Industrial Automation MKT4152

Introduction to
Programmable Logic Controllers
(PLC)

Industrial Automation
Course Overview

- Feedback control.

- Microcontrollers and Micro-computers.

- Programmable Logic Controllers (PLCs) for Industrial Automation.

- Hardware and architecture of PLCs and Memory

- Operating System of PLC and PLC Programming Techniques.

- Being able to use Timer, Counters and Copying and Shifting Data

- Data Comparison, BCD and Binary Calculations, Transformation.

- Logic Commands, Subroutines, Special Functions and Commands.

- PLC Compatible Terminals and Drivers.

- PLC Network Systems and Structures

- Analog Signal Acquisition

- Digital Bus Communication – CAN, CANopen, Modbus, EtherCat, …..

Introduction to
Programmable Logic Controllers
(PLC)

The Need for PLCs

- Hardwired panels were very time consuming to wire, debug and change.

- GM identified the following requirements for computer controllers to replace hardwired panels.
  - Solid-state not mechanical
  - Easy to modify input and output devices
  - Easily programmed and maintained by plant electricians
  - Be able to function in an industrial environment

The First Programmable Logic Controllers (PLCs)

- Introduced in the late 1960's

- Developed to offer the same functionality as the existing relay logic systems

- Programmable, reusable and reliable
  - Could withstand a harsh industrial environment
  - They had no hard drive, they had battery backup
  - Could start in seconds
  - Used Ladder Logic for programming

Programmable Logic Controller

- A programmable logic controller (PLC) is a specialized computer used to control machines and process.

- It uses a programmable memory to store instructions and specific functions that include On/Off control, timing, counting, sequencing, arithmetic, and data handling

Advantages of PLC Control Systems

- Flexible
- Faster response time
- Less and simpler wiring
- Solid-state - no moving parts
- Modular design - easy to repair and expand
- Handles much more complicated systems
- Sophisticated instruction sets available
- Allows for diagnostics "easy to troubleshoot"
- Less expensive

Advantages of a PLC Control System

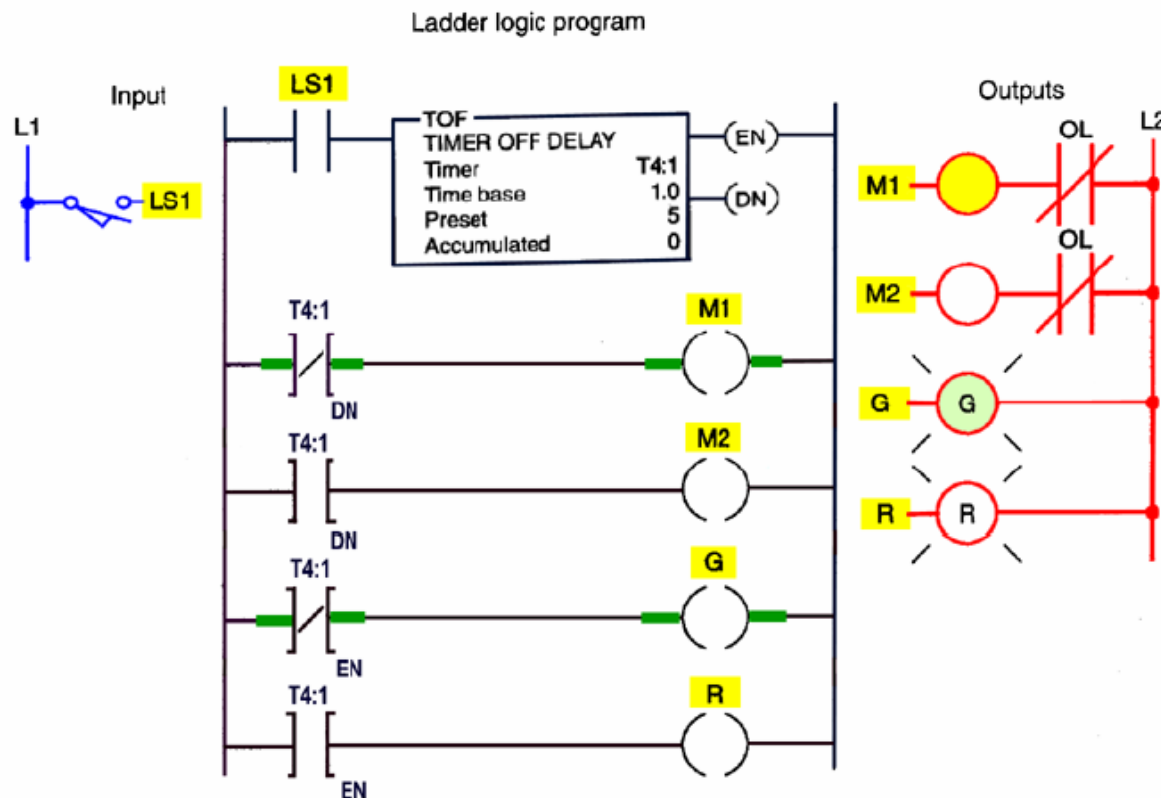Eliminates much of the hard wiring that was associated with conventional relay control circuits.
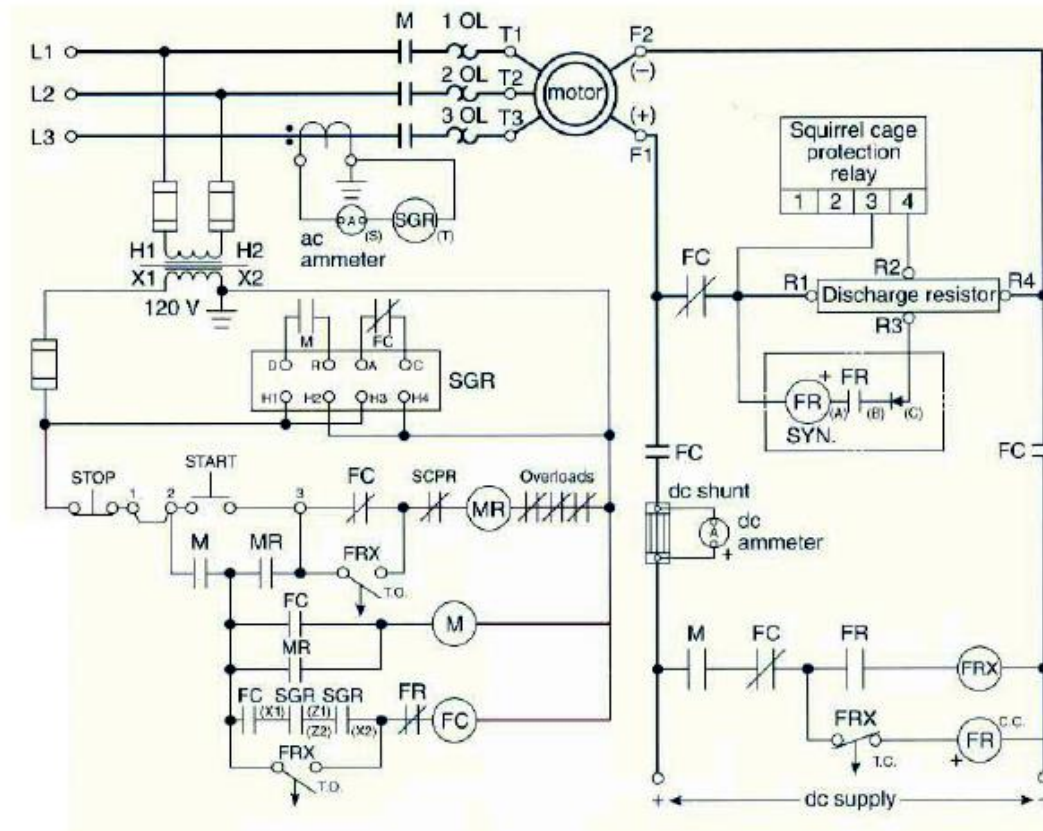
The program takes the place of much of the external wiring that would be required for control of a process.

Advantages of a PLC Control System

Increased Reliability:
Once a program has been written and tested it can be downloaded to other PLCs.

Ladder logic program

Since all the logic is contained in the PLC's memory, there is no chance of making a logic wiring error.

Conversely ......

Advantages of a PLC Control System

More Flexibility:
Original equipment manufacturers (OEMs) can provide system updates for a process by simply sending out a new program.

Wood

Cutter control

Rotary encoder

Pulses

Programmable controller
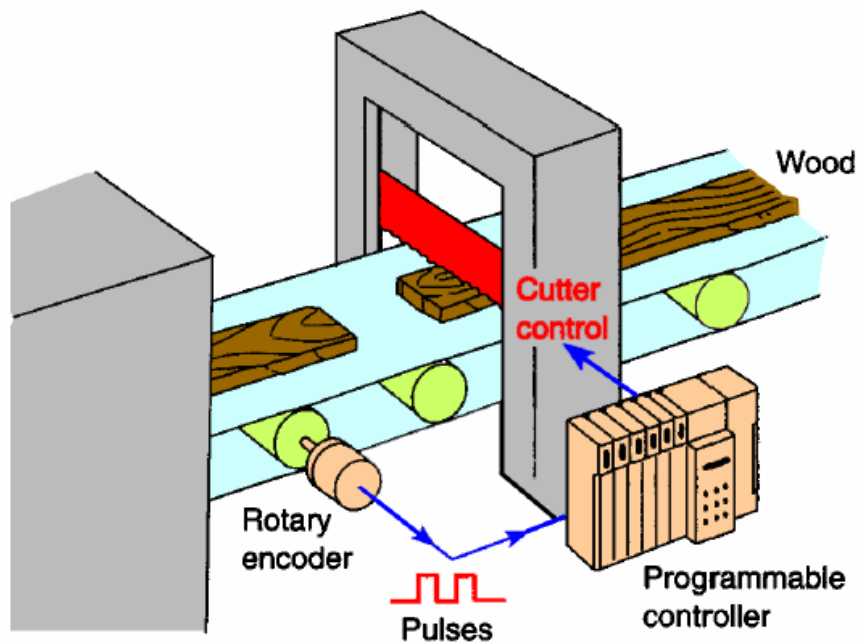
It is easier to create and change a program in a PLC than to wire and rewire a circuit. End-users can modify the program in the field.

Advantages of a PLC Control System

Lower Costs:

Originally PLCs were designed to replace relay control logic. The cost savings using PLCs have been so significant that relay control is becoming obsolete, except for power applications.
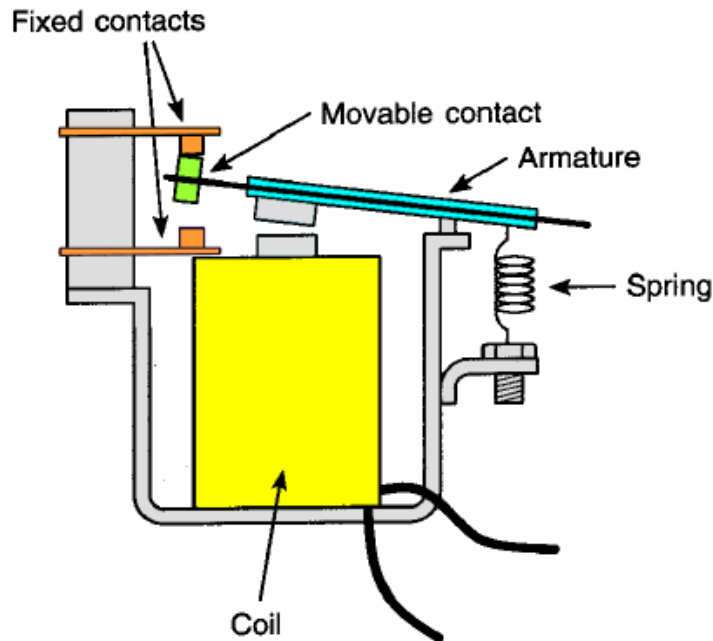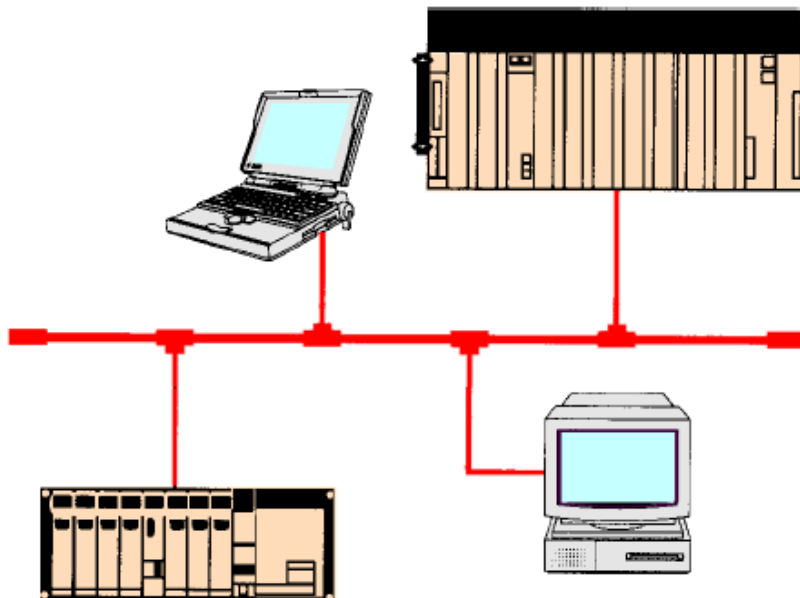

Generally, if an application requires more than about 6 control relays, it will usually be less expensive to install a PLC.

Advantages of a PLC Control System

Communications Capability:
A PLC can communicate with other controllers or computer equipment.

They can be networked to perform such functions as: supervisory control, data gathering, monitoring devices and process parameters, and downloading and uploading of programs.

Advantages of a PLC Control System

Faster Response Time:
PLCs operate in real-time which means that an event taking place in the field will result in an operation or output taking place.

Counting the number of tea bags

Counter

Photoelectric sensor

Cylinder

TEA
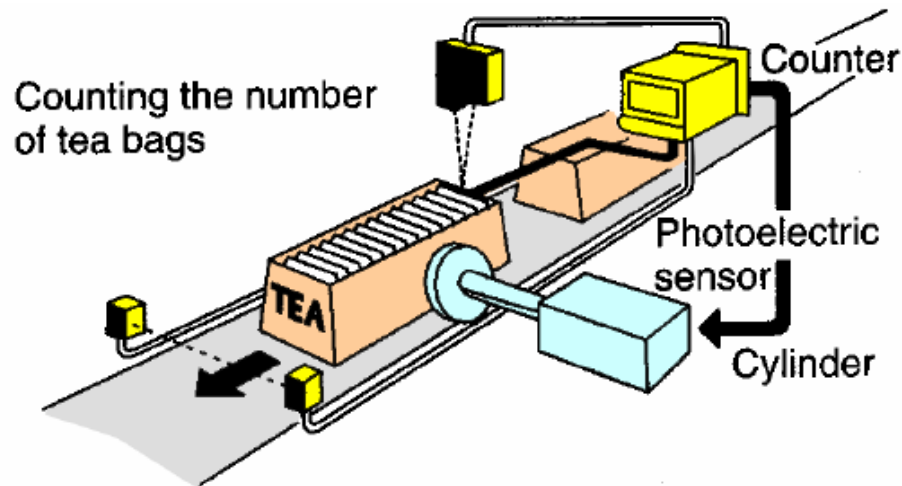
Machines that process thousands of items per second and objects that spend only a fraction of a second in front of a sensor require the PLC's quick response capability.
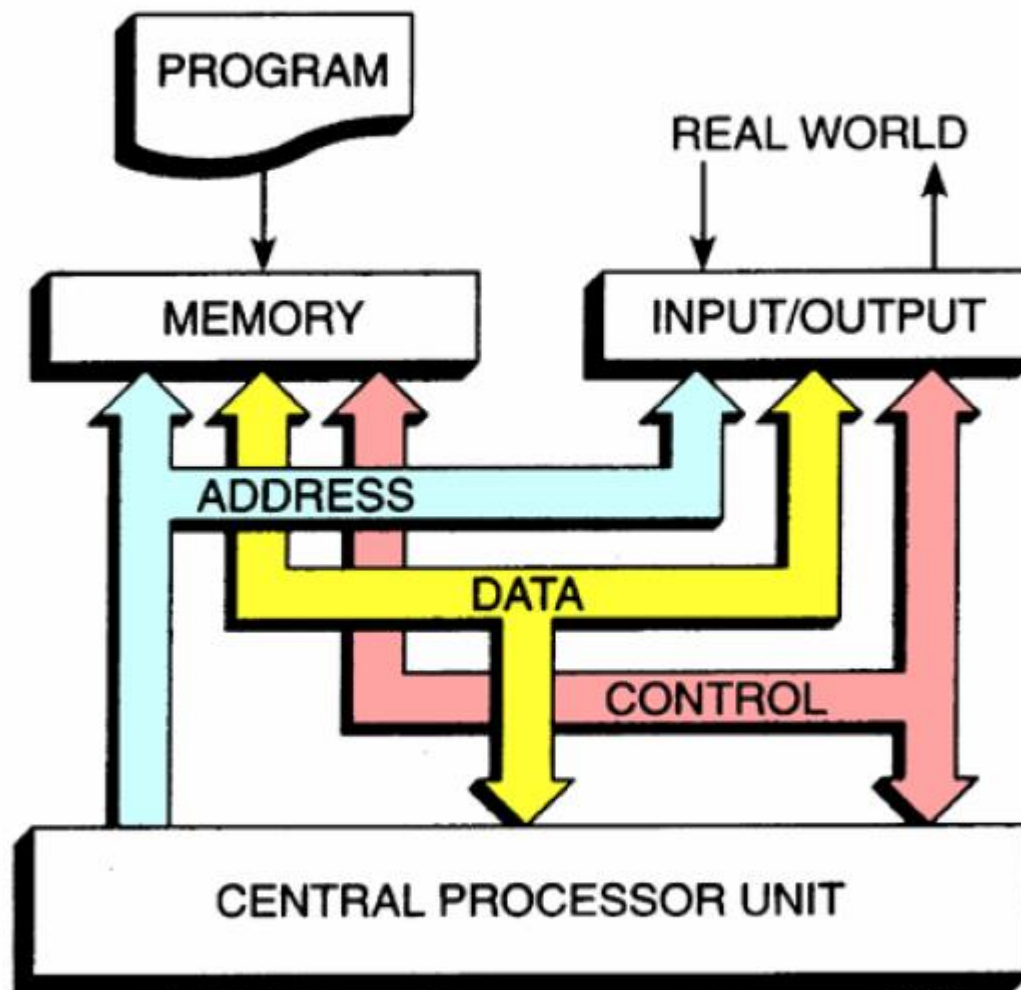
Advantages of a PLC Control System

Easier To Troubleshoot:
PLCs have resident diagnostic and override functions allowing users to easily trace and correct software and hardware problems.
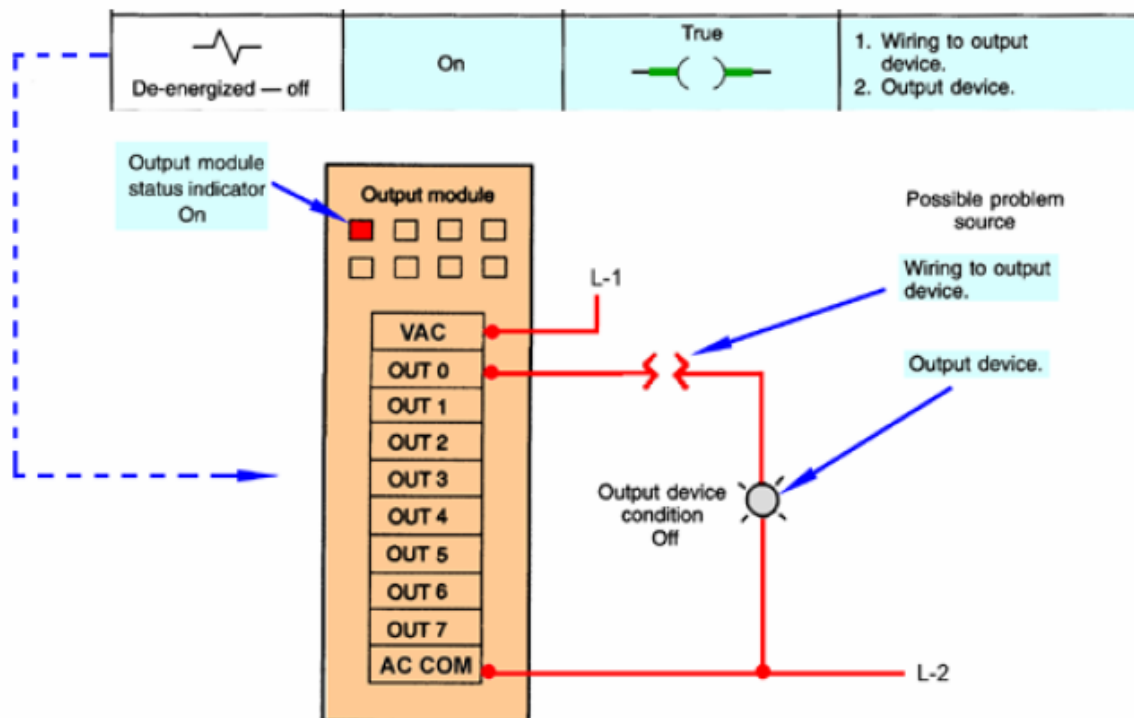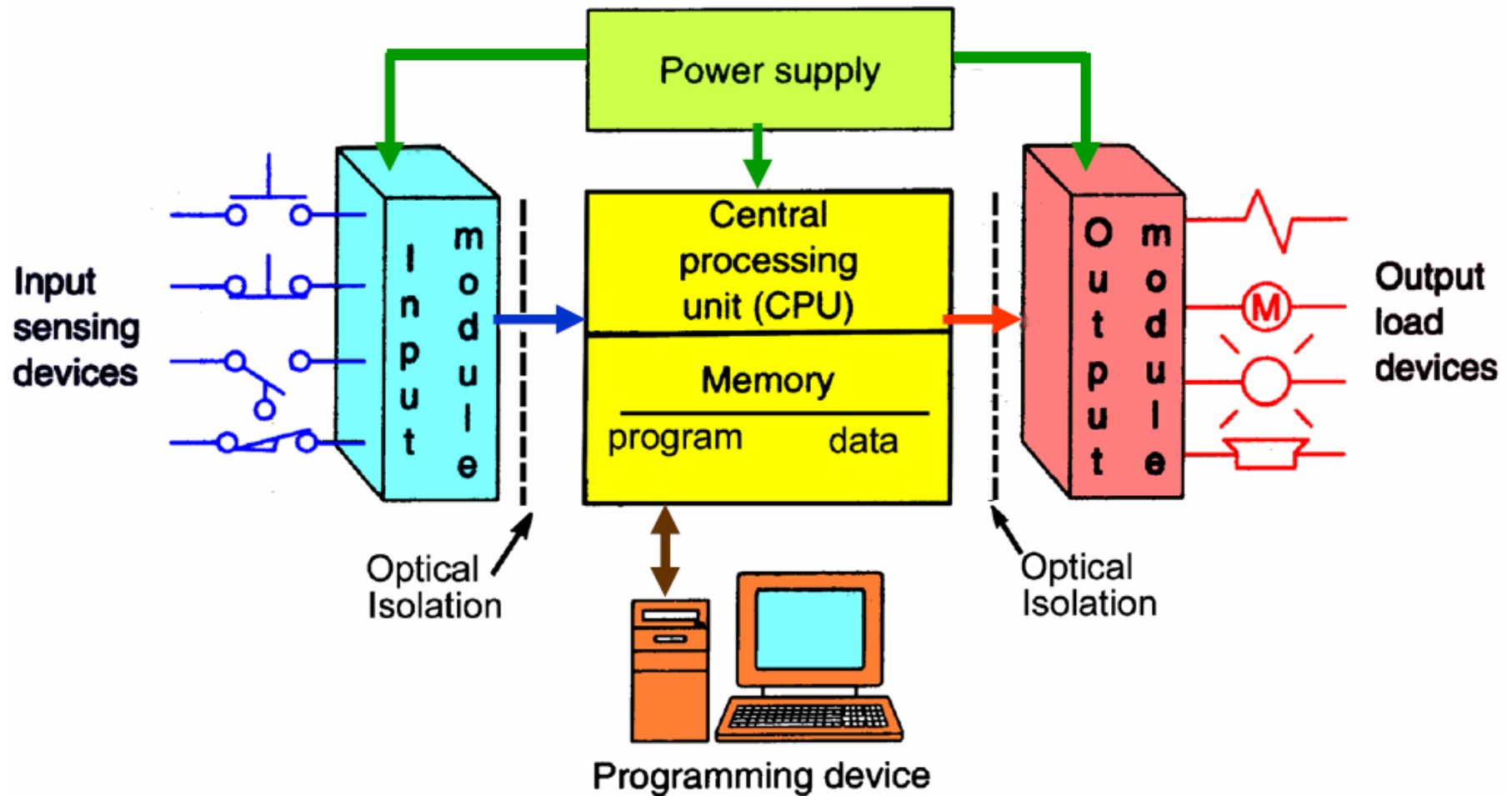
The control program can be watched in real-time as it executes to find and fix problems

PLC Architecture

The structure of a PLC is based on the same principles as those employed in computer architecture.

PLC System

Input sensing devices

Optical Isolation

Input module

Power supply

Central processing unit (CPU)

Memory

program   data

Output module

Optical Isolation

Output load devices

Programming device

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.

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.

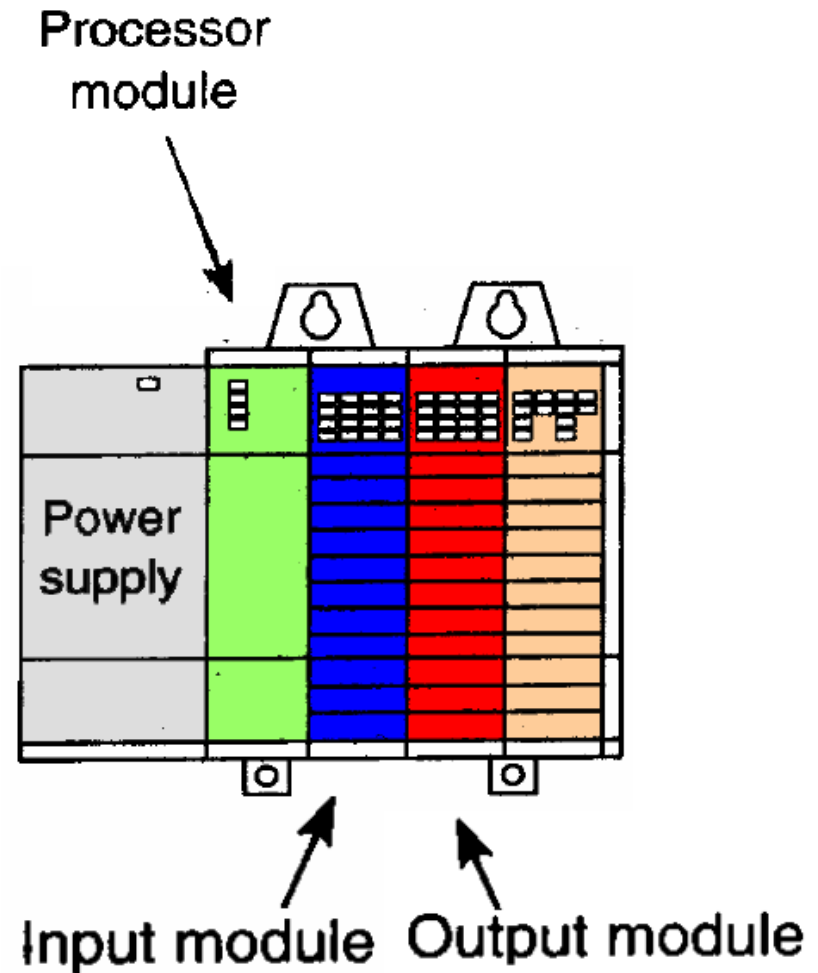- Lower in cost – but lacks flexibility.
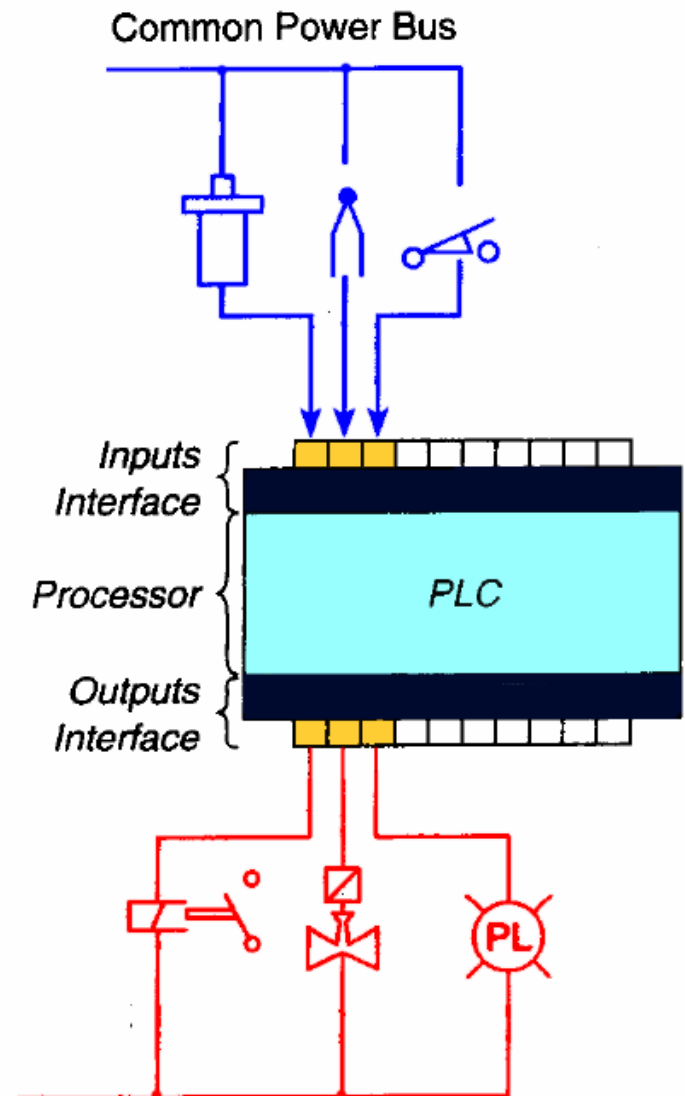
I/O Configurations

Modular I/O

Is divided by compartments into which separate modules can be plugged.

This feature greatly increases your options and the unit's flexibility. You can choose from all the modules available and mix them in any way you desire.

Processor module

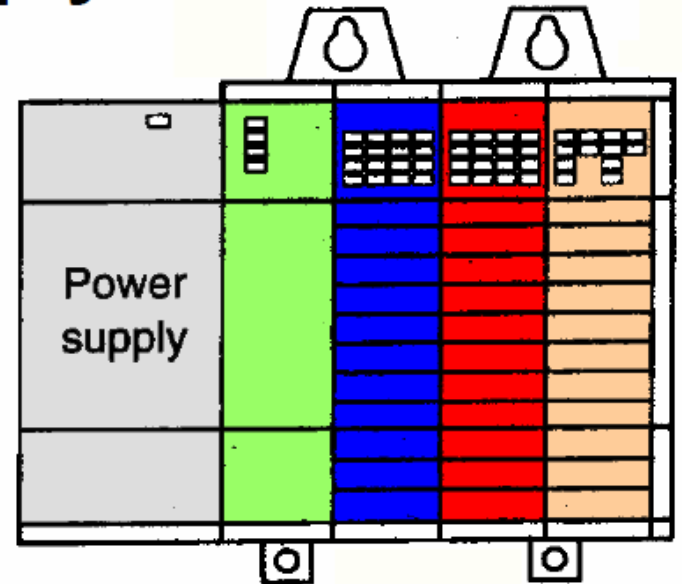Power supply

Input module   Output module

I/O Configurations

Modular I/O

When a module slides into the rack,
it makes an electrical connection with a series of
contacts - called the *backplane*. The backplane
is located at the rear of the rack.
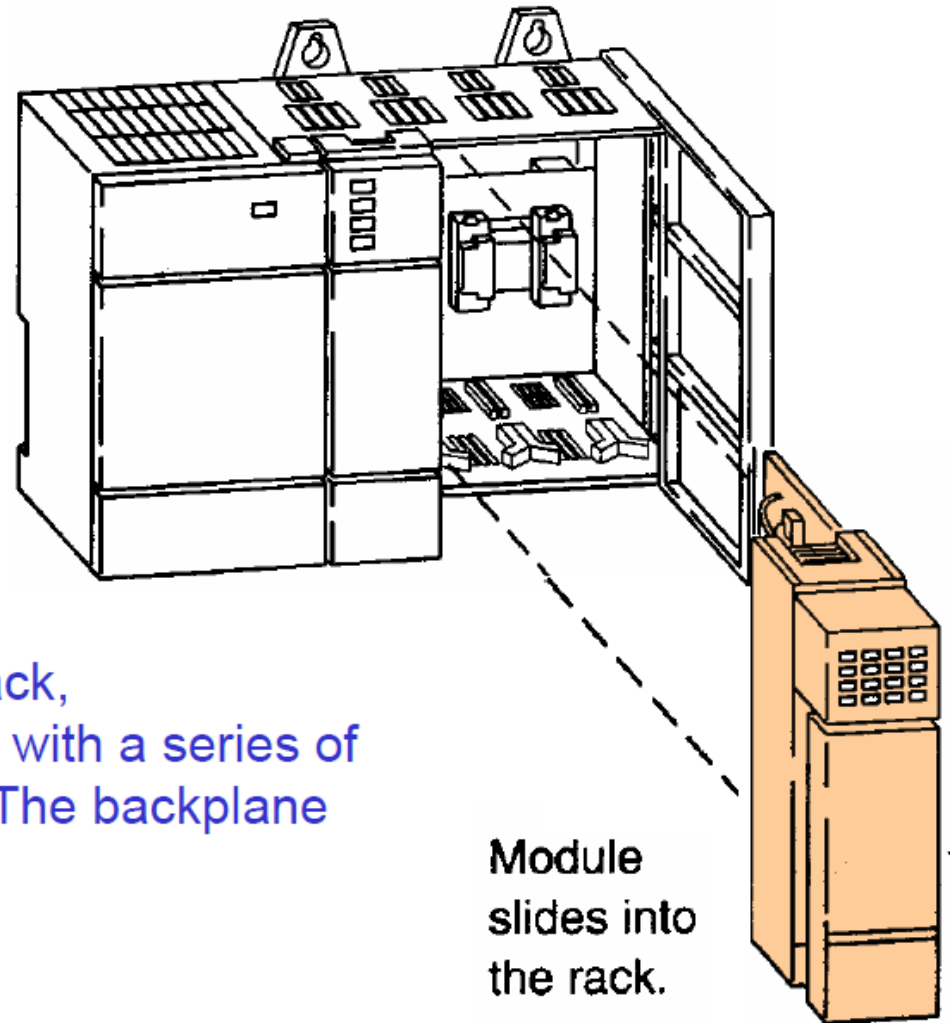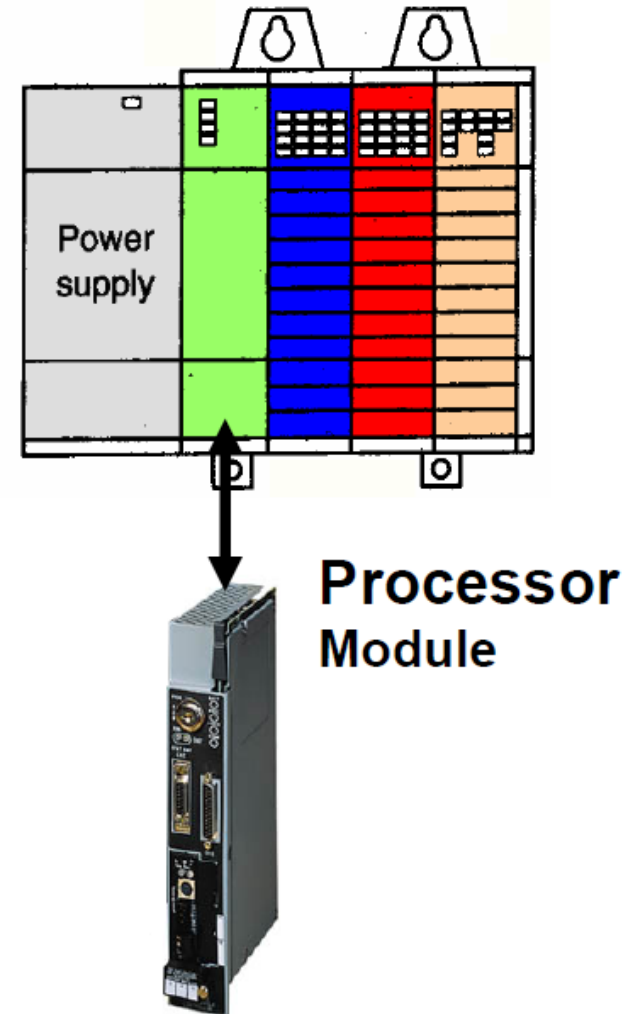
Module
slides into
the rack.

Power Supply

- Supplies DC power to other modules that plug into the rack.

- In large PLC systems, this power supply does not normally supply power to the field devices.

- In small and micro PLC systems, the power supply is also used to power field devices.

Processor (CPU)

- Is the "brain" of the PLC.

- Consists of a microprocessor for implementing the logic, and controlling the communications among the modules.

- Designed so the desired circuit can be entered in relay ladder logic form.

- The processor accepts input data from various sensing devices, executes the stored user program, and sends appropriate output commands to control devices.

Processor
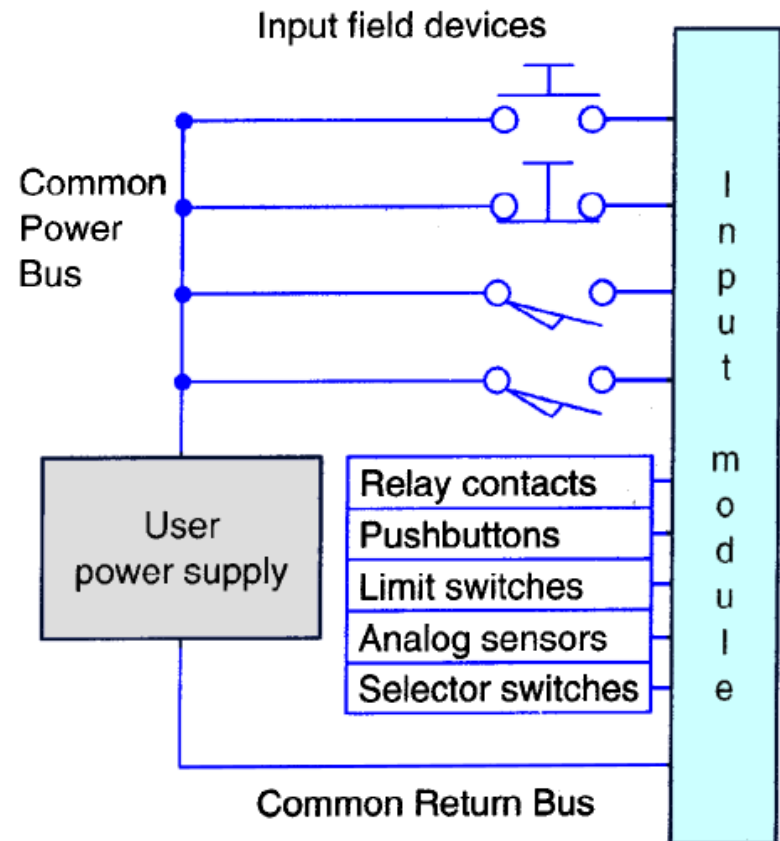**Module**

I/O Section

Consists of

- Input Modules

- Output Modules
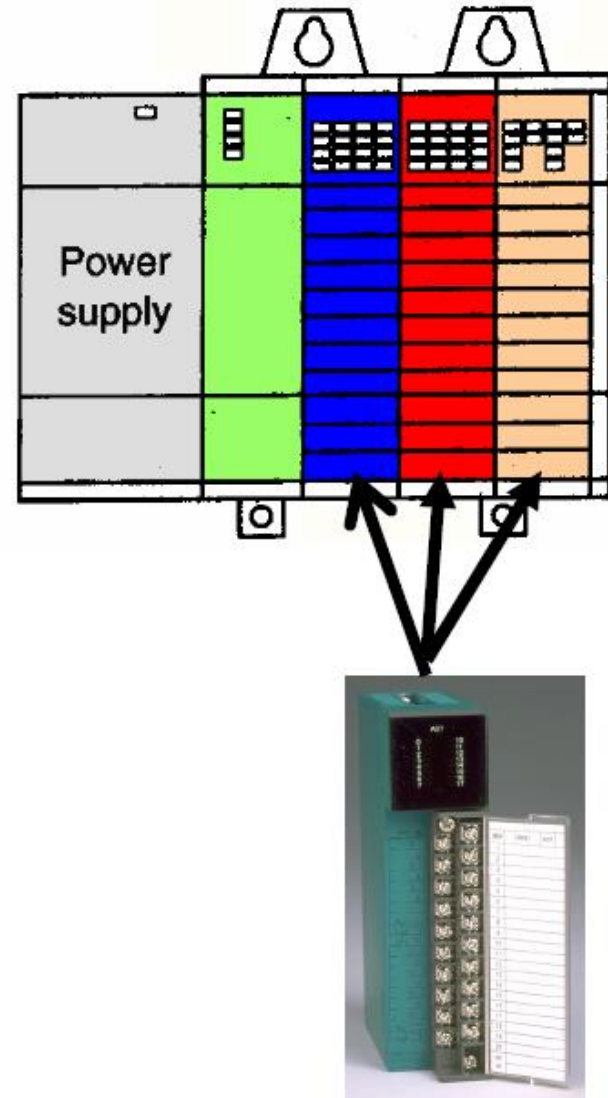
I/O Section

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

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

Programming Device

PC with appropriate software
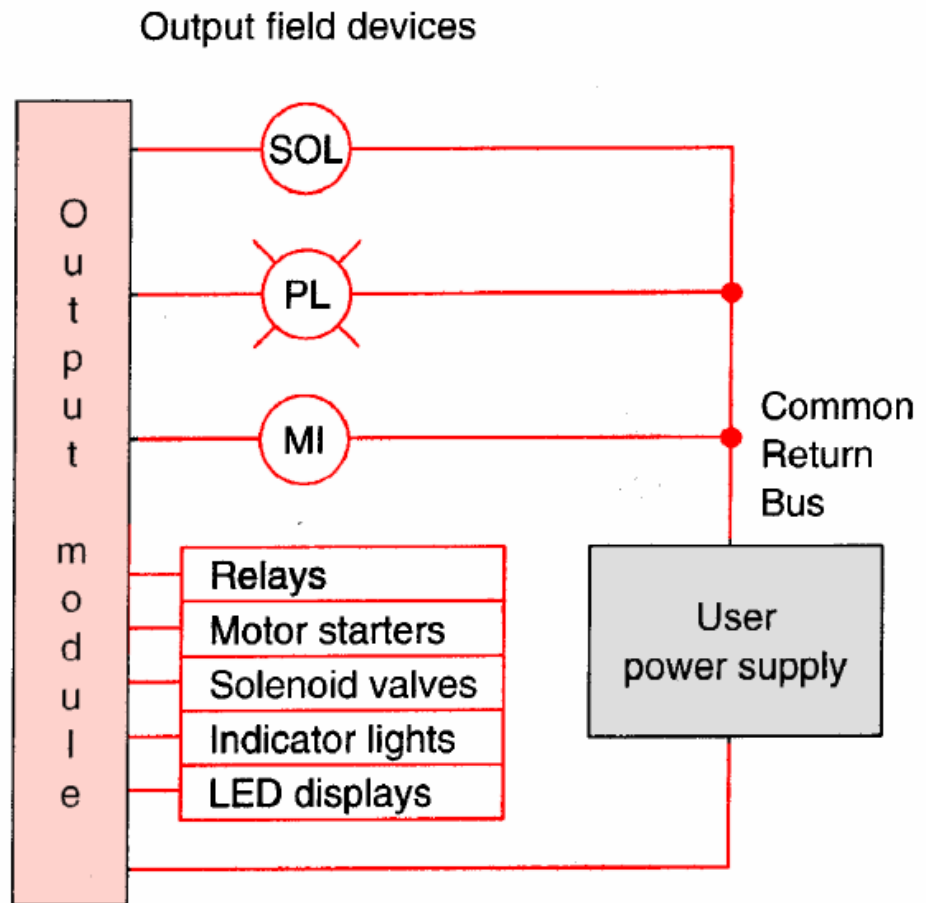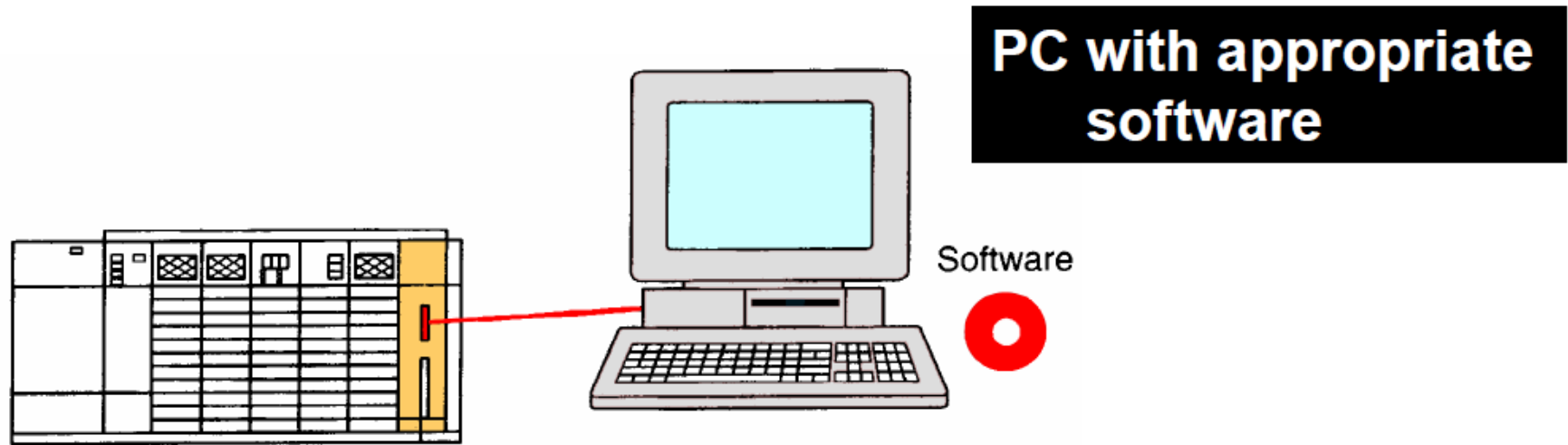
Software

- 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
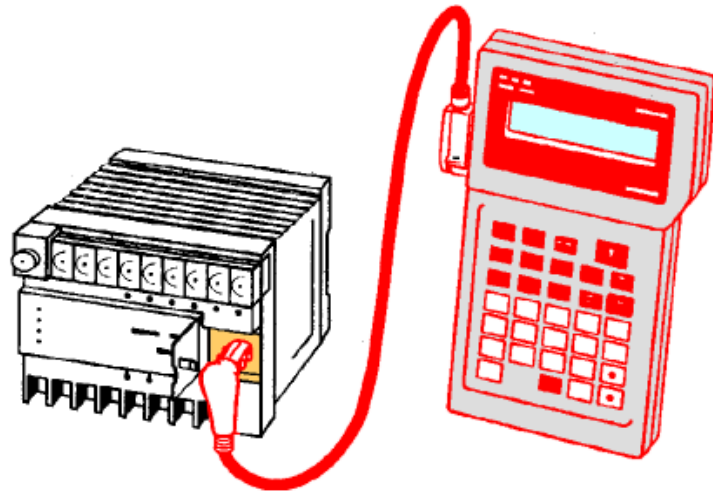
Programming Device

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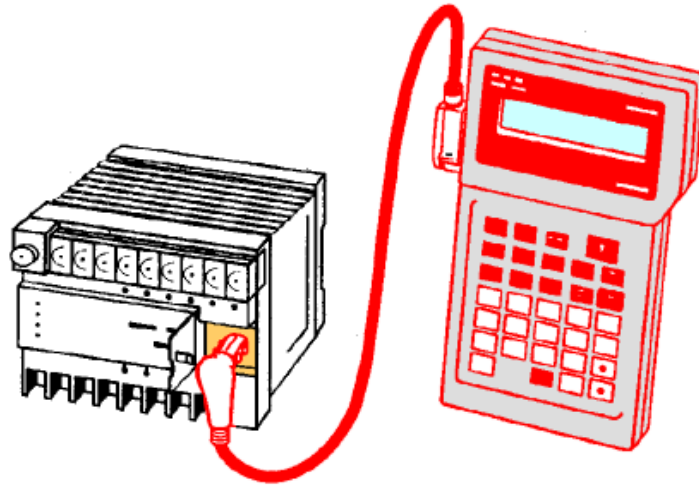
- Hand-held programming devices are sometimes used to program small PLCs

- 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.

PLC Mixer Process Control Problem

Mixer motor to automatically
stir the liquid in the vat
when the temperature and
pressure reach preset values

Alternate manual
pushbutton control
of the motor to be
provided

The temperature and
pressure sensor switches
close their respective contacts when conditions reach
their preset values

Motor

Process vat

Pressure
sensor
switch

Temperature
sensor switch

Manual pushbutton station
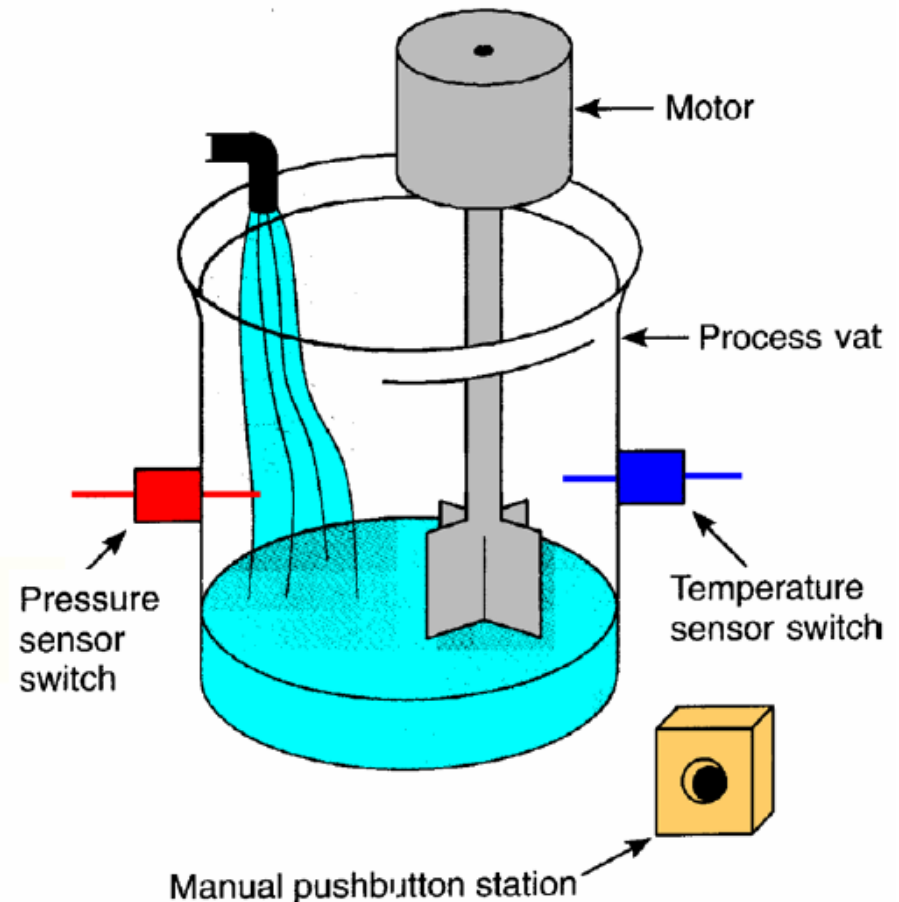
Process Control Relay Ladder Diagram
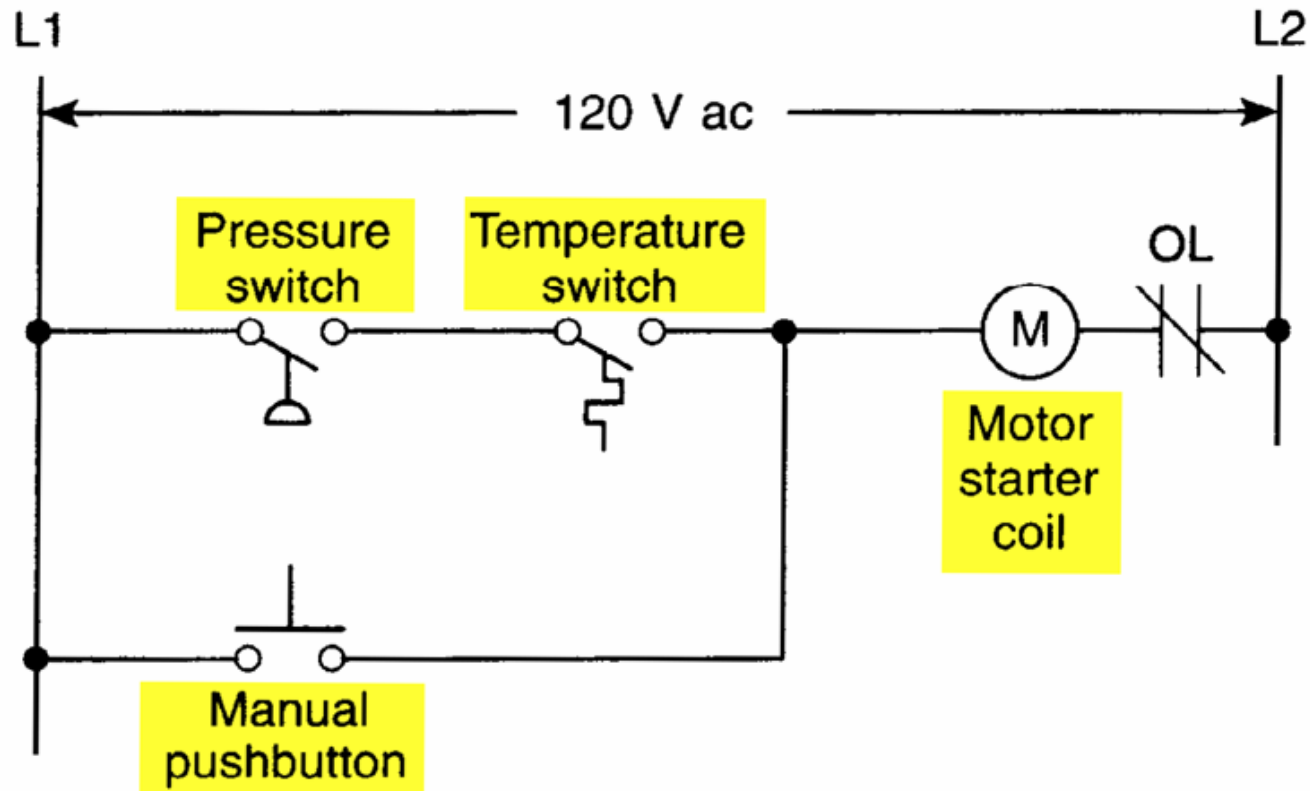
Motor starter coil is energized when both the pressure and temperature switches are closed or when the manual pushbutton is pressed
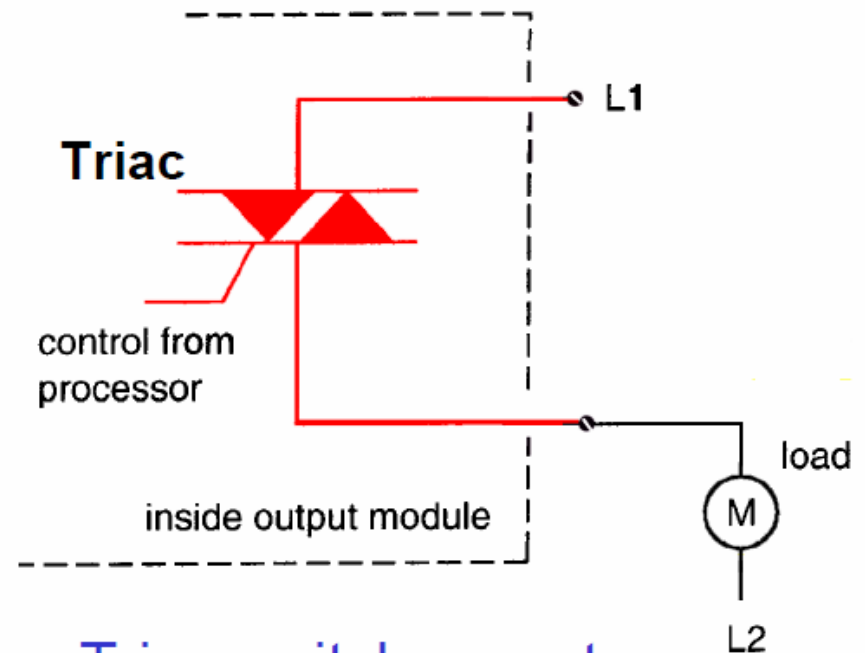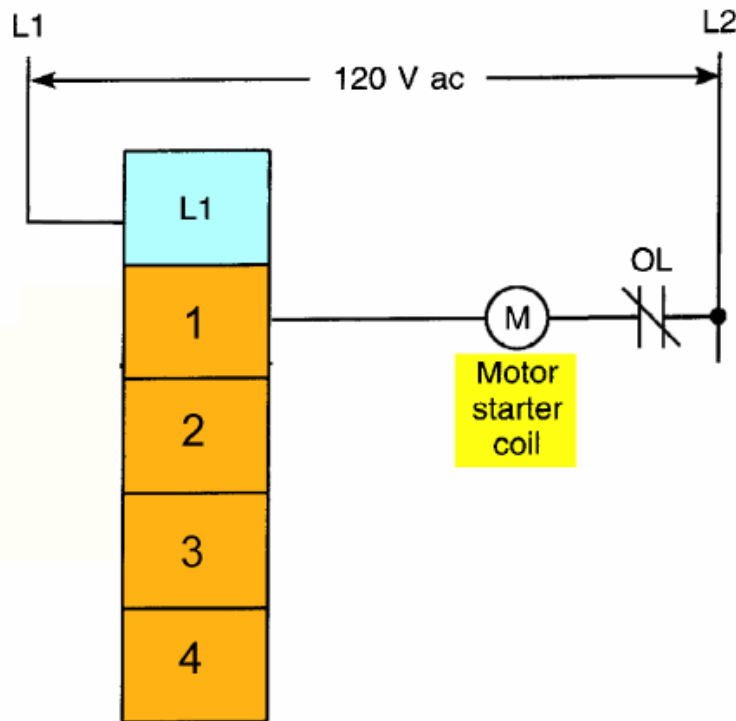
PLC Input Module Connections

- The same input field devices are used

- These devices are wired to the input module according to the manufacturer's labeling scheme
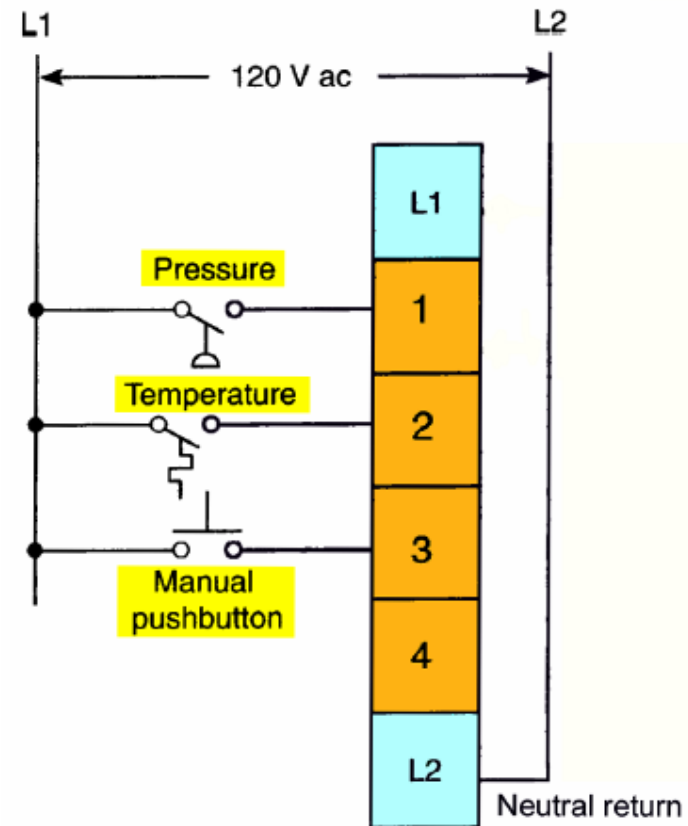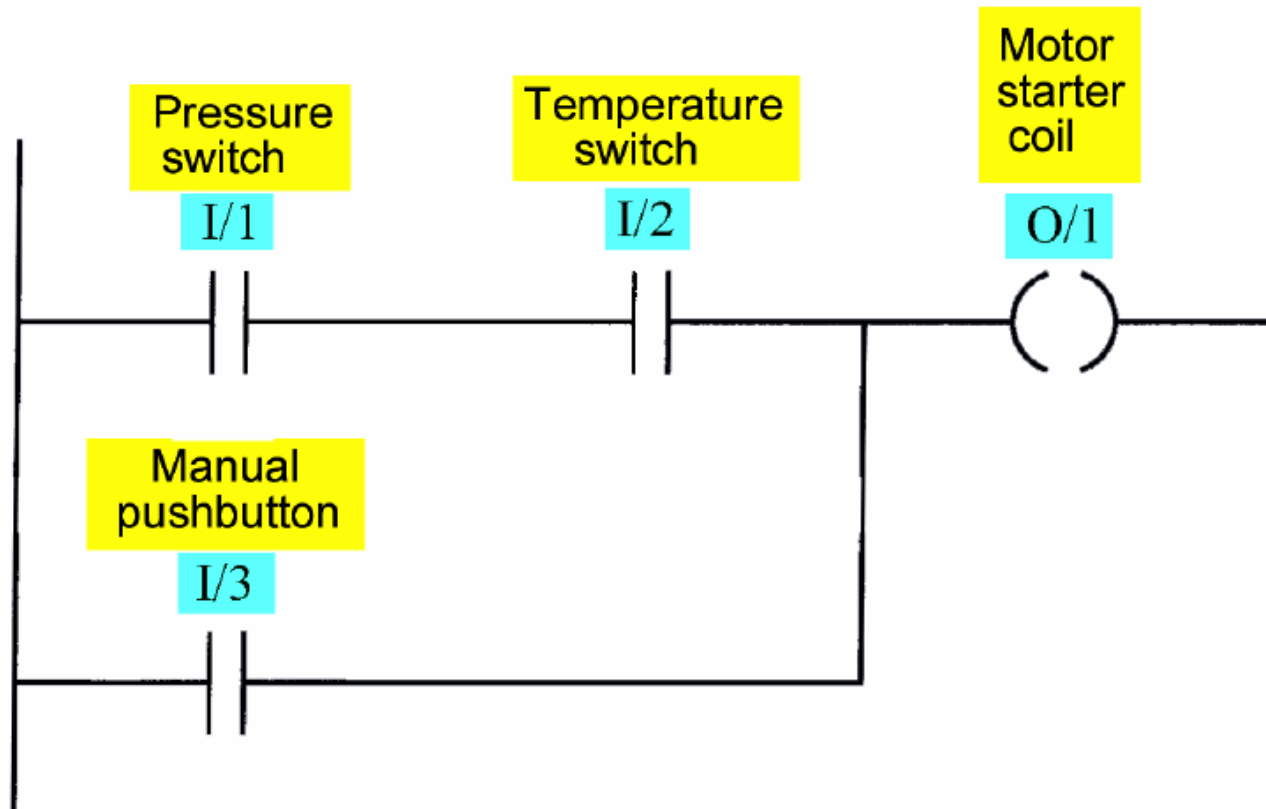
PLC Output Module Connections

Same output field device is used and wired to the output module

120 V ac

L1
L2

L1

1

2

3

4

OL

M

Motor starter coil

Triac

control from processor

inside output module

L1

load

M

L2

Triac switches motor ON and OFF in accordance with the control signal from the processor
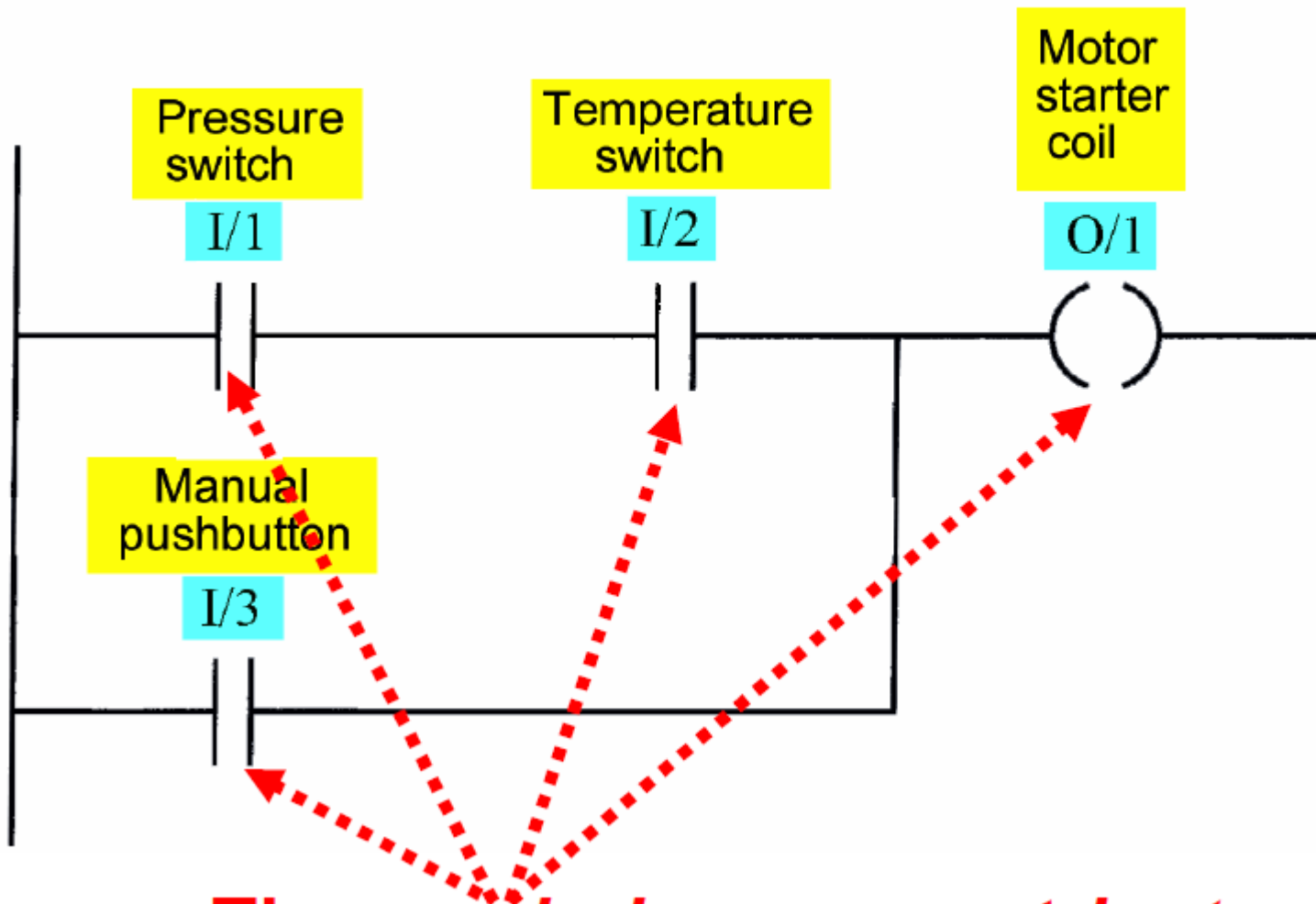
PLC Ladder Logic Program

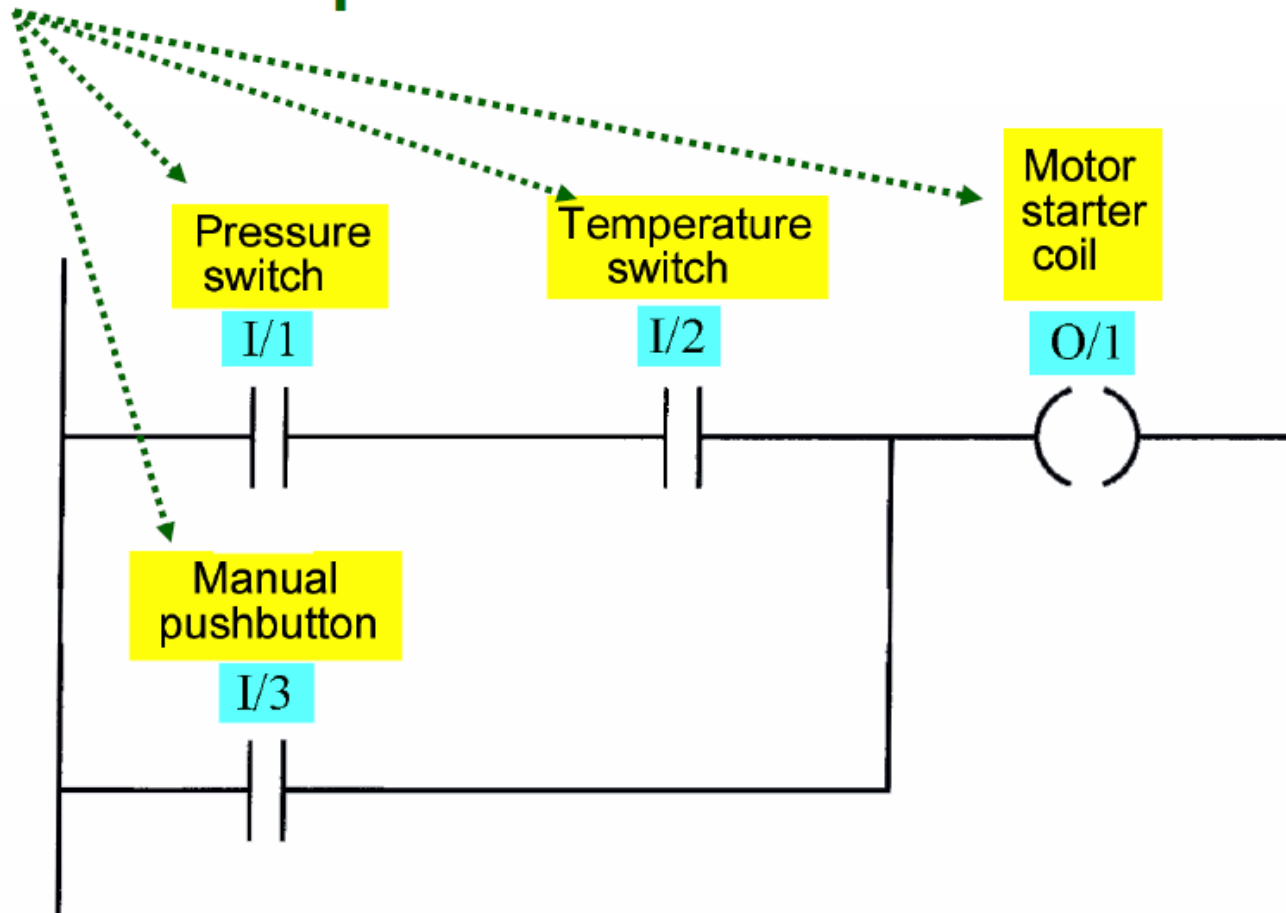- The format used is similar to that of the hard-wired relay circuit
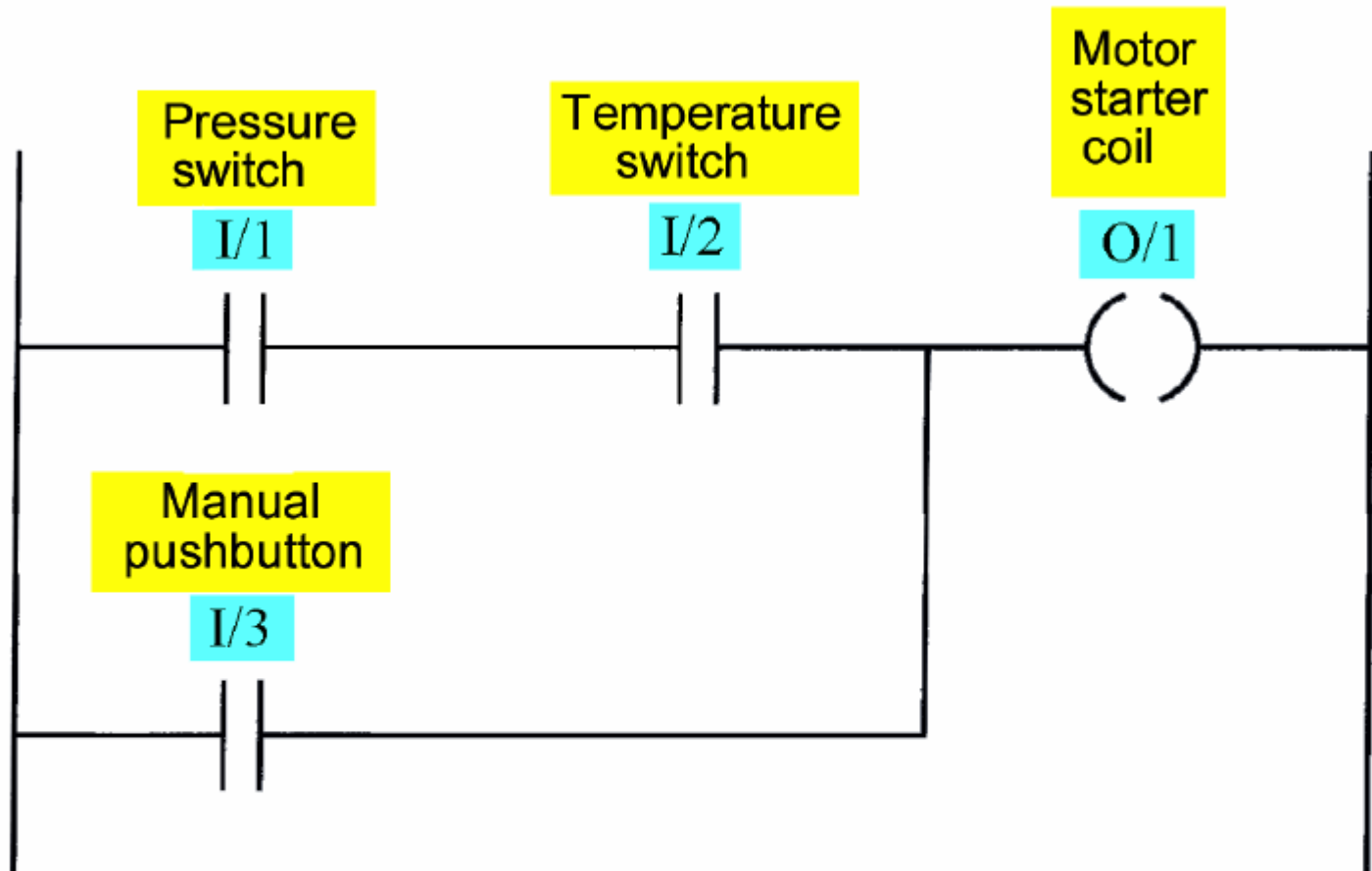
PLC Ladder Logic Program

The *symbols* represent *instructions*

PLC Ladder Logic Program

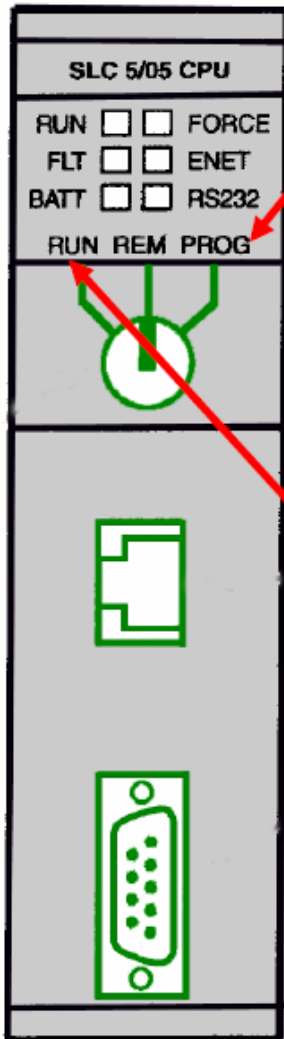## The *numbers* represent *addresses*

PLC Ladder Logic Program

- I/O address format will differ, depending on the PLC manufacturer. You give each input and output device an address. This lets the PLC know where they are physically connected

Entering And Running The PLC Program

SLC 5/05 CPU

RUN ☐ ☐ FORCE
FLT ☐ ☐ ENET
BATT ☐ ☐ RS232

RUN REM PROG

To enter the program into the PLC, place the processor in the PROGRAM mode and enter the instructions one-by-one using the programming device

To operate the program, the controller is placed in the RUN mode, or operating cycle
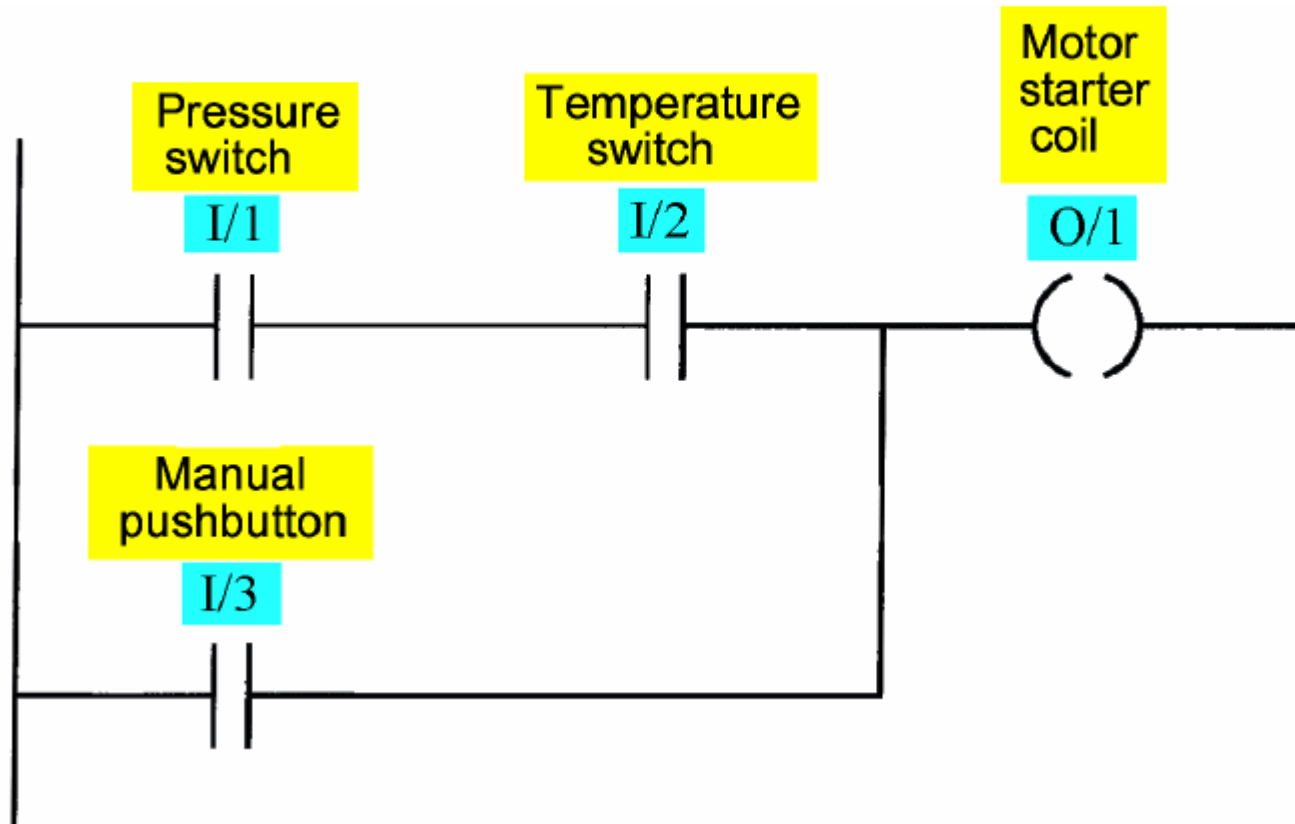
PLC Operating Cycle

During each operating cycle, the controller examines the status of input devices, executes the user program, and changes outputs accordingly

I/O scan

Program scan
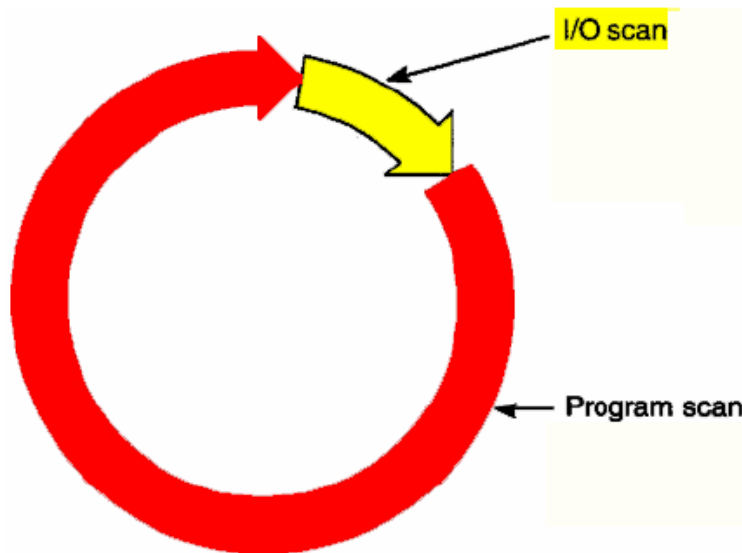
The completion of one cycle of this sequence is called a *scan*. The scan time, the time required for one full cycle, provides a measure of the speed of response of the PLC

PLC Operating Cycle

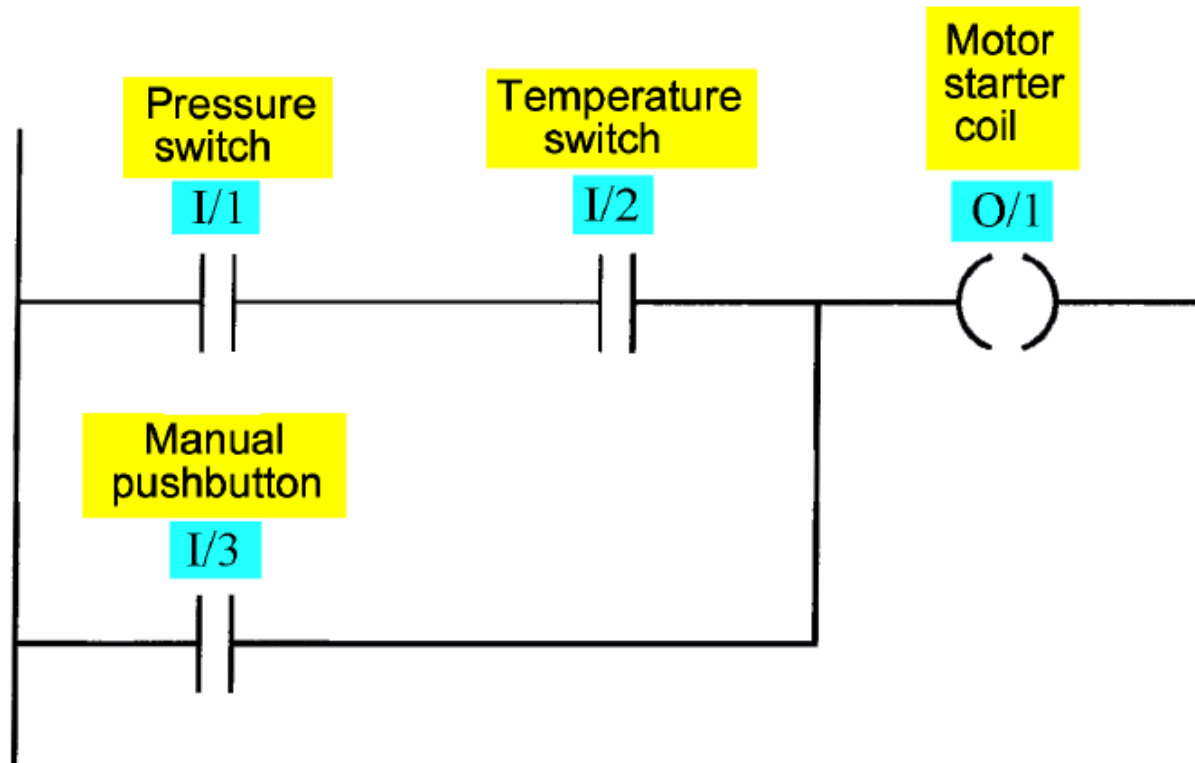| Pressure switch	Temperature switch	Motor starter coil
I/1	I/2	O/1

Manual pushbutton
I/3

This element can be thought of as a set of normally open contacts

This can be considered to represent the coil of a relay, that closes a set of contacts when energized
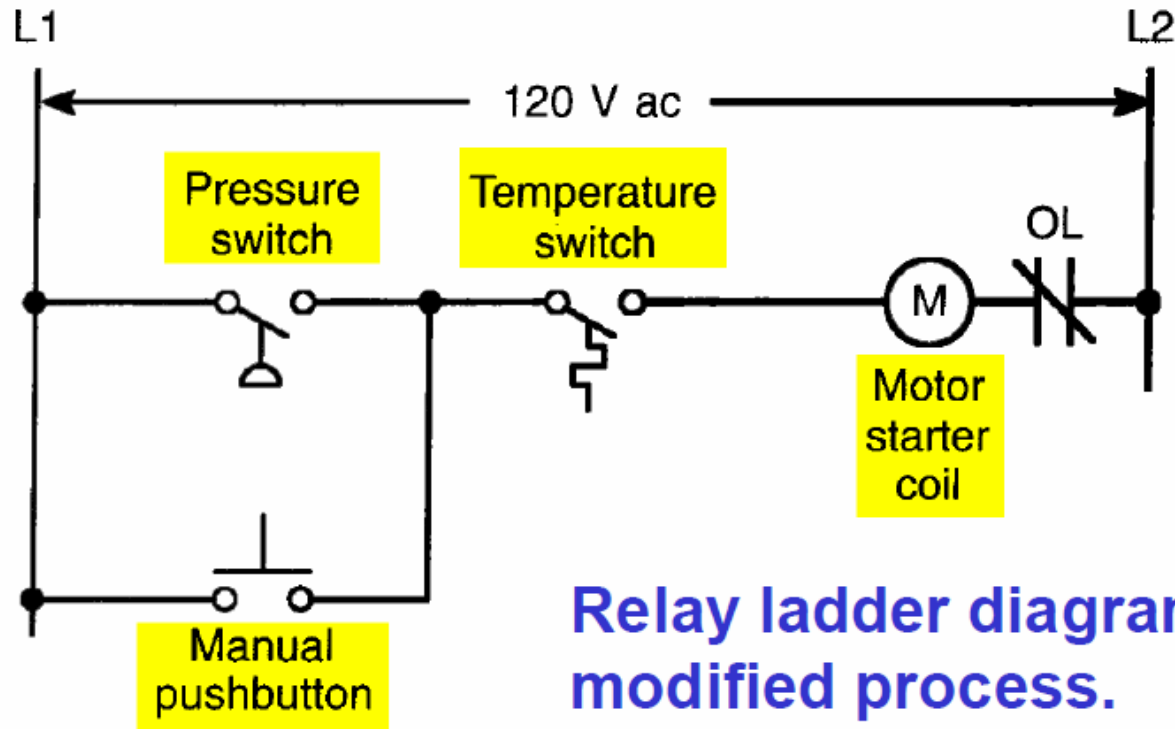
PLC Operating Cycle

Coil O/1 is energized when contacts I/1 and I/2 are closed or when contact I/3 is closed. Either of these conditions provides a continuous path from left to right across the rung that includes the coil.
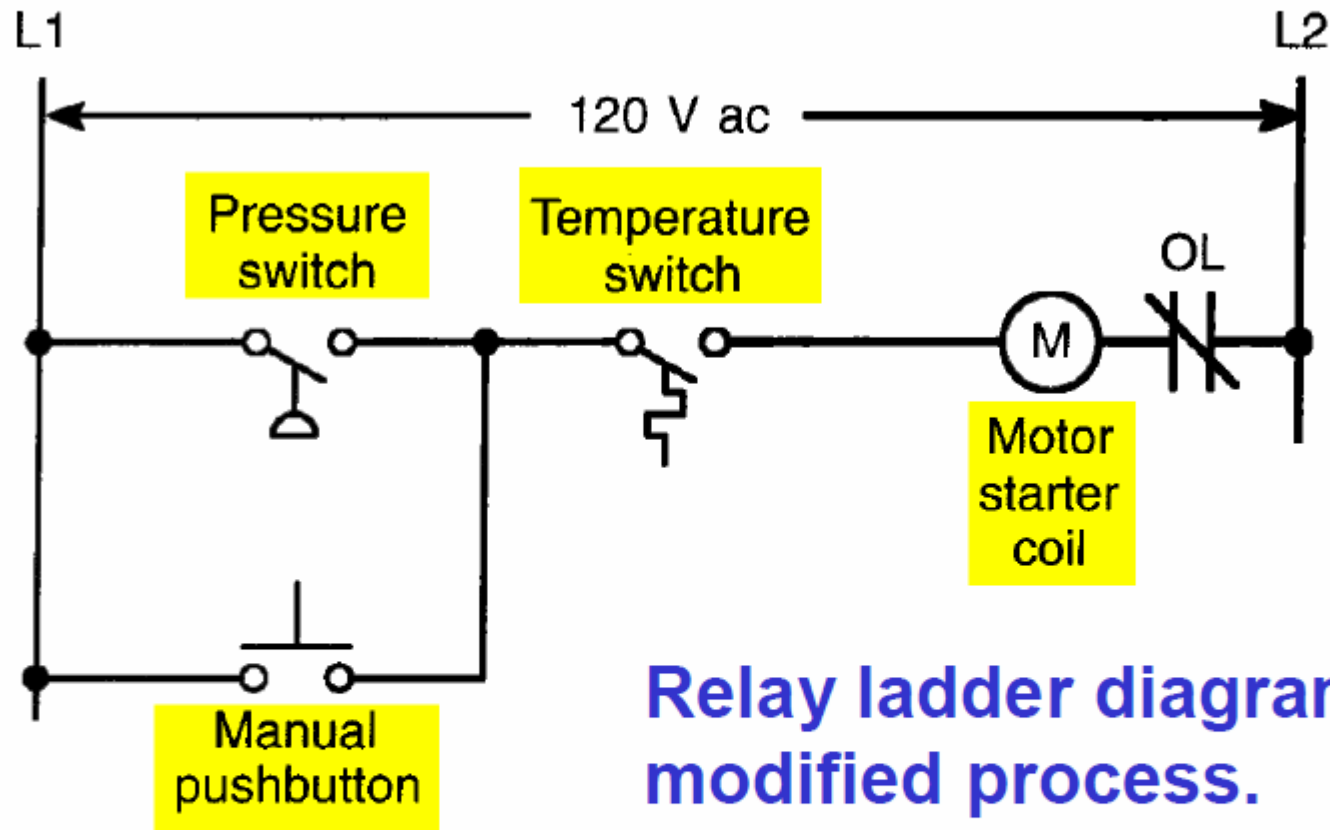
Modifying A PLC Program
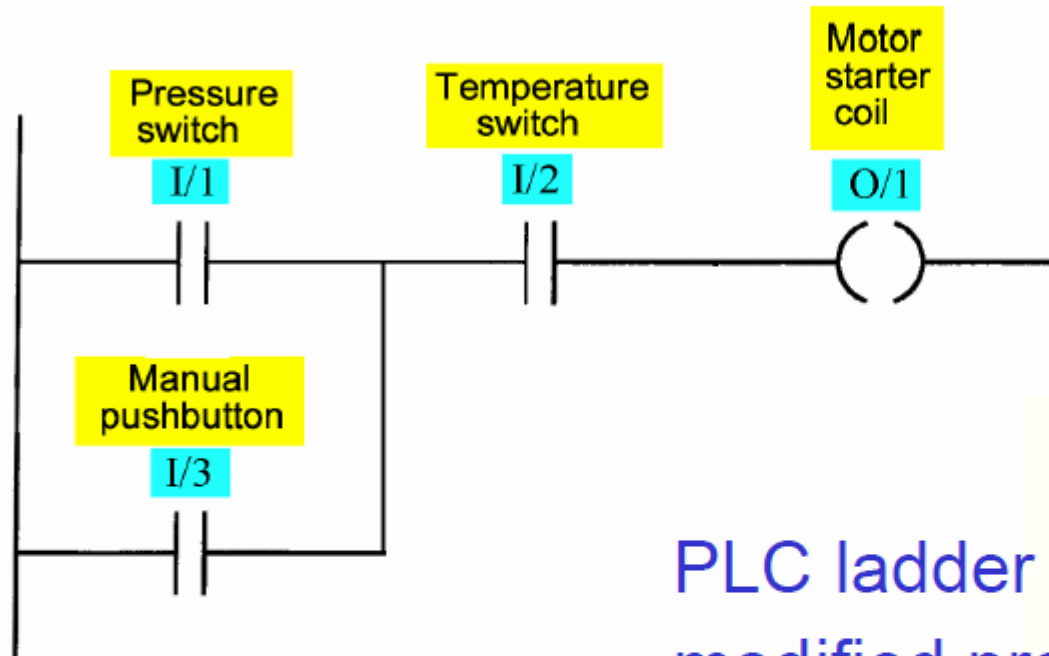

Relay ladder diagram for modified process.

The change requires that the manual pushbutton control should be permitted to operate at any pressure but not unless the specified temperature setting has been reached.

Modifying A PLC Program

Relay ladder diagram for modified process.

If a relay system were used, it would require some rewiring of the system, as shown, to achieve the desired change.

Modifying A PLC Program

PLC ladder logic diagram for modified process.

If a **PLC** is used, no rewiring is necessary!

The inputs and outputs are still the same.

All that is required is to change the PLC program

PLC Size Classification

Criteria
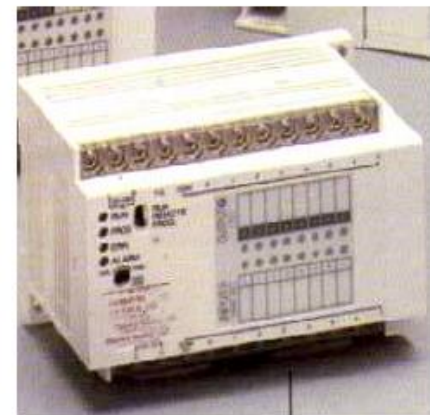- Number of inputs and outputs (I/O count)
- Cost
- Physical size

Nano PLC
- Smallest sized PLC
- Handles up to 16 I/O points

Micro PLC
- Handles up to 32 I/O points
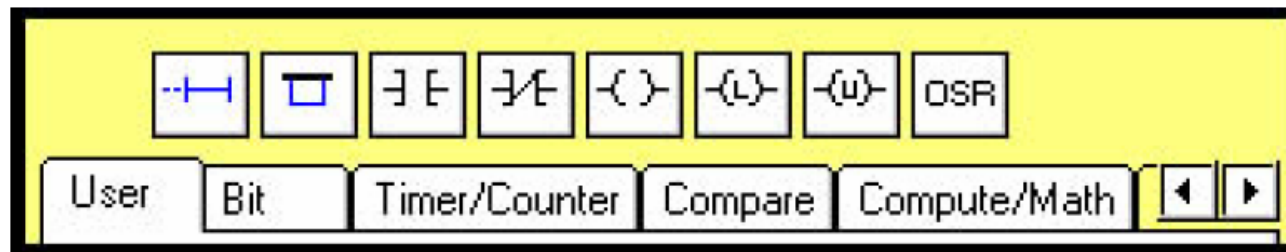
PLC Size Classification

Allen-Bradley SLC-500 Family
- Handles up to 960 I/O points

Allen-Bradley PLC-5 Family
- Handles several thousand I/O points

PLC Instruction Set

The instruction set for a particular PLC type lists the different types of instructions supported.

An instruction is a command that will cause a PLC to perform a certain predetermined operation.

PLC Variants

Basic PLC Device
- Digital I/O
- Rugged
- Small
- Cheap
- Reliable

Modular PLC Devices
- Configurable input modules
- Digital I/O
- Analog Inputs/Outputs
- Field Bus modules- CAN, CANopen, Ethercat, ….
  - Vision Systems
  - Servo Drivers
  - …
- Motion Control Modules

Soft PLC
- Dedicated Realtime Software on OS, such as Windows, Linux, propriatary OS
- Powerfull CPU
- Modular
- Better Connectivity
- PLC Networking
- Human-Machine Interface

Open Architecture
Open design, open source software allows other manufacturers to integrate custom soft- and hardware.

Closed Architecture
Propriatary Software and Hardware. Often Problems in connecting devices from other manufacturers.

PLC Variants

- **Open Architecture**
  Open design, open source software allows other manufacturers to integrate custom soft- and hardware.

- **Closed Architecture**
  Propriatary Software and Hardware. Often Problems in connecting devices from other manufacturers.
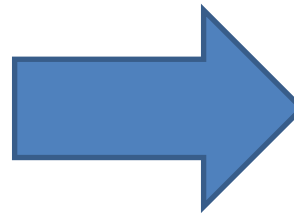
CODESYS

Development environment for programming controller applications according to the international industrial standard IEC 61131-3

Programming using multiple different languages/styles
- Ladder Logic
- Instruction List
- Function Block Diagram
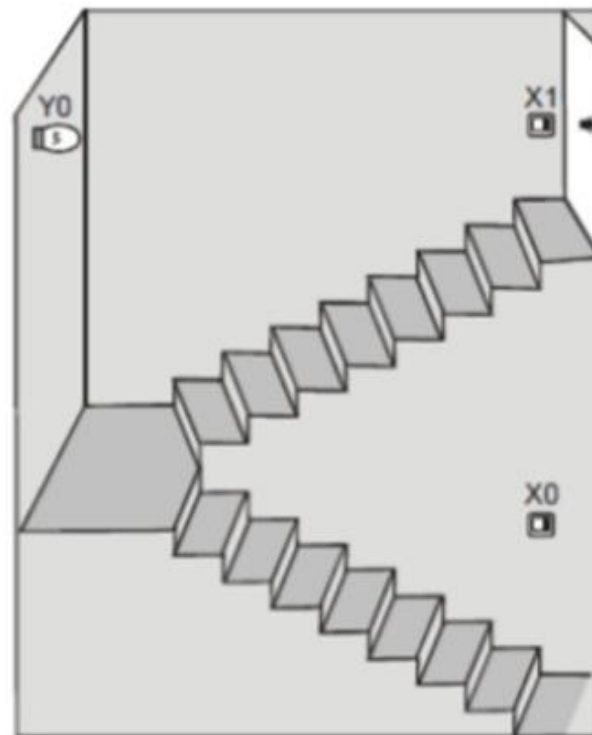- Sequential Function Chart
- Structured Text

Application Example #2

Problem:

We have a stairway with lighting (Y0).

Two switches X0 and X1 are installed at the bottom and top of the stairway.

They should switch the light on or off, whether the user is at top or bottom.

Realization should be done using a PLC.

Normally open contact

Normally closed contact

Output coil: if the power flow to it is on then the coil state is on

Application Example #2 Solution

Input X0

X0   X1
‖‖   ‖‖   (Y0)

X0   X1
‖‖   ‖/‖

Negated Input X0
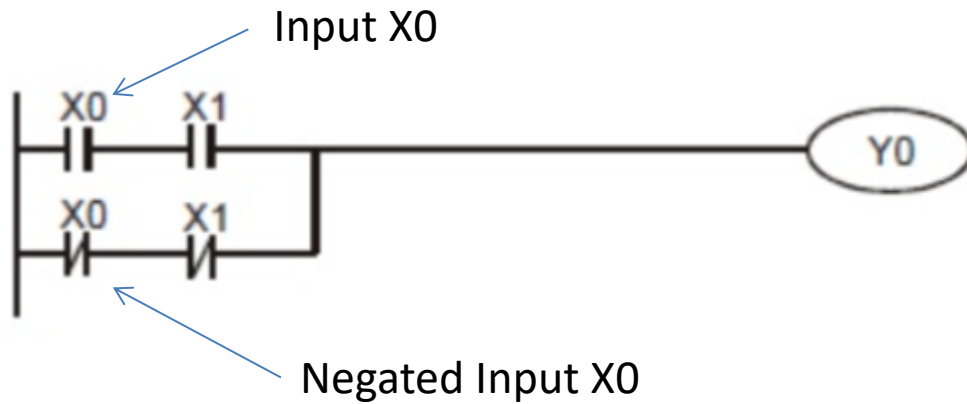
A) X0 closed and X1 closed -> Y0 on
B) X0 open and X1 open -> Y0 on
C) X0 open X1 closed -> Y0 off
D) X0 closed X1 open -> Y0 off

Users can now change the state of the light by changing the state
of either one of the switches.