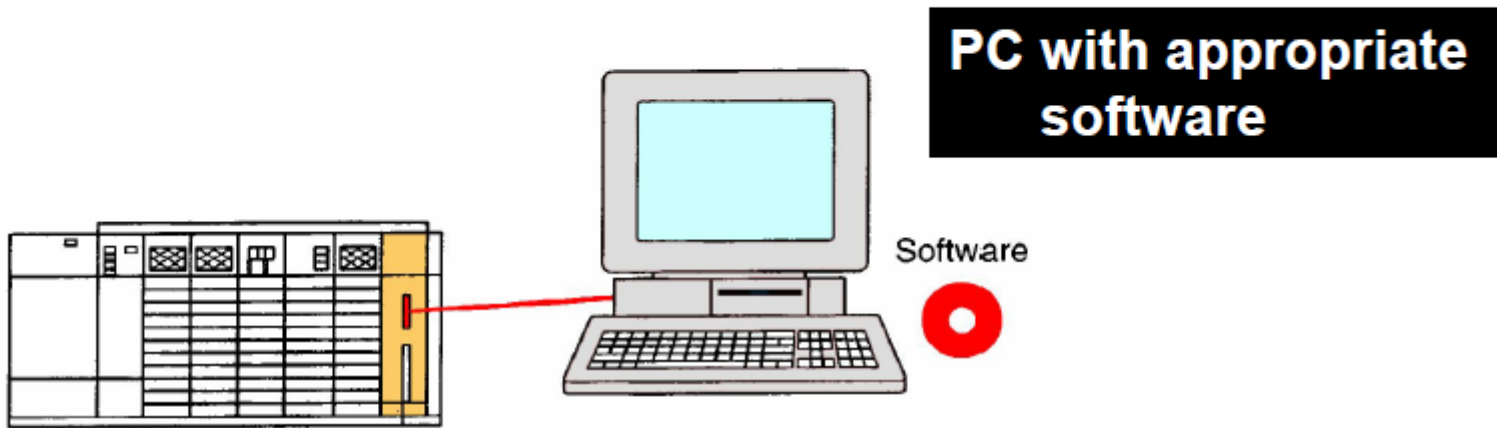
Software
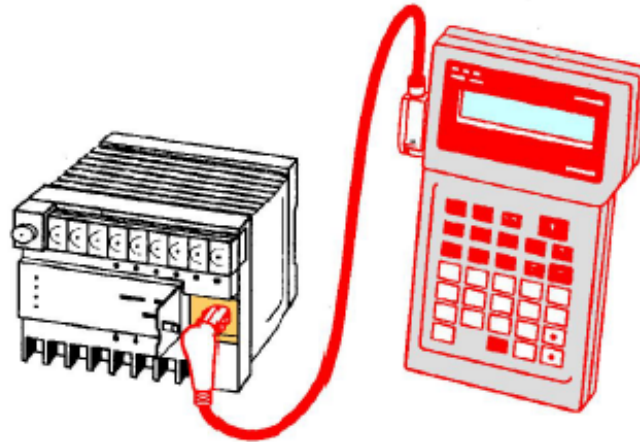
- A personal computer (PC) is the most commonly used programming device
- The software allows users to create, edit, document, store and troubleshoot programs
- The personal computer communicates with the PLC processor via a serial or parallel data communications link
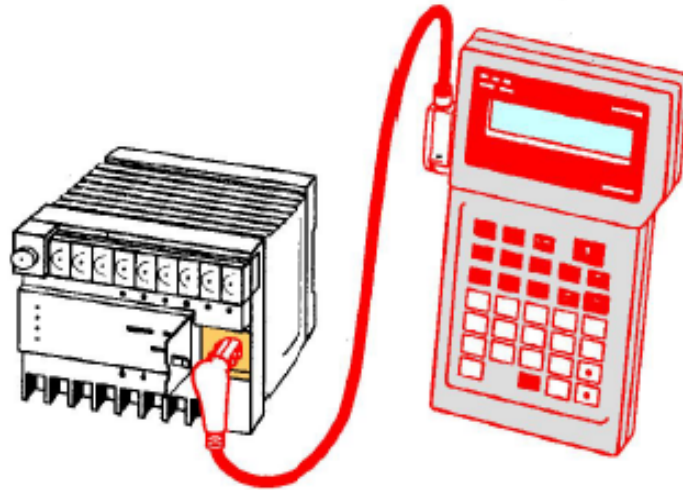
Programming Device

Hand-held unit with display

- Hand-held programming devices are sometimes used to program small PLCs

- They are compact, inexpensive, and easy to use, but are not able to display as much logic on screen as a computer monitor

Programming Device
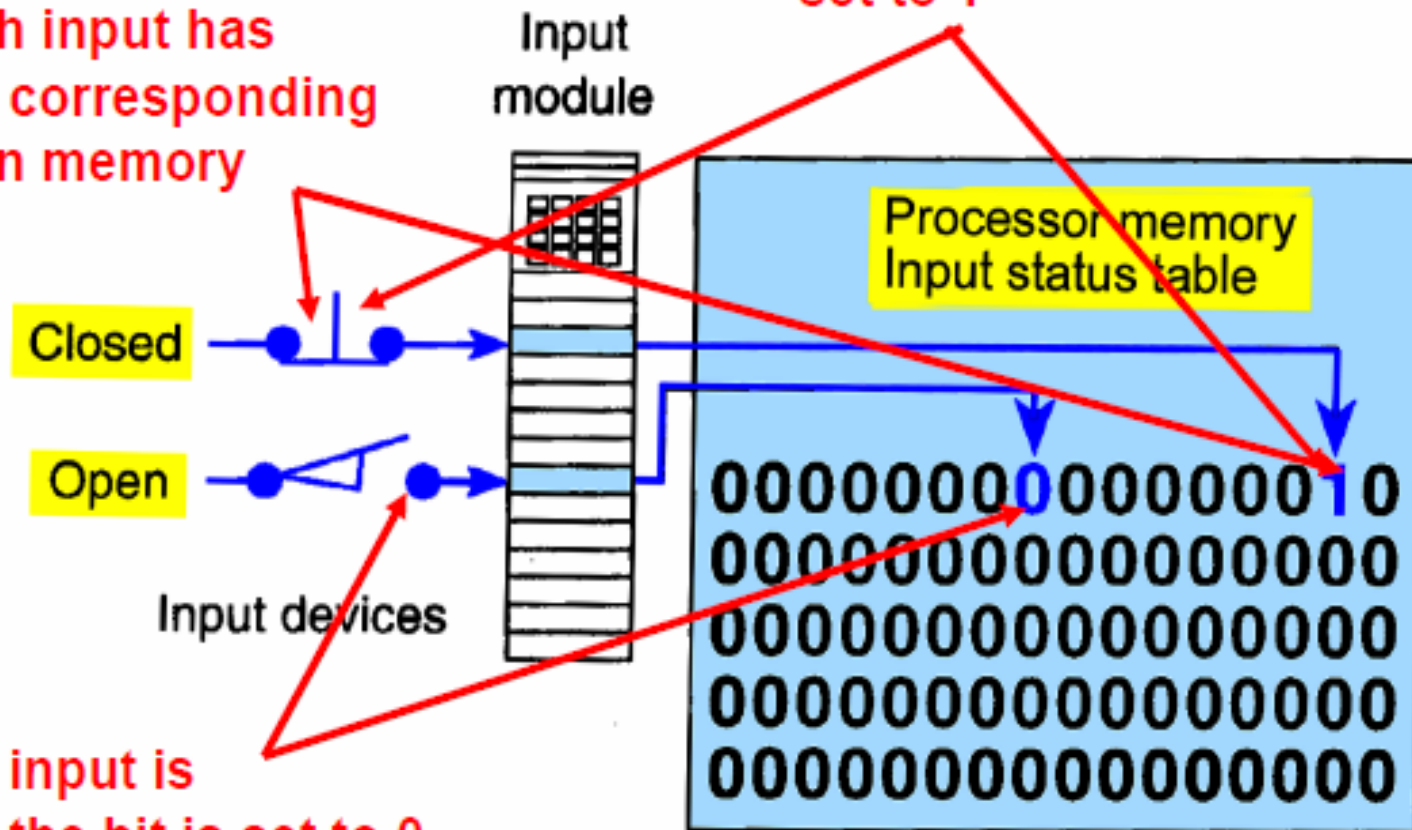
Hand-held unit with display

- Hand-held units are often used on the factory floor for troubleshooting, modifying programs, and transferring programs to multiple machines.

Input Status Table Or File

The memory of a PLC is divided into sections that have specific functions.

If the input is closed the bit is set to 1

Each input has one corresponding bit in memory

Input module

Closed

Open

Input devices

Processor memory
Input status table

```
00000000000000010
00000000000000000
00000000000000000
00000000000000000
00000000000000000
```
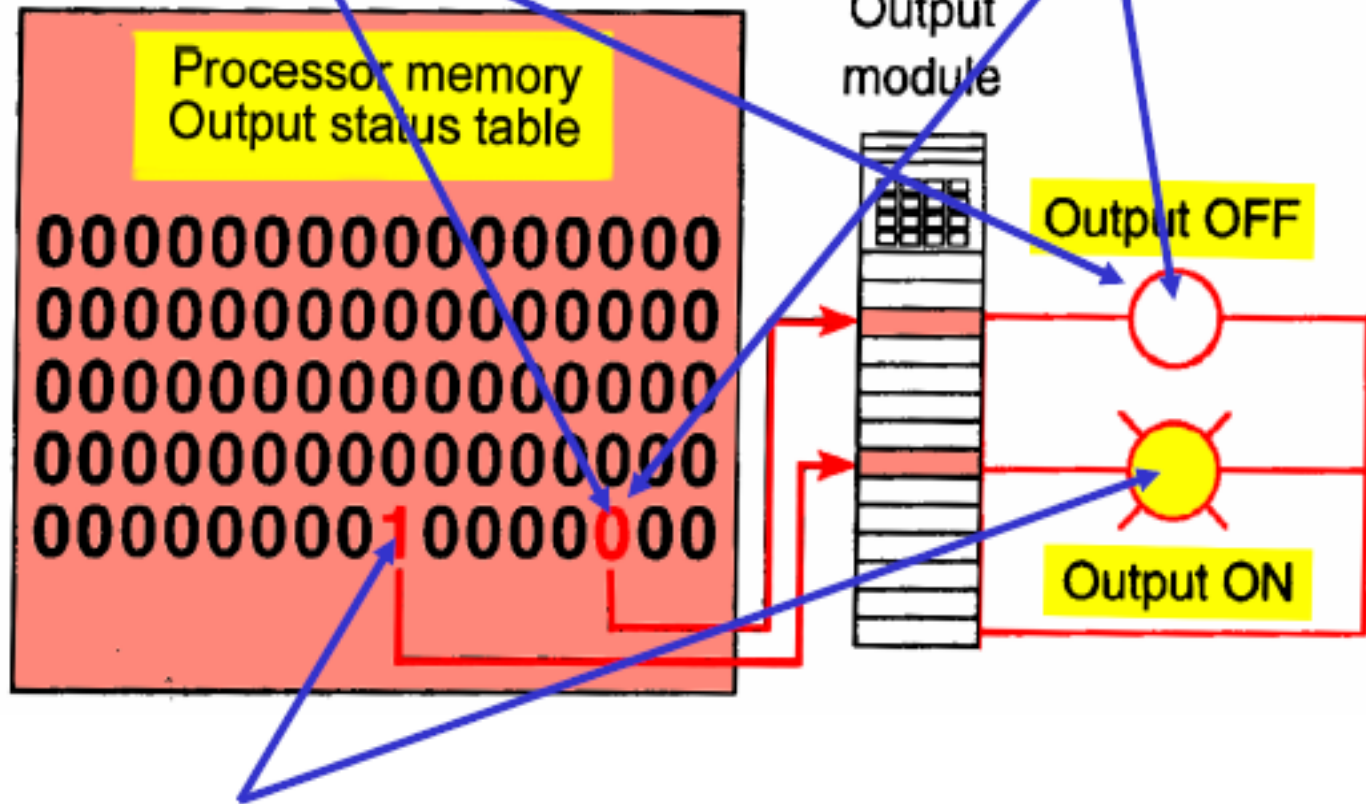
If the input is open the bit is set to 0

Output Status Table Or File

Each output has one corresponding bit in memory

If the bit is a 0, the output will be OFF

Processor memory
Output status table

0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0

Output module

Output OFF

Output ON

If the bit is a 1, the output will be ON

Industrial Automation ICE 3252

Discrete I/O Modules

The I/O modules receive their module voltage and current from the power supply module through the backplane of the rack enclosure into which they are inserted. Power from this supply is used to power the electronics, that reside on the I/O board. The relatively higher currents required by the loads of an output module are supplied by user-supplied power.

Power Supply

- **Programming Software :**

- System s/w
- Application s/w
- Drive s/w
- Software that runs on a PC is required to configure and program PLCs.
- Different products may require different programming software.

i.e

AB- Rs logix /Rs view

Simens- Simatic manger,microwin,total integrated

GE Fanuc- versa pro

Network Interface :COMMUNICATION

Most PLCs have the ability to communicate with other devices. These devices include computers running programming software, or collecting data about the manufacturing process, a terminal that lets an operator enter commands into the PLC, or I/O that is located in a remote location from the PLC..
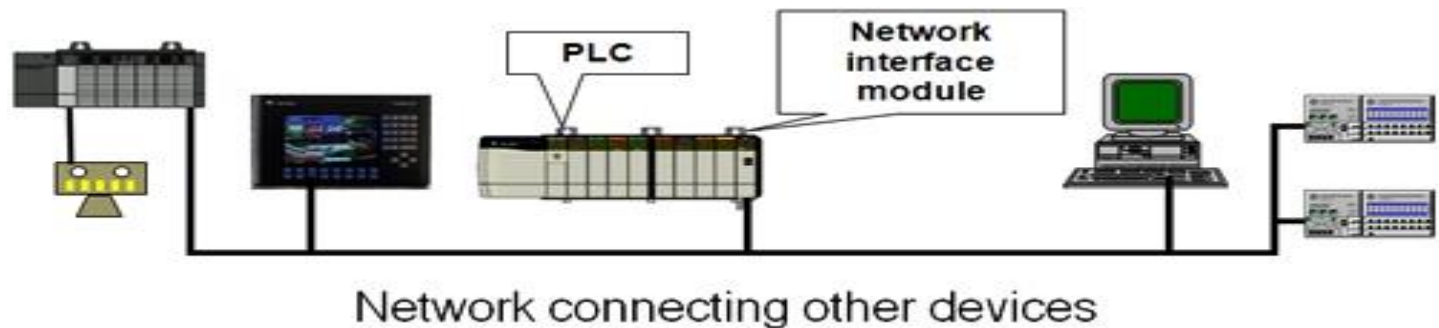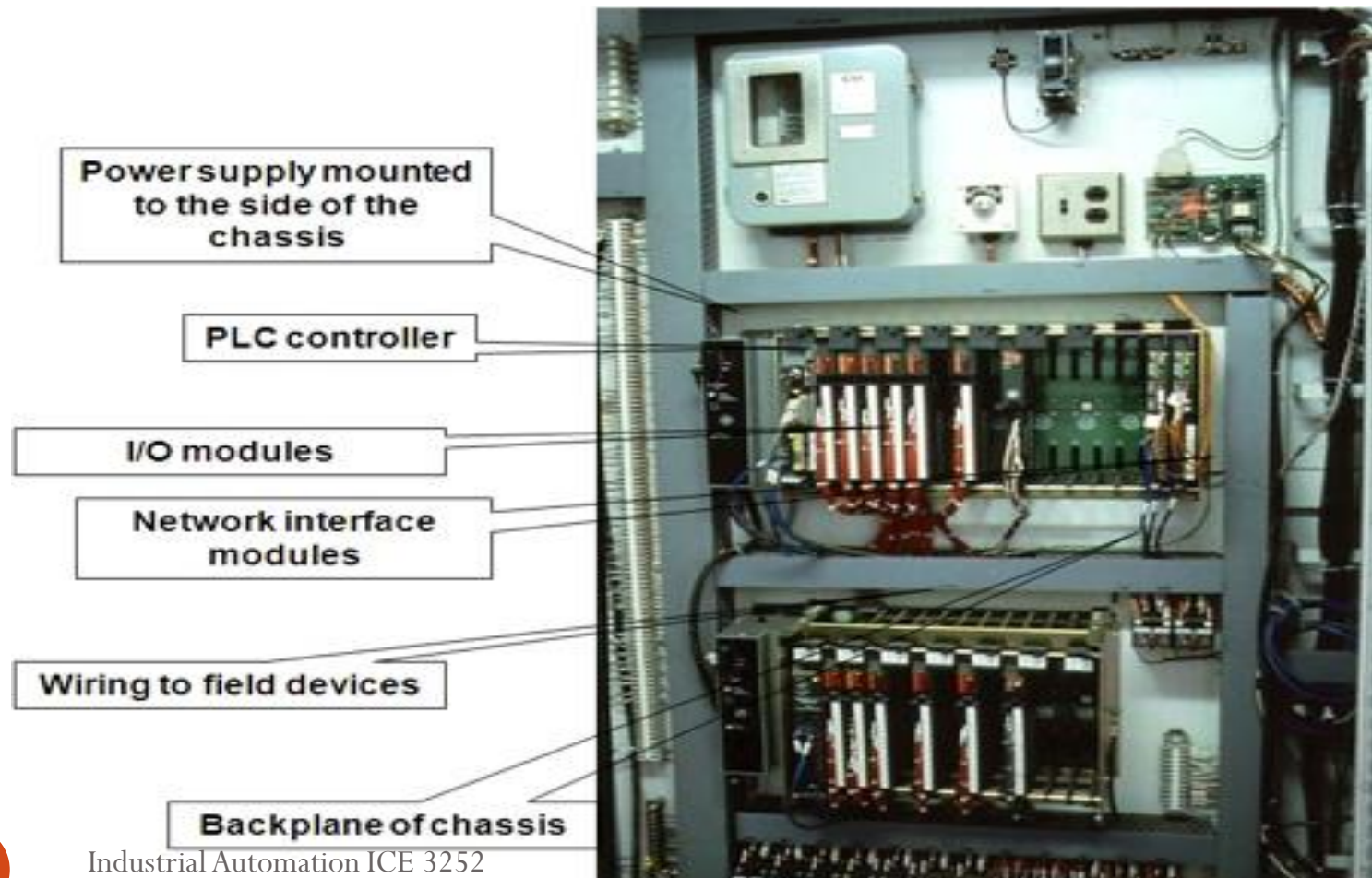
Rs232

Ehernet

Fieldbus

Profibus

Modbus

Canbus

Etc,

Network connecting other devices

The PLC will communicate to the other devices through a network interface.

Industrial Automation ICE 3252

PLC Control Panel :

Typically, PLCs are installed in enclosures, on a "panel"

Power supply mounted to the side of the chassis

PLC controller

I/O modules

Network interface modules

Wiring to field devices

Backplane of chassis

Industrial Automation ICE 3252

Reerence

- Frank D. Petruzella, *Programmable Logic Controllers,* MGH, (2e), 1997.