What is Sequence and Logic Control?

Many control applications do not involve analog process variables, that is, the ones which can assume a continuous range of values, but instead variables that are set valued, that is they only assume values belonging to a finite set. The simplest examples of such variables are binary variables, that can have either of two possible values, (such as 1 or 0, on or off, open or closed etc.). These control systems operate by turning on and off switches, motors, valves, and other devices in response to operating conditions and as a function of time. Such systems are referred to as sequence/logic control systems.

For example, in the operation of transfer lines and automated assembly machines, sequence control is used to coordinate the various actions of the production system (e.g., transfer of parts, changing of the tool, feeding of the metal cutting tool, etc.).

Typically the control problem is to cause/ prevent occurrence of

♦ particular values of outputs process variables

♦ particular values of outputs obeying timing restrictions

♦ given sequences of discrete outputs

♦ given orders between various discrete outputs

Note that some of these can also be operated using analog control methods. However, in specific applications they may be viewed as discrete control or sensing devices for two reasons, namely,

A. The inputs to these devices only belong to two specific sets. For example in the control of a reciprocating conveyor system, analog motor control is not applied. Simple on-off control is adequate. Therefore for this application, the motor-starter actuation system may be considered as discrete.

B. Often the control problem considered is supervisory in nature, where the problem is provide different types of supervisory commands to automatic control systems, which in turn carry out analog control tasks, such that over all system operating modes can be maintained and coordinated to achieve system objectives.

Industrial Example of Discrete Sensors and Actuators : There are many industrial sensors which provide discrete outputs which may be interpreted as the presence/absence of an object in close proximity, passing of parts on a conveyor.

Type	Signal	Remark
Switch	**Binary Command**	**External Input Device**
Limit switch	**Position**	**Feedback Sensor Device**
Thumbwheel switch	**Set valued Command**	**External Input Device**
Thermostat	**Temperature Level**	**Feedback Sensor Device**
Photo cell	**Position of objects**	**Feedback Sensor Device**
Proximity detector	**Position of objects**	**Feedback Sensor Device**
Push button	**Command (unlatched)**	**External Input Device**

Table 1 Discrete Sensors

Programmable Logic Controllers (PLC) :

A modern controller device used extensively for sequence control today in transfer lines, robotics, process control, and many other automated systems is the Programmable Logic Controller (PLC). In essence, a PLC is a special purpose industrial microprocessor based real time computing system, which performs the following functions in the context of industrial operations .

• Monitor Input/Sensors

• Execute logic, sequencing, timing, counting functions for Control/Diagnostics

• Drives Actuators/Indicators

• Communicates with other computers Some of the following are advantages of PLCs due to standardized hardware technology, modular design of the PLCs, communication capabilities and improved development program development environment:

• Easy to use to simple modular assembly and connection;

• Modular expansion capacity of the input, outputs and memory;

• Simple programming environments and the use of standardized task libraries and debugging aids;

• Communication capability with other programmable controllers and computers

or

A PLC (i.e. Programmable Logic Controller) is a device that was invented to replace the necessary sequential relay circuits for machine control. The PLC works by looking at its inputs and depending upon their state, turning on/off its outputs. The user enters a program, usually via software, that gives the desired results. PLC acts as a controller in automated systems which are responsible for automatic controlling of various devices associated with the system.

What does 'PLC' mean?

A PLC (Programmable Logic Controllers) is an industrial computer used to monitor inputs, and depending upon their state make decisions based on its program or logic, to control (turn on/off) its outputs to automate a machine or a process.

NEMA defines a PROGRAMMABLE LOGIC CONTROLLER as:
"A digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions such as logic sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machines or processes".

PLC History:

PLC development began in 1968 in response to a request from an US car manufacturer (GE). The first PLCs were installed in industry in 1969.

Communications abilities began to appear in approximately 1973. They could also be used in the 70's to send and receive varying voltages to allow them to enter the analog world.

The 80's saw an attempt to:
standardize communications with manufacturing automation protocol (MAP), reduce the size of the PLC, and making them software programmable through symbolic programming on personal computers instead of dedicated programming terminals or handheld programmers.

The 90's have seen a gradual reduction in the introduction of new protocols, and the modernization of the physical layers of some of the more popular protocols that survived the 1980's.

The latest standard "IEC 1131-3" has tried to merge plc programming languages under one international standard. We now have PLCs that are programmable in function block diagrams, instruction lists, C and structured text all at the same time.

Evolution of the PLC

Before the advent of microprocessors, industrial logic and sequence control used to be performed using elaborate control panels containing electromechanical or solid-state relays, contactors and switches, indicator lamps, mechanical or electronic timers and counters etc., all hardwired by complex and elaborate wiring. In fact, for many applications such control panels are used even today. However, the development of microprocessors in the early 1980's quickly led to the development of the PLCs, which had significant advantages over conventional control panels. Some of these are:

• Programming the PLC is easier than wiring physical components; the only wiring required is that of connecting the I/O terminals.

• The PLC can be reprogrammed using user-friendly programming devices. Controls must be physically rewired.

• PLCs take up much less space.

• Installation and maintenance of PLCs is easier, and with present day solid-state technology, reliability is grater.

• The PLC can be connected to a distributed plant automation system, supervised and monitored.

• Beyond a certain size and complexity of the process, a PLC-based system compare favorably with control panels.

• Ability of PLCs to accept digital data in serial, parallel and network modes imply a drastic reduction in plant sensor and actuator wirings, since single cable runs to remote terminal I/O units can be made. Wiring only need to be made locally from that point.

• Special diagnostic and maintenance modes for quick troubleshooting and servicing, without disrupting plant operations.

However, since it evolved out of relay control panels the PLCs adopted legacy concepts, which were applicable to such panels. To facilitate maintenance and modification of the physically wired control logic, the control panel was systematically organized so that each control formed a rung much like a rung on a ladder. The development of PLCs retained the ladder logic concept where control circuits are defined like rungs on a ladder where each rung begins with one or more inputs and each rung usually ends with only one output.

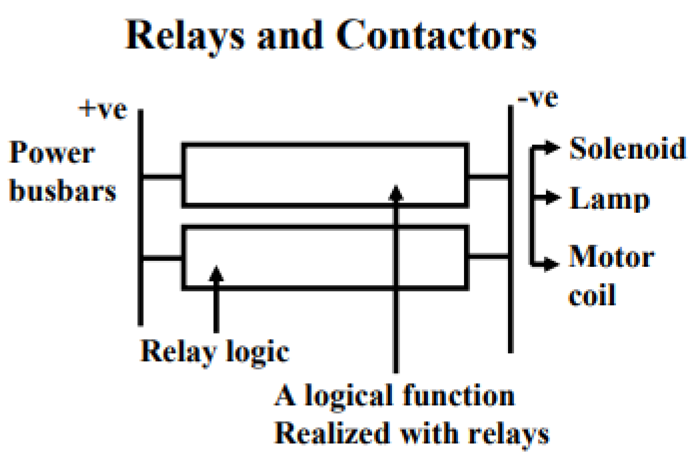


Fig. The structure of Relay Logic Circuits

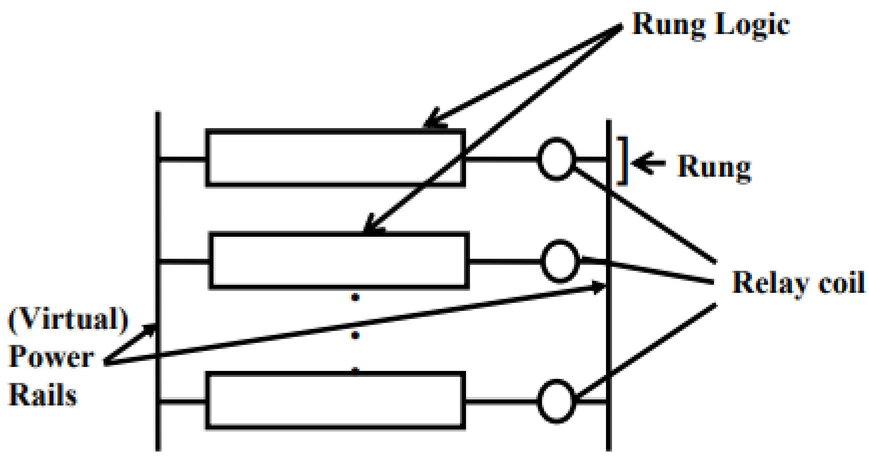


Fig. The structure of Relay Ladder Logic Programs for PLCs

Application Areas :

Programmable Logic Controllers are suitable for a variety of automation tasks. They provide a simple and economic solution to many automation tasks such as

- Logic/Sequence control
- PID control and computing
- Coordination and communication
- Operator control and monitoring
- Plant start-up, shut-down

Any manufacturing application that involves controlling repetitive, discrete operations is a potential candidate for PLC usage, e.g. machine tools, automatic assembly equipment, molding and extrusion machinery, textile machinery and automatic test equipment. Some typical industrial areas that widely deploy PLC controls are named below:

Chemical/ Petrochemical	Metals	Manufacturing/Machining
Batch process	Blast Furnace	Material Conveyors, Cranes
Pipeline Control	Continuous Casting	Assembly
Weighing, Mixing	Rolling Mills	Milling, Grinding, Boring
Finished Product Handling	Soaking Pit	Plating, Welding, Painting
Water/ Waste Treatment	Steel Melting Shop	Molding/ casting/forming

Architecture of PLCs: The PLC is essentially a microprocessor-based real-time computing system that often has to handle significant I/O and Communication activities, bit oriented computing, as well as normal floating point arithmetic. A typical set of components that make a PLC System is shown in Fig.below.

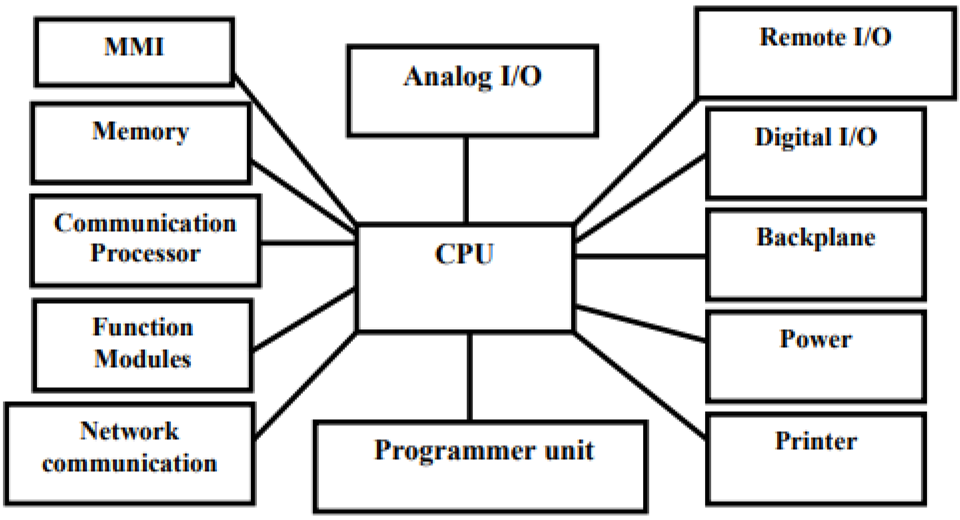


Fig. Conventional PLC Architecture

Central controller The central controller (CC) contains the modules necessary for the main computing operation of the Programmable controller (PC). The central controller can be equipped with the following:

♦ Memory modules with RAM or EPROM (in the memory sub modules) for the program (main memory);

♦ Interface modules for programmers, expansion units, standard peripherals etc;

♦ Communications processors for operator communication and visualization, communication with other systems and configuring of local area networks. A bus connects the CPUs with the other modules.

Central Processing units

The CPUs are generally microprogrammed processors sometimes capable of handling multiple data width of either 8, 16 or 24 bits. In addition some times additional circuitry, such as for bit processing is provided, since much of the computing involves logical operations involving digital inputs and auxiliary quantities. Memory with battery backup is also provided for the following: ♦ Flags (internal relays), timers and counters;

♦ Operating system data

♦ Process image for the signal states of binary inputs and outputs.

The user program is stored in memory modules. During each program scan, the processor reads the statement in the program memory, executes the corresponding operations. The bit processor, if it exists, executes binary operations. Often multiple central controllers can be configured in hot standby mode, such that if one processor fails the other can immediately pick up the computing tasks without any failure in plant operations.

Communications processors Communications processors autonomously handle data communication with the following:

♦ Standard peripherals such as printers, keyboards and CRTs,

♦ Supervisory Computer Systems,

♦ Other Programmable controllers,

The data required for each communications processors is stored in a RAM or EPROM sub module so that they do not load the processor memories. A local area network can also be configured using communications processors. This enables the connection of various PLCs over a wide distance in various configurations. The network protocols are often proprietary. However, over the last decade, interoperable network protocol standards are also supported in modern PLCs.

Input/Output Units A host of input and output modules are connected to the PLC bus to exchange data with the processor unit. These can be broadly categorized into Digital Input Modules, Digital Output Modules, Analog Input Modules, Analog Output Modules and Special Purpose Modules.

Digital Input Modules : The digital inputs modules convert the external binary signals from the process to the internal digital signal level of programmable controllers.

Digital Output Modules : The digital output modules convert the internal signal levels of the programmable controllers into the binary signal levels required externally by the process. Analog Input Modules :The analog input modules convert the analog signals from the process into digital values which are then processed by the programmable controller.

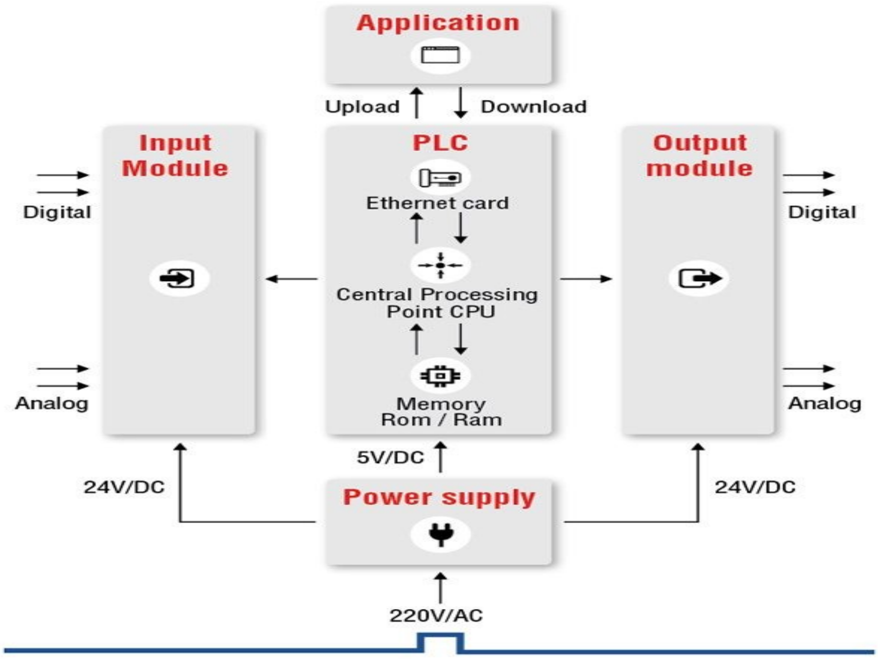
Analog Output Modules: The analog output modules convert digital values from the programmable controller into the analog signals required by the process. Special Purpose Modules These may include special units for:

- High speed counting •
- High accuracy positioning
- On-line self-optimizing control
- Multi axis synchronisation, interpolation

These modules contain additional processors, and are used to relieve the main CPU from the high computational loads involved in the corresponding tasks.

How Does PLC work?

The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a PLC can monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application.



Name three major elements of a PLC System

Ans: CPU, I/O Modules, Communication Processor B. What is the need for special purpose I/O modules? Explain with an example Ans: Some i/o operations like high speed counting of shaft encoder pulses to measure speed is very computationally intensive. Therefore to free the CPU from this load, so that other control logics can be computed, special i/o modules with dedicated processors for the task are used.

Traditional PLC Applications
*In automated system, PLC controller is usually the central part of a process control system.
*To run more complex processes it is possible to connect more PLC controllers to a central computer.

Disadvantages of PLC control
– Too much work required in connecting wires.
– Difficulty with changes or replacements.
– Difficulty in finding errors; requiring skillful work force.
– When a problem occurs, hold-up time is indefinite, usually long.

Advantages of PLC control
* Rugged and designed to withstand vibrations, temperature, humidity, and noise.
* Have interfacing for inputs and outputs already inside the controller.
* Easily programmed and have an easily understood programming language.

Major Types of Industrial Control Systems
Industrial control system or ICS comprise of different types of control systems that are currently in operation in various industries. These control systems include PLC, SCADA and DCS and various others:

PLC

They are based on the Boolean logic operations whereas some models use timers and some have continuous control. These devices are computer based and are used to control various process and equipments within a facility. PLCs control the components in the DCS and SCADA systems but they are primary components in smaller control configurations.

DCS

Distributed Control Systems consists of decentralized elements and all the processes are controlled by these elements. Human interaction is minimized so the labor costs and injuries can be reduced.

Embedded Control

In this control system, small components are attached to the industrial computer system with the help of a network and control is exercised.

SCADA

Supervisory Control And Data Acquisition refers to a centralized system and this system is composed of various subsystems like Remote Telemetry Units, Human Machine Interface, Programmable Logic Controller or PLC and Communications.

PLC Hardware

Hardware Components of a PLC System

- Processor unit (CPU),
- Memory, I
- nput/Output,
- Power supply unit,
- Programming device, and other devices.

Central Processing Unit (CPU)

CPU – Microprocessor based, may allow arithmetic operations, logic operators, block memory moves, computer interface, local area network, functions, etc.
CPU makes a great number of check-ups of the PLC controller itself so eventual errors would be discovered early.

System Busses
The internal paths along which the digital signals flow within the PLC are called busses.
The system has four busses:
– The CPU uses the data bus for sending data between the different elements,
– The address bus to send the addresses of locations for accessing stored data,
– The control bus for signals relating to internal control actions,
– The system bus is used for communications between the I/O ports and the I/O unit.

Memory
System (ROM) to give permanent storage for the operating system and the fixed data used by the CPU. RAM for data. This is where information is stored on the status of input and output devices and the values of timers and counters and other internal devices. EPROM for ROM's that can be programmed and then the program made permanent.

I/O Sections
Inputs monitor field devices, such as switches and sensors.
Outputs control other devices, such as motors, pumps, solenoid valves, and lights.

Power Supply
Most PLC controllers work either at 24 VDC or 220 VAC. Some PLC controllers have electrical supply as a separate module, while small and medium series already contain the supply module.

Programming Device
The programming device is used to enter the required program into the memory of the processor. The program is developed in the programming device and then transferred to the memory unit of the PLC.

PLC selection criteria

PLC selection criteria consists of:

* System (task) requirements.
* Application requirements.
* What input/output capacity is required?
* What type of inputs/outputs are required?
* What size of memory is required?
* What speed is required of the CPU?
* Electrical requirements.
* Speed of operation.
* Communication requirements.
* Software.
* Operator interface.
* Physical environments.

Electrical Requirements
The electrical requirements for inputs, outputs, and system power; When determining the electrical requirements of a system, consider three items:

- Incoming power (power for the control system);

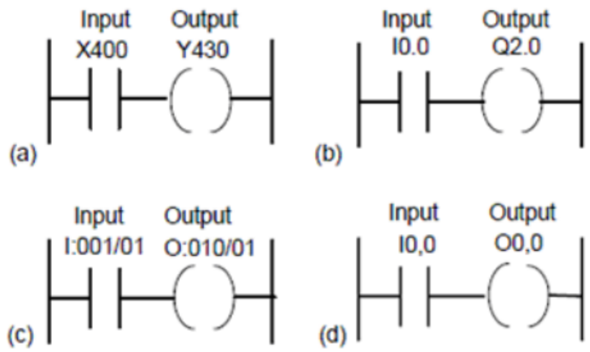
- Input device voltage; and
- Output voltage and current.

.

Why are relays required in a PLC circuit?

Ans: Usually PLCs have low voltage at their outputs about 24 volts which are unable to operate devices of higher voltage ratings, in such cases the relays are used which are energized using PLC's outputs and relays themselves connect or disconnect devices from higher power sources.

The Allen-Bradley PLC-5 has I: 012/03 to indicate an input in rack 01 at module 2 and terminal 03



(a) Mitsubishi, (b) Siemens, (c) Allen-Bradley, (d) Telemecanique

PLC Programming:

Programming Languages

A program loaded into PLC systems in machine code, a sequence of binary code numbers to represent the program instructions.
Assembly language based on the use of mnemonics can be used, and a computer program called an assembler is used to translate the mnemonics into machine code.
High level Languages (C, BASIC, etc.) can be used.

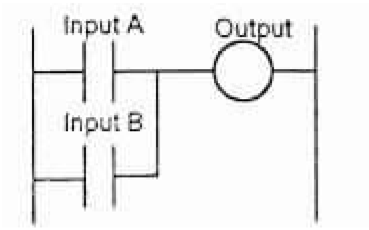
Programming Devices
PLC can be reprogrammed through an appropriate programming device:
- Programming Console
- PC
- Hand Programmer

Introduction to Ladder Logic:
Ladder logic uses graphic symbols similar to relay schematic circuit diagrams.
Ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines between these two verticals.

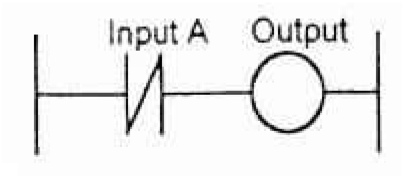
Ladder diagram features
- Power flows from left to right.
- Output on right side can not be connected directly with left side.
- Contact can not be placed on the right of output.

 Each rung contains one output at least.
 Each output can be used only once in the program.
 A particular input a/o output can appear in more than one rung of a ladder.
 The inputs a/o outputs are all identified by their addresses, the notation used depending on the PLC manufacturer.

AND



OR



NOT

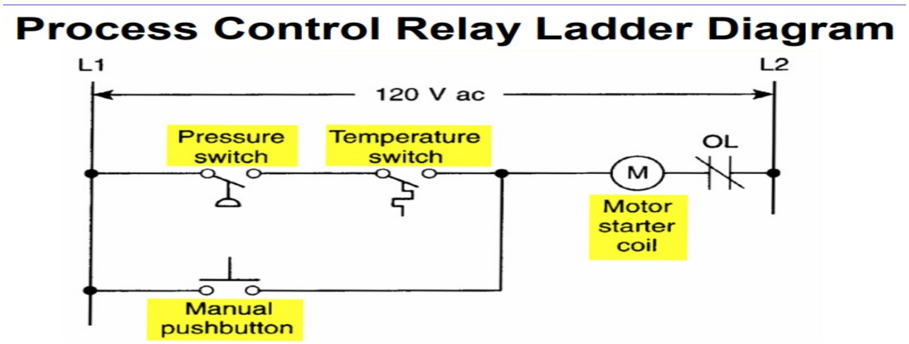
Introduction to Statement list
Statement list is a programming language using mnemonic abbreviations of Boolean logic operations. Boolean operations work on combination of variables that are true or false.
A statement is an instruction or directive for the PLC.

Statement List Operations
* Load (LD) instruction.
* And (A) instruction.
* Or (O) instruction.
* Output (=) instruction.

Function Block Diagrams
Function block is represented as a box with the function name written in.

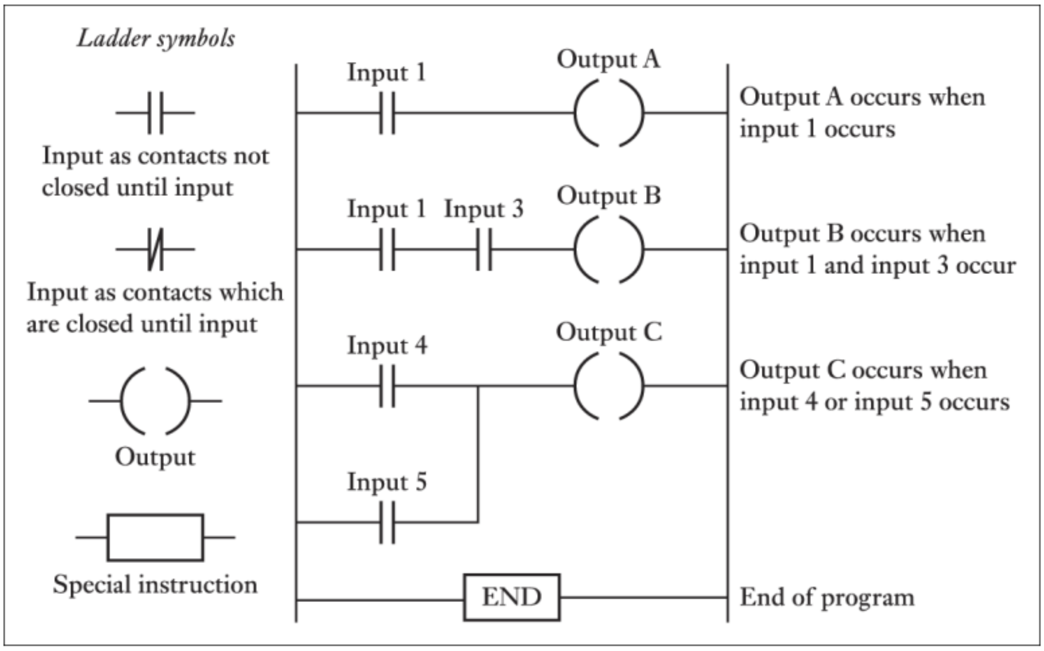
Ladder Programming Example:

1. Motor starter coil is energised when both the pressure and temp swiches are closed or when manual pushbutton are pressed.



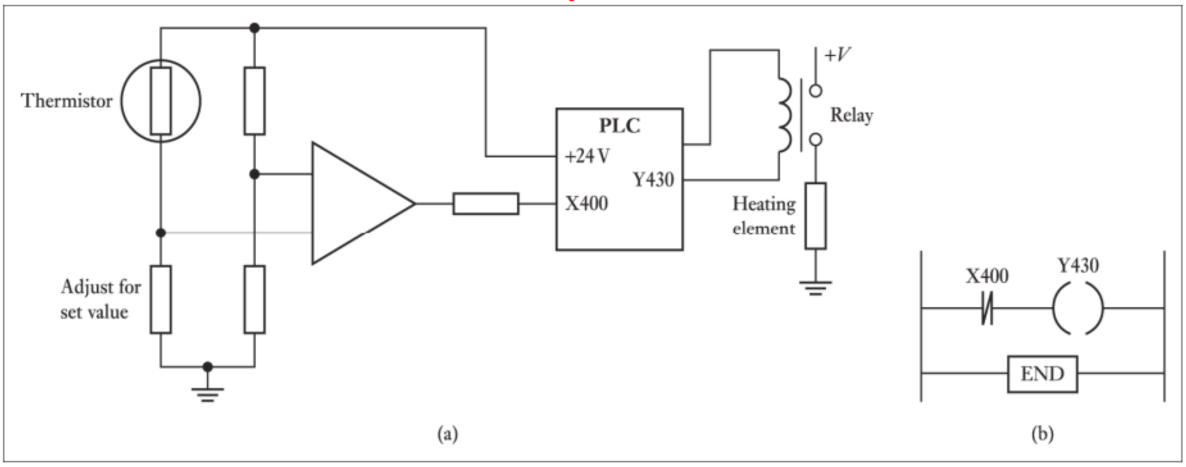
2. **Example of ladder symbols**

Each rung must start with an input or series of inputs and end with an output

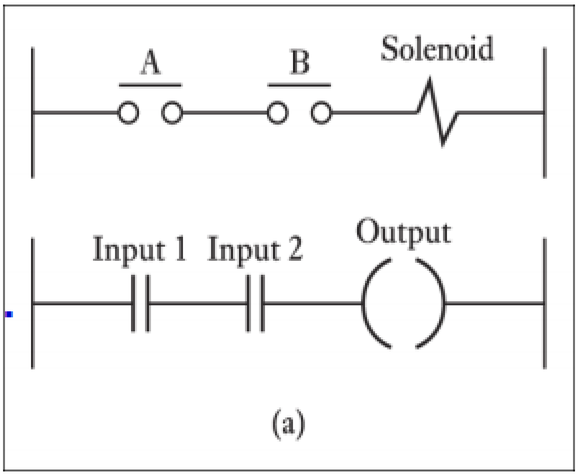


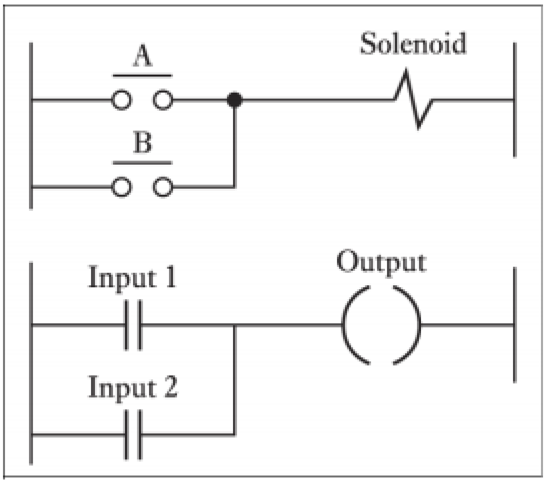
3. Ladder programming on-off control:
   The input goes from low to high when the temparature sensor reaches the set temperature. The output is then to go from ON to OFF.

An ON/OFF temperature control



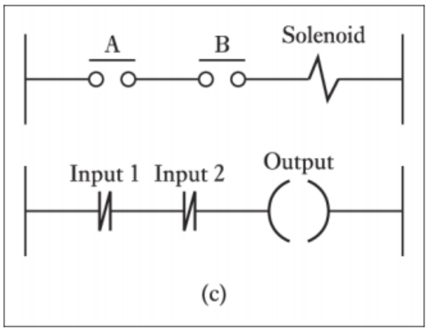
4. Ladder programme on digital gates (2nd fig of AND,OR, NOR …are the ladder diagram

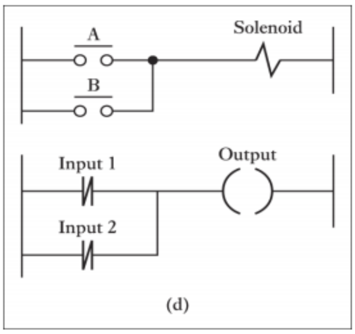


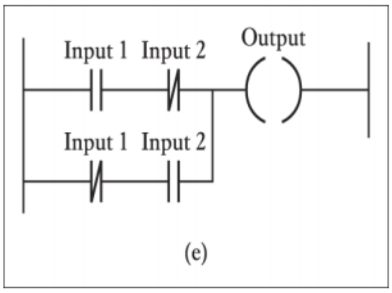


AND circuit

OR circuit



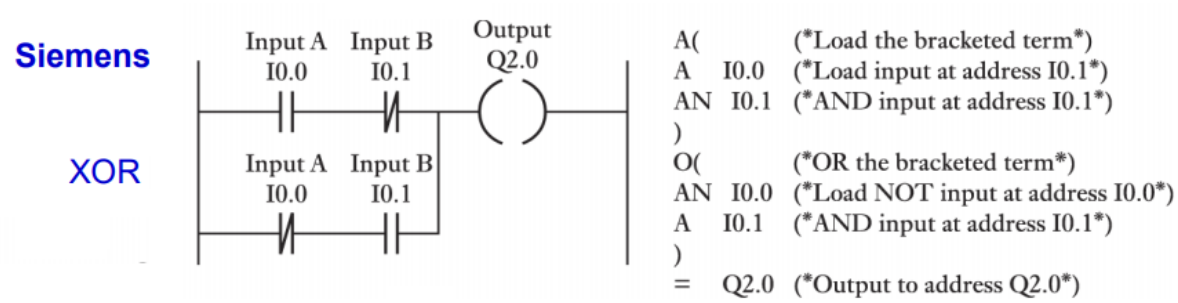




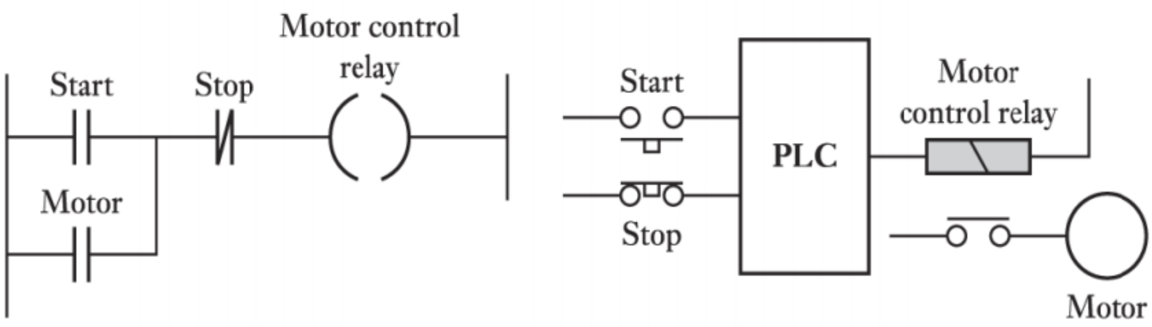
NOR circuit

NAND circuit

XOR circuit



5. Ladder program for motor control



Try to solve

1. Y= (A+B)(C+D)E
2. Z=XY+X'Y'
3. Adder circuit
4. BCD to Excess3 code converter

Book:

1. **Jay F. Hooper,Introduction to PLCs**