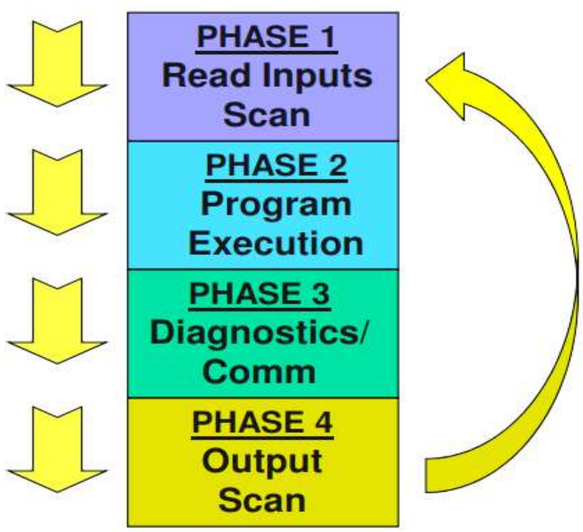
PLC
Unit 2nd

PLC Working Principle

PLC read all field input devices via the input interfaces, execute the user program stored in application memory, then, based on whatever control scheme has been programmed by the user, turn the field output devices on or off, or perform whatever control is necessary for the process application.

This process of sequentially reading the inputs, executing the program in memory, and updating the outputs is known as scanning.

While the PLC is running, the scanning process includes the following four phases, which are repeated continuously as individual cycles of operation:



PHASE 1 – Input Status scan

- A PLC scan cycle begins with the CPU reading the status of its inputs.

PHASE 2– Logic Solve/Program Execution

- The application program is executed using the status of the inputs

PHASE 3– Diagnostics and communication

- Once the program is executed, the CPU performs diagnostics and communication tasks

PHASE 4 - Output Status Scan

- An output status scan is then performed, whereby the stored output values are sent to actuators and other field output devices. The cycle ends by updating the outputs.

As soon as Phase 4 are completed, the entire cycle begins again with Phase 1 input scan.

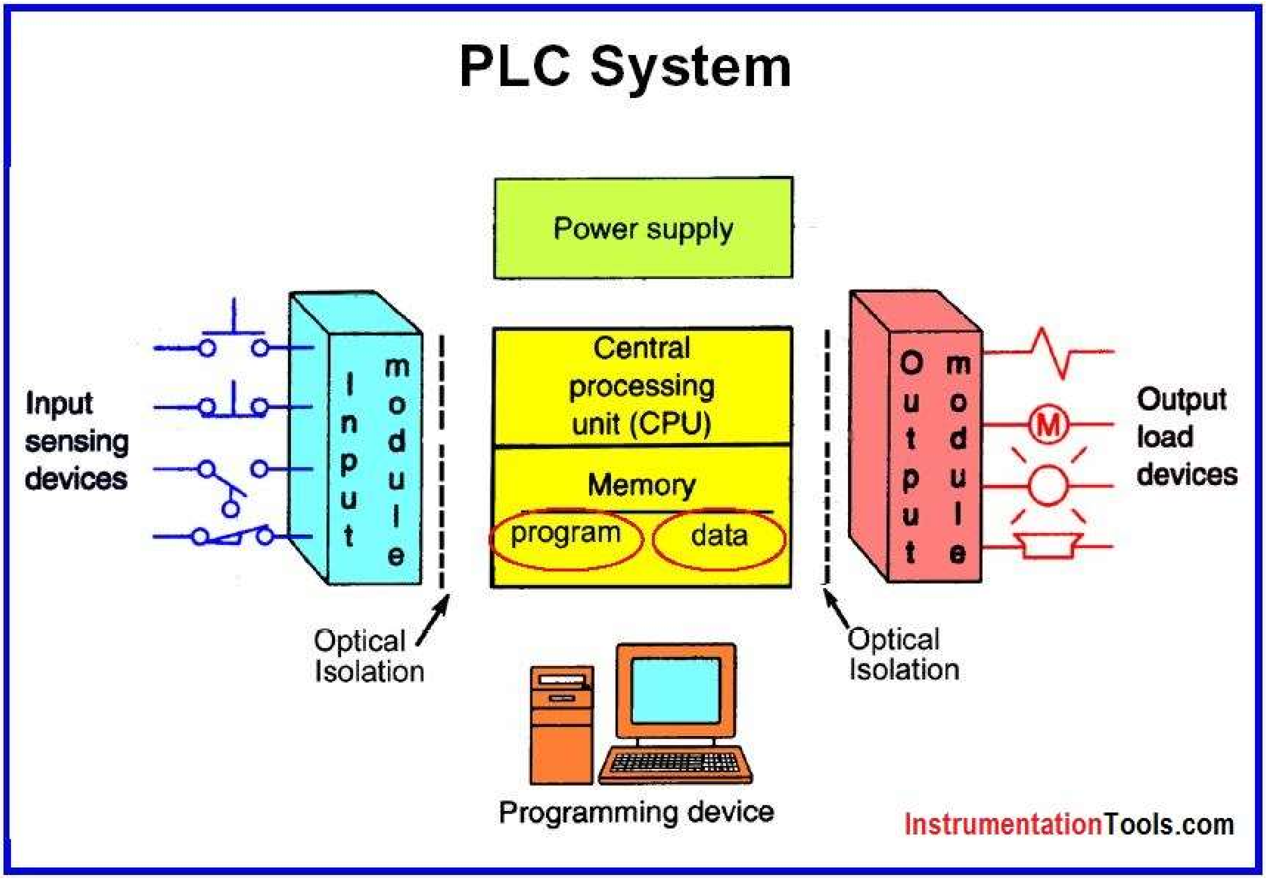
The time it takes to implement a scan cycle is called SCAN TIME. The scan time composed of the program scan time, which is the time required for solving the control program, and the I/O update time, or time required to read inputs and update outputs.

The program scan time generally depends on the amount of memory taken by the control program and type of instructions used in the program. The time to make a single scan can vary from 1 ms to 100 ms.

Architecture of PLC

PLC system contains of the following parts

- Power supply
- CPU
- Input modules
- Output modules
- Programming Device



Architecture of PLC

Power Supply:

This module supplies power to the CPU, input and output modules. It can be built into the PLC or be an external unit. Common voltage levels required by the PLC (with and without the power supply) are 24Vdc, 110Vac, 220Vac.

CPU (Central Processing Unit):

This module is considered as the brain of the PLC system and where ladder logic is stored and processed.

The memory contains the data and the ladder program.

It contains an "Executive" program that tells the PLC how to:

• Execute the control Instructions

• User's Program

• Communicate with other devices

• Other PLCs, Programming devices, I/O devices, etc.

• Perform Housekeeping activities

• Diagnostics, etc

This program is stored in "non-volatile" memory

• Meaning that the program will not be lost if power is removed.

I/O MODULES:

- The I/O interface section of a PLC connects it to external field devices.
- The main purpose of the I/O interface is to condition the various signals received from or sent to the external input and output devices
- Inputs to, and outputs from, a PLC are necessary to monitor and control a process. Both inputs and outputs can be categorized into two basic types: logical or continuous.

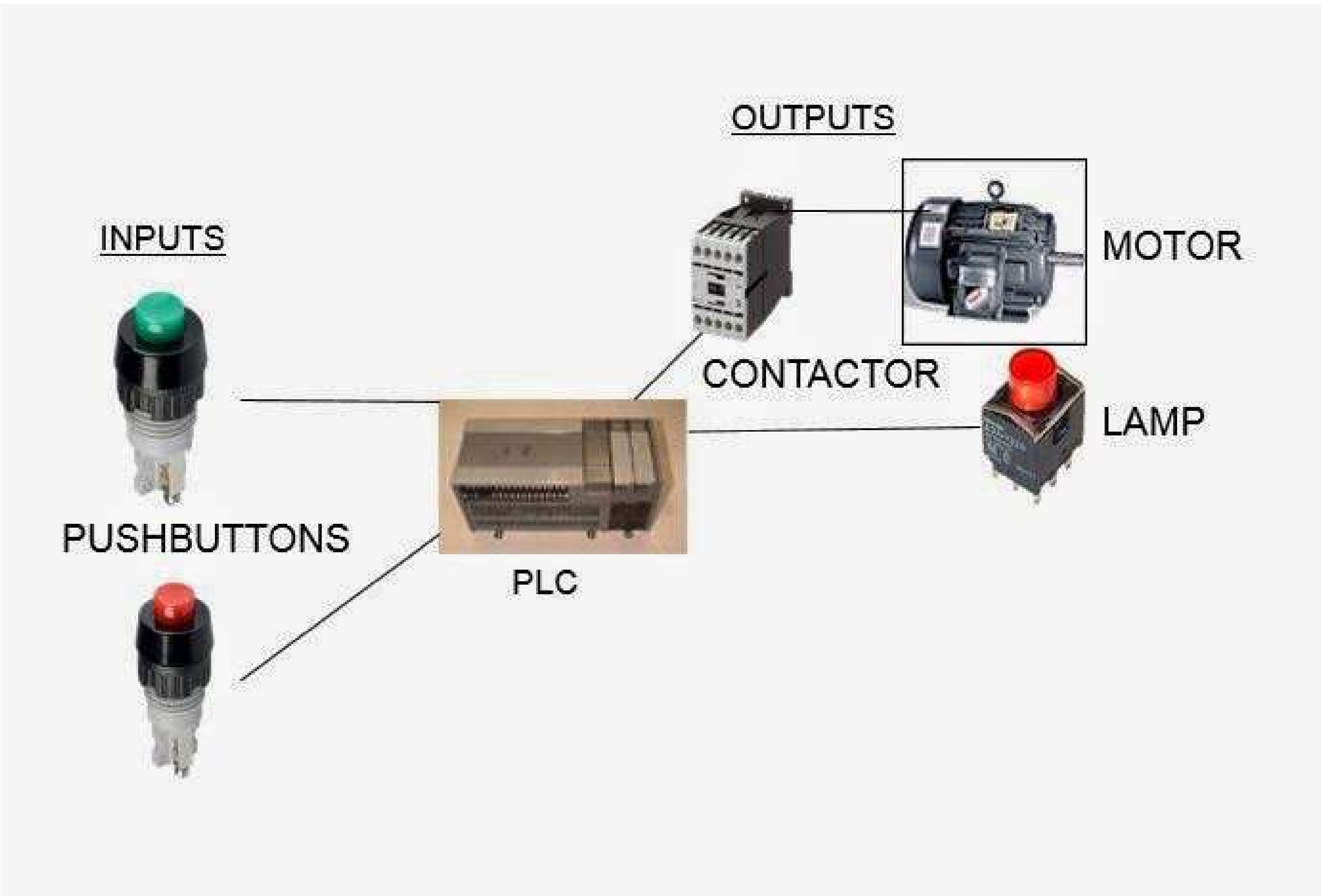
Consider the example of a light bulb:

- If it can only be turned on or off, it is logical control.
- If the light can be dimmed to different levels, it is continuous. Continuous values seem more intuitive, but logical values are preferred because they allow more certainty, and simplify control. As a result, most controls applications (and PLCs) use logical inputs and outputs for most applications.

Input module:

The input module connects the input terminals to the rest of the system. Each terminal is usually electrically isolated from the internal electronics by OPTO ISOLATORS. This is a way of passing on the status of the input (on or off) by use of a light emitting diode and phototransistor. They have the advantage of reducing the effects of spurious pulses generated from electromagnetic sources. It is also a safety feature to prevent live voltages appearing on the input lines in the event of a fault.

Internally a computer usually operates at 5 V DC. The external devices (solenoids, motor starters, limit switches, etc.) operate at voltages up to 110 V AC. The mixing of these two voltages will cause severe and possibly irreparable damage to the PLC electronics. Less obvious problems can occur from electrical noise introduced into the PLC from voltage spikes on signal lines, or from load currents flowing in AC neutral or DC return lines. Differences in earth potential between the PLC cubicle and outside plant can also cause problems.



Inputs and Outputs connected to PLC

Outputs Modules:

Outputs to actuators allow a PLC to cause something to happen in a process. A short list of popular actuators is given below in order of relative popularity.

Solenoid Valves - Logical outputs that can switch a hydraulic or pneumatic flow.

Lights - Logical outputs that can often be powered directly from PLC output boards.

Motor Starters - Motors often draw a large amount of current when started, so they require motor starters, which are basically large relays.

Servo Motors - A continuous output from the PLC can command a variable speed

or position.

Outputs from PLCs are often relays, but they can also be solid state electronics such as transistors for DC outputs or Triacs for AC outputs. Continuous outputs require special output cards with digital to analog converters.

Memory ❋

All PLCs contain both RAM and ROM in varying amounts depending upon the design of the PLC. The use of a PLC's memory is determined again by the design of the unit. However, 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.

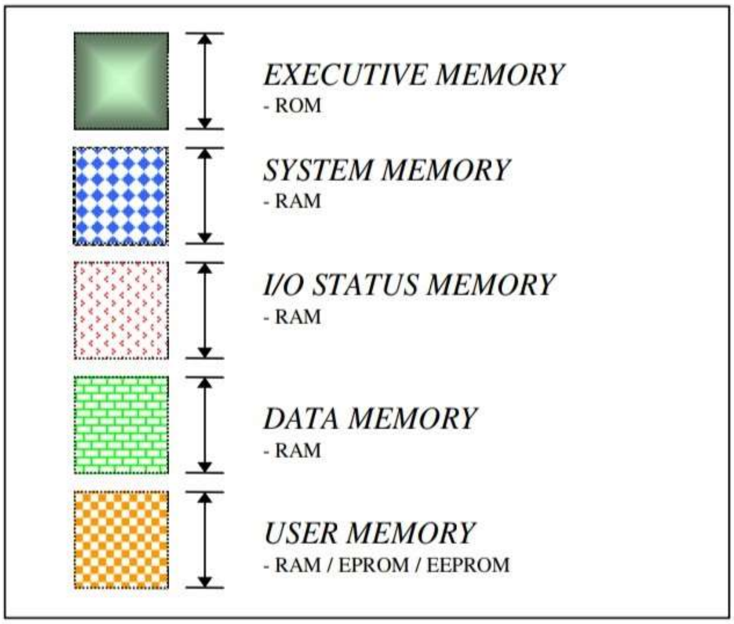


Fig. 4 : **Typical PLC memory utilization map** ❋

a. **Executive Memory**

The *operating system* or *executive memory* for the PLC is always in ROM since, 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.

b. **System memory**

In order for the operating system to function, a section of the memory is allotted for system administration. As the executive program performs its duties, it often requires a place to store intermediate results and information. A section of RAM is installed for this purpose. Normally this area is allotted for use of the operating system only and is not available to the user for programming. It might be thought of as a scratch pad for the operating system to doodle on as necessary. Some PLCs use this area for storing the information which passes between programmer and operating system, e.g. the operating system generates certain error codes store in the specific address in this area during the execution of user program which can be read by user program; or the user may also give additional information to the operating system before execution of user program by writing some codes in the specific address in this area, etc.

c. **I/O Status Memory - I/O Image Table**

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 of user program, the microprocessor scans the user program and interpret the user commands, 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 (not directly to output modules). (*Find out about input scan and output scan.*)

d. **Data Memory**

Whenever timers, counters, mathematics and process parameters are required, an area of memory must be set aside for data storage. The data storage portion of memory is allocated for the storage of such items as timers or counter preset/accumulated values, mathematics instruction data and results, and other miscellaneous data and information which will be used by any data manipulation functions in the user program.

Some manufacturers subdivide the data memory area into two sub-memories, one for fixed data and other for variable data. The fixed data portion can only be programmed via the programming device. The CPU is not permitted to place data values in this area. The variable portion of the data memory is available to the CPU for data storage.

e. **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. The user program area may be subdivided if the CPU allocates a portion of this memory area for the storage of ASCII messages, subroutine programs, or other special programming functions or routines. In the majority PLCs, the internal data storage and user program areas are located in RAM.

Several systems do offer an option that places both the user program and the fixed data storage areas in EPROM type memory. The user can develop program in RAM and run the system to ensure correct operation. Once the user is satisfied that the programming is correct, a set of EPROMs is then duplicated from the RAM. Then the user can shut down the CPU and replaces the RAM with the newly programmed EPROM. Any future change would require that the EPROMs be reprogrammed.

Input/Output Module Units

The input/output unit of PLCs handles the job of interfacing high power industrial devices to the low-power electronic circuitry that stores and executes the control program.

Most PLCs operate internally at between 5 and 15V d.c. (common TTL and CMOS voltages), whilst signal from input devices can be much greater, typically 24V d.c. to 240V a.c. at several amperes.

The I/O module units form the *interface* between the microelectronics of the programmable controller and the real world outside, and must therefore provide all necessary signal conditioning and isolation functions. This often allows a PLC to be *directly connected* to process actuators and input devices without the need for intermediate circuitry or relays.

To provide this signal conversion, programmable controllers are available with a choice of input/output units to suit different requirements. For example:

Input	**Output**
5 V (TTL level)	24 V 100 mA dc
24 V dc/ac	110 V 1 A ac
110 V ac	240 V 1 A ac (triac)
240 V ac	240 V 1 A ac (relay)

It is standard practice for all I/O channels to be electrically isolated from the controlled process, using opto-isolator circuits on the I/O modules. An opto-isolator allows small signal to pass through, but will clamp any high-voltage spikes or surges down to the same small level. This provides protection against switching transients and power-supply surges, normally up to 1500 V.

In small self-contained PLCs in which all I/O points are physically located on one casing, all inputs will be of one type (e.g. 24V) and the same for outputs (e.g. 240V triac). This is because manufacturers supply only standard function boards for economic reasons. On the other hand, modular PLCs have greater flexibility of I/O, since the user can select from several different types and combinations of input and output modules.

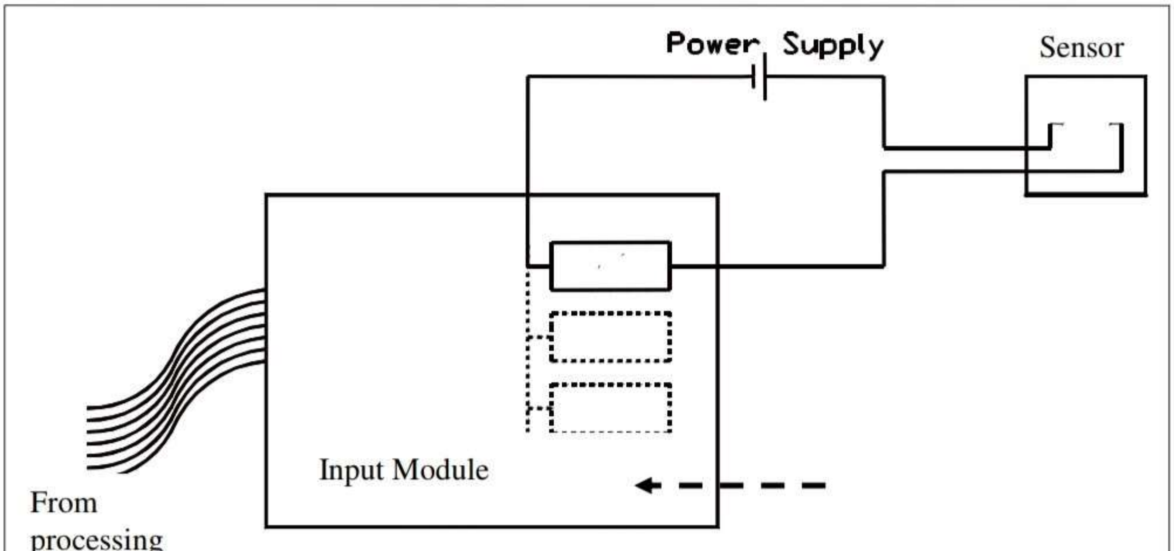


Fig. 5 : **PLC's input module connection**

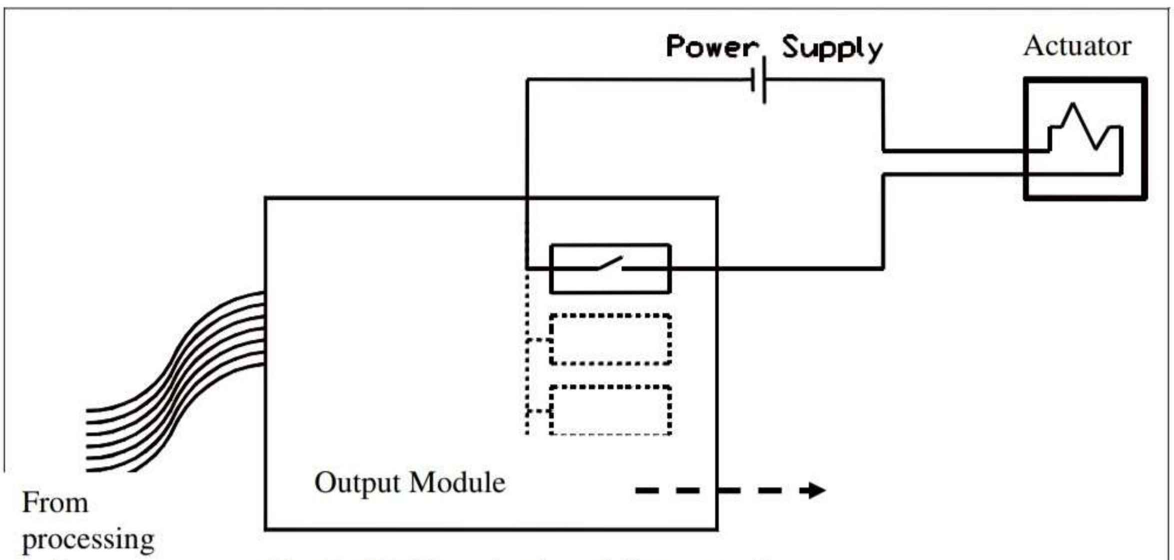
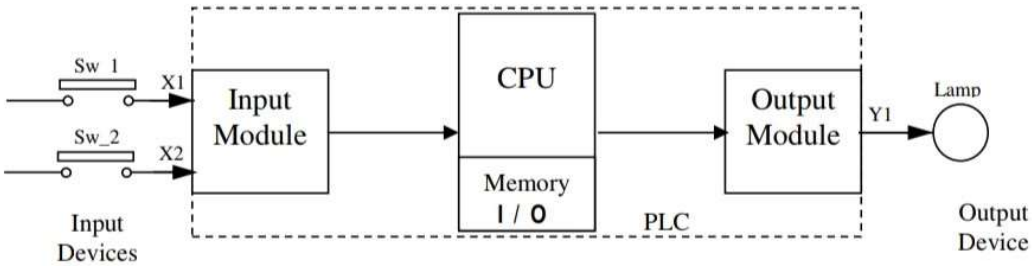


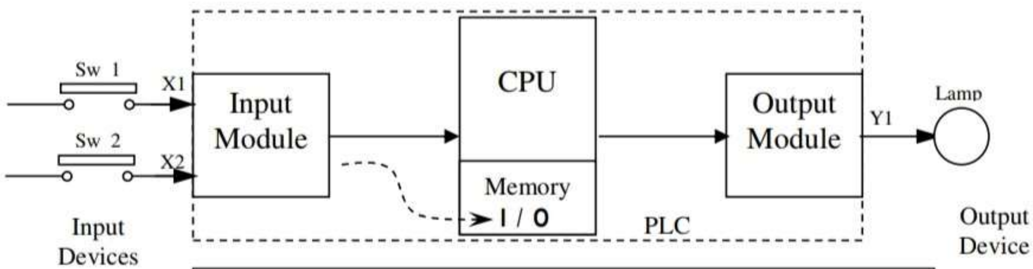
Fig. 6 : **PLC's output module connection**

In all cases the <u>input/output module units</u> are designed with the aim of <u>simplifying the connection of input devices and actuators to the PLC</u>. For this purpose, all PLCs are equipped with standard screw terminals or plugs on every I/O point, allowing the rapid and simple removal and replacement of a faulty I/O card. <u>Every input/output module point has a unique address</u> or channel number which is used during program development to specify the monitoring of an input or the activating of a particular output within the program. <u>Indication of the status of input/output channels</u> is provided by light-emitting diodes (<u>LEDs</u>) on the PLC or I/O unit, making it simple to check the operation of processed inputs and outputs from the PLC itself.

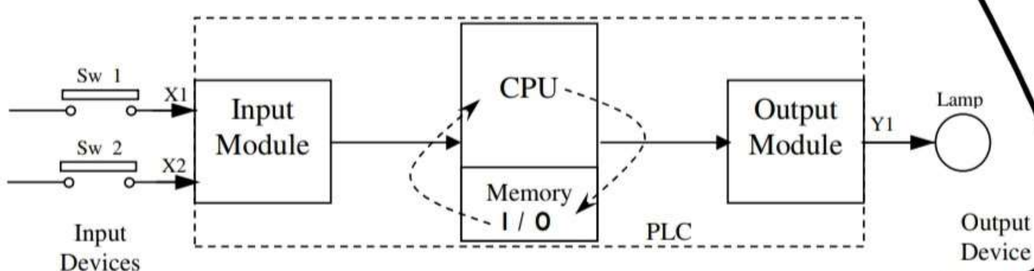
How does a PLC work ?



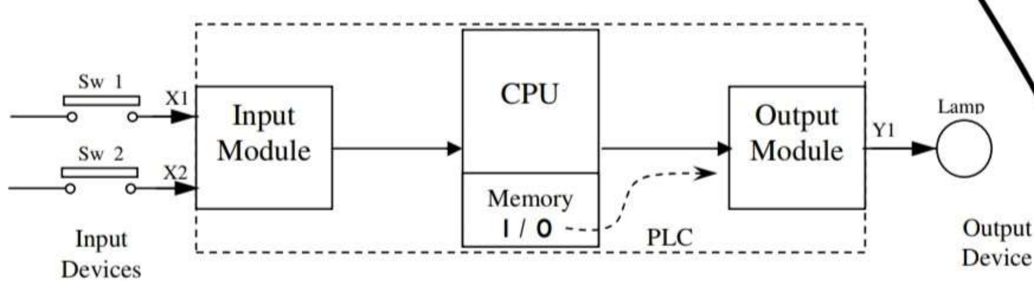
Eg. PLC Program : Sw_1 AND Sw_2 = Lamp



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

8.4 Internal Operation and Signal Processing

The CPU of the PLC executes the user-program **over and over again** when it is in the **RUN** mode. The following figure shows the entire repetitive series of events.

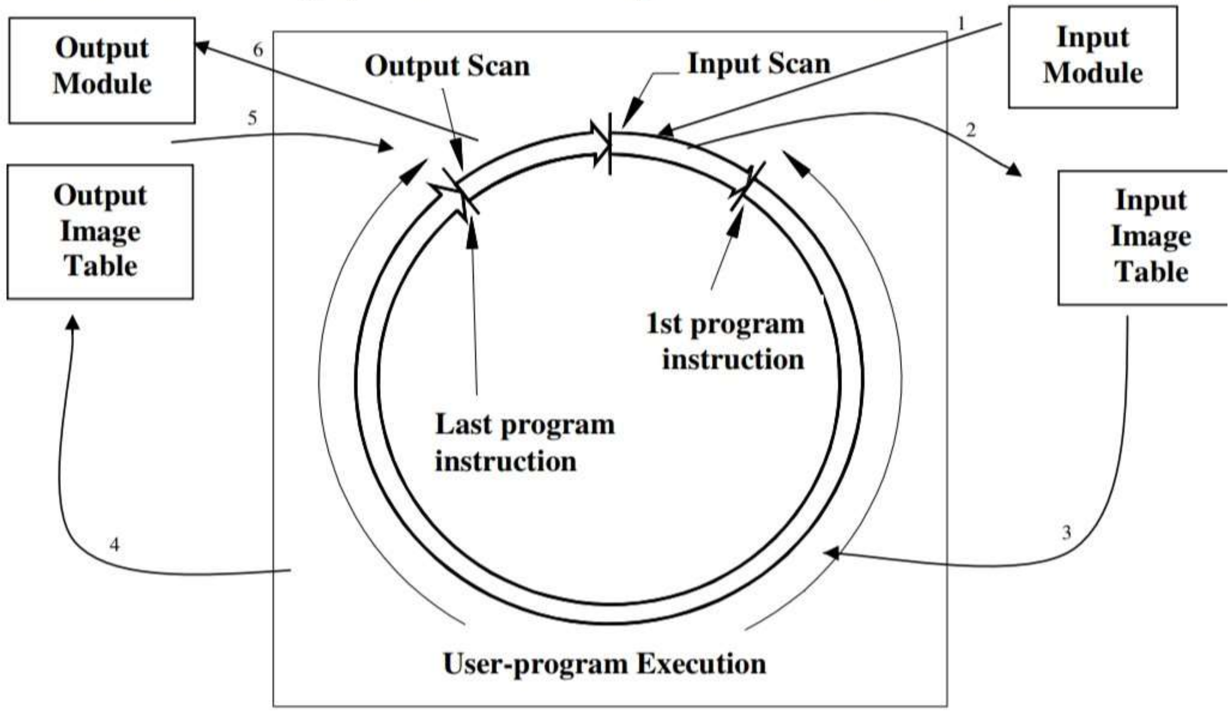


Fig. 7 : **PLC scan cycle** ✱

(a) **Input scan**

During the input scan, the **current status of every input module is stored in the input image (memory) table**, bringing it up-to-date. Thus all the status of the input devices (which in turn is connected to the input module) are updated in the input memory table.

(b) **Program scan**

Following the input scan, the CPU enters its user **program execution**, or **program scan**. The execution involves starting at the program's **first instruction**, then moving on to the second instruction and carrying out its execution sequence. This continues to the **last program instruction**. Throughout the user-program execution, the CPU continually keeps **its output image (memory) table up-to-date**.

(c) **Output scan**

During **program scan**, the output modules themselves are **not kept continually up to date**. Instead, **the entire output image table** is transferred to the output modules **during the output scan** which comes after the program execution. Thus the output devices are activated accordingly during the output scan.

Power Supply Module

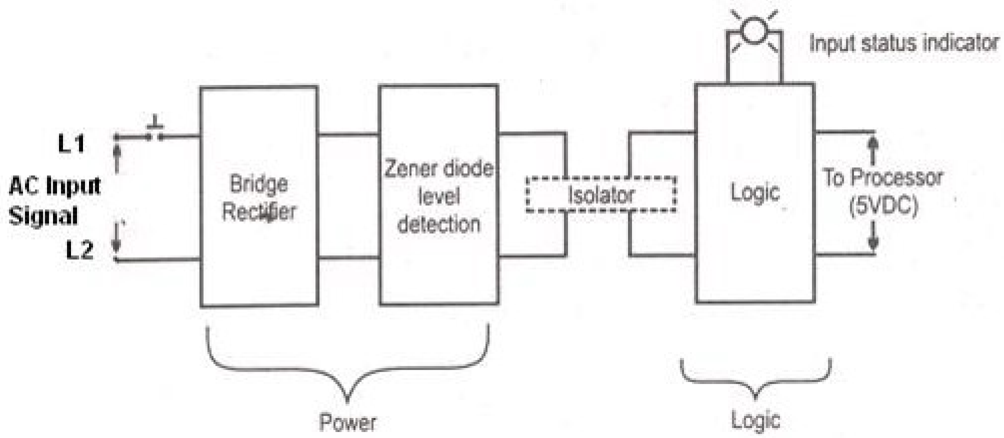
This module is used to provide the required power to the whole PLC system. It converts the available AC power to DC power which is required by the CPU and I/O module. PLC generally works on 24V DC supply. Few PLC uses an isolated power supply.

CPU Module and Memory

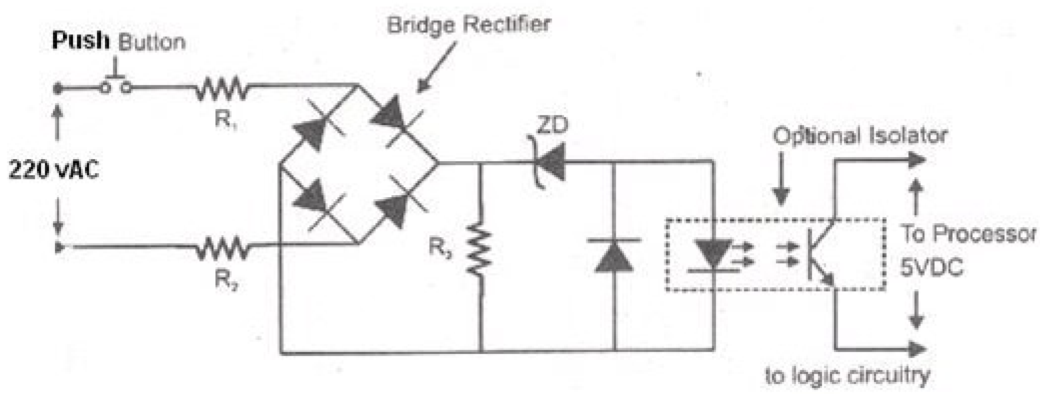
CPU module has a central processor, ROM & RAM memory. ROM memory includes operating system, driver and application program. RAM memory is used to store programs and data. CPU is the brain of PLC with an octal or hexagonal microprocessor. Being a microprocessor-based CPU, it replaces timers, relays, and counters. Two types of processors as a single bit or word processor can be incorporated with a PLC. One-bit processor is used to perform logic functions. Whereas word processors are used for processing text, numerical data, controlling and recording data. CPU reads the input data from sensors, process it and finally sends the command to controlling devices. DC power source, as mentioned in the previous discussion is required voltage signals. CPU also contains other electrical parts to connect cables used by other units.

Input and Output Module

Have you ever thought about how to sense physical parameters like temperature, pressure, flow, etc? using PLC? Of course, PLC has an exclusive module for interfacing inputs and output, which is called an input & output module. Input devices can be either start and stop push buttons, switches, etc and output devices can be an electric heater, valves, relays, etc. I/O module helps to interface input and output devices with a microprocessor. The input module of PLC is explained in the below figure.



PLC Input Module



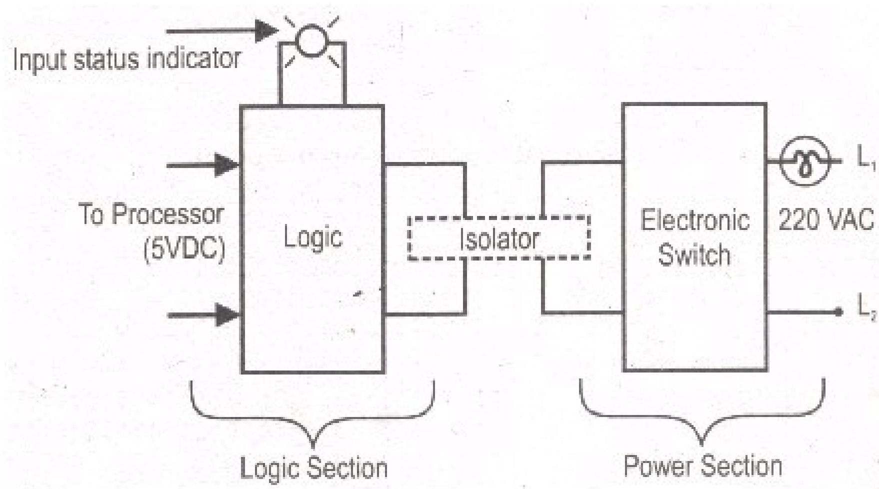
Circuit Diagram of PLC Input Module

The input module of PLC does four main functions.

1. Input module interface receives the signal from process devices at 220 V AC
2. Converts the input signal to 5 V DC that can be used by PLC
3. Isolator block is used to isolate/prevent PLC from undergoing fluctuation
4. After which the signal is sent to the output end i.e the PLC

There are two main sections in the input module namely power section and logical section. Both the sections are electrically isolated from each other. Initially push button is closed. So, 220 V AC supply is given to the bridge circuit through the resistors R1 and R2. The bridge rectifier is used to convert the AC signal into DC and zener diode is used to provide low voltage supply to LED. When the light from LED falls on the phototransistor, it works in the conduction region. Finally, 5V DC supply is given to the processor.

The output module of PLC works similar to the input module but in the reverse process. It interfaces the output load and processor. So here the first section would be logic session and power section comes next. The working of the output module is shown in the below figure



PLC Output Module

So, here when the logic high signal is generated from the processor, LED will turn ON and allow the light to fall on a phototransistor. When the transistor goes to conduction region, it generates a pulse to the gate of the triac. Isolator block is used to isolate the logic section and control section.