15EE562 Programmable Logic Controllers (PLC)

Module-I:

Programmable Logic Controllers (PLC):

Introduction:

Controller:

What type of task might a control system handle?

It might be reqd to control a sequence of events. For eg., the control system for an automatic drilling m/c might be reqd to start lowering the drill when the workpiece is in position, start drilling when the drill reaches the workpiece, stop drilling when the drill has produced the reqd depth of whole, retract the drill, and then switch off & wait for the next workpiece to be put in position before repeating the operation. Another control system might be used to control the no. of items moving along a conveyor belt and direct them into a packing case. The i/p's to such control systems might come from switches being closed or opened.

What form might a controller have?

For an automatic drilling m/c we could wire up electrical ckts in which closing or opening of switches would result in motors being switched on or valves being actuated. Thus we might have the closing of a switch activating a relay, which in turn, switches on the c^{t} to a motor & causes the drill to rotate.

Another switch might be used to activate a relay & switch on the C^t to a pneumatic or hydraulic valve & ~~so~~ results in workpiece being pushed into req^d position. Such electrical ckts would have to be specific to the automatic drilling m/c. For controlling the no. of items packed into a packing case, we could likewise wire up electrical ckts involving sensors & motors.

However, the controller ckts we have used for these two situations would be different. In traditional form of control system, the rules governing the control system are determined by the wiring. When the rules used for the control actions are changed, the wiring has to be changed.

Micro processor - Controlled Systems

Instead of hardwiring each control ckt for each control situations, we can use the same basic system for all situations if we use a microprocessor based system & write a program to instruct the microprocessor how to react to each i/p signal from, say, switches & give the req^d o/ps to, say, motors & valves. Thus we might have a program of the form,

If switch A closes
o/p to motor ckt
If switch B closes
o/p to valve ckt.

By changing the instructions in the program, we can use the same µp system to control a wide variety of situations.

As an illustration, the modern domestic washing m/c used a µp system.

Programmable Logic Controller (PLC)

The first PLC was developed in 1969. PLC's are now widely used. ~~& extend from small~~

The PLC is basically a digital computer designed for use in m/c control. Unlike a personal computer, it has been designed to operate in the industrial environment & is equipped with special i/p/o/p interfaces & a control programming language. The common abbreviation used in industry for these devices 'PC' can be confusing because it is also the abbreviation of 'Personal Computer'. Hence, most manufacturers refer to their programmable controller as PLC i.e, programmable Logic Controller.

"A ~~pro~~ PLC is a special form of µp based controller that uses programmable memory to store instructions & to implement functions such as logic, sequencing, timing, counting & arithmatic in order to control m/cs & processes."

It is designed to be operated by engineers with a limited knowledge of computers & computing languages. The designers of the PLC have preprogrammed it so that the control program can be entered using a simple, rather a robust form of language.

The term logic is used because programming is primarily concerned with implementing logic & switching operations.
For eg: if A or B occurs, switch on C, if A & B occurs switch on D.

I/p devices (i.e, sensors & switches) & o/p devices (motors & valves) in the system being controlled are connected to the PLC. The operator then enters a sequence of instructions, a program, into the memory of PLC. The controller then monitors the i/ps & o/ps according to this program & carries out control rules for which it has been programmed.

PLC's have the great advantage that the same basic controller can be used with wide range of control systems. To modify a control system & the rules that are to be used, all that is necessary is for an operator to key in a different set of instructions. There is no need to rewire. Also, PLC has an advantage over conventional relay type of control. Relays have to be hardwired to perform a specific function. When the system requirements change, the relay wiring has to be changed or modified. But PLC has eliminated much of the hardwiring associated with conventional relay control ckts. Hence it is flexible & cost-effective compared to conventional relay based process control systems.

PLC's are similar to computers, but whereas computers are optimized for calculation & display tasks, PLC's are optimized for control tasks & industrial environment.

Thus PLC's,

- are rugged & designed to withstand vibrations, temp, humidity & noise.
- have interfacing for i/ps & o/ps already inside the controller.
- are easily programmed & have an easily understood programming language that is primarily concerned with logic & switching operations.

Advantages of PLC's

1) Increased Reliability:

Once a program has been written & tested, it can be easily downloaded to other PLC's, since all the logic is contained in the PLC's memory, there is no chance of making a logic wiring error.

2) More Flexibility:

It is easier to create & change a program in a PLC than to wire & rewire a ckt. With a PLC the relationships betⁿ the i/ps & o/ps are determined by the user program instead of the manner in which they are interconnected.

3) Lower Cost:

PLC's were originally designed to replace relay control logic, ~~& the~~ & if an application has more than about a half dozen control relays, it will probably be less expensive to install a PLC.

4) Communications Capability:

A PLC can communicate with other controllers or computer equipments easily & to perform various functions.

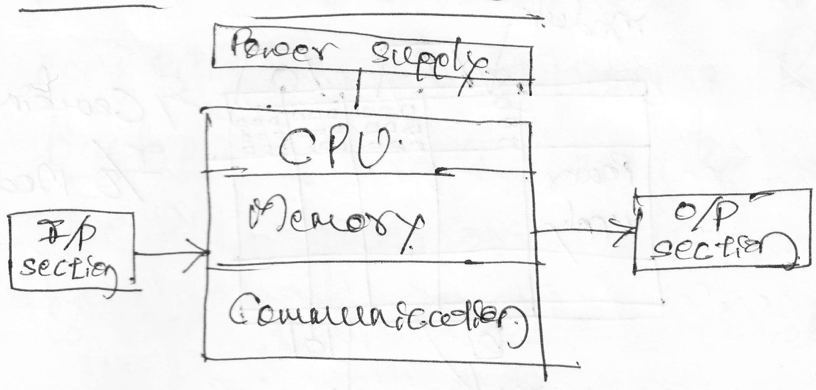
5) Faster Response Time:

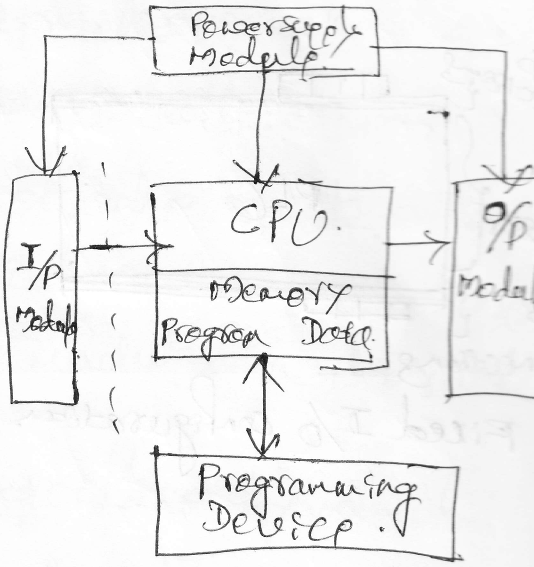
PLC's are designed for high speed & real-time applications. The PLC operates in real time, which means that an event taking place in the field will result in the o/p.

6): Easier to Troubleshoot:

PLC's have resident diagnostics & override functions that allow users to easily trace & correct software & hardware problems. To find & fix problems, users can display the control program on a monitor & watch it in real time as it executes.

Parts of a PLC



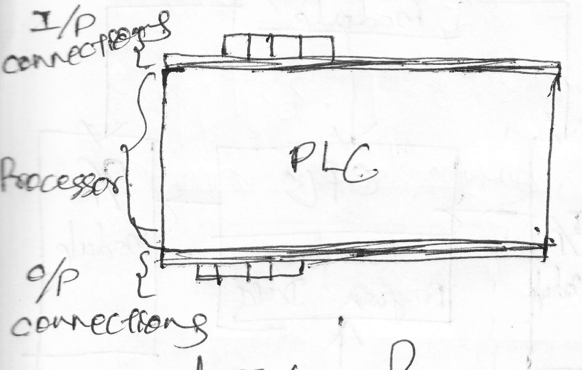


A typical PLC can be divided into following parts: These are, Central Processing Unit (CPU), the i/p/o/p (I/O) section, the power supply, program & data memory, & Programming device & ~~the communication interface~~.

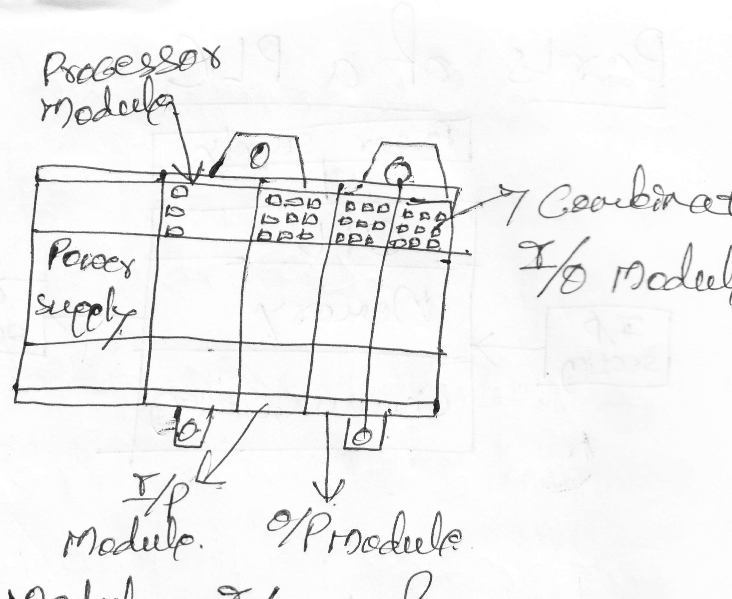
The term PLC architecture refers to PLC hardware or to PLC software or to a combination of both. An open architecture design allows the PLC system to be connected easily to devices & programs made by other manufacturers.

A system with a closed architecture is one whose design is proprietary, making it more difficult to connect to other systems. Most of the PLC systems are proprietary. Consequently PLC programs cannot be interchanged among different PLC manufacturers.

There are two ways in which I/O's (Inputs outputs) are incorporated into the PLC: Fixed & Modular.



Fixed I/O configuration



Modular I/O configuration

Fixed I/O is typical of small PLC's that come in one package with no separate, removable units. The processor & I/O are packaged together and I/O terminals have a fixed no. of connections built in for i/ps & o/p's. The main advantage of this type of packaging is lower cost.

One disadvantage of fixed I/O is its lack of flexibility. Also, for some models, if any part in the unit fails, the whole unit has to be replaced.

Modular I/O is divided by compartments into which separate modules can be plugged. This feature greatly increases the unit's flexibility. The basic modular controller consists of a rack, power supply, processor module (CPU), Input/o/p modules and an operator interface for programming & monitoring. The modules plug into a rack. When a module is slid into the rack, it makes an electrical connection with a series of contacts called the backplane, located at the rear of the rack. The PLC processor is also connected to the backplane & can communicate with all the modules in the rack.

The I/O system forms the interface by which field devices (external or real world devices) are connected to the controller. The purpose of this interface is to condition the various signals received from or sent to external field devices. I/p devices such as push buttons, limit switches & sensors are hardwired to the i/p terminals. O/p devices such as small motors, motor starters, solenoid valves & indicator lights are hardwired to the o/p terminals. To electrically isolate the internal components from the i/p & o/p terminals, PLCs commonly employ an optical isolator ~~which uses light~~

The power supply unit is needed to convert the mains AC voltage to the low DC voltage necessary for the processor & the chips in the i/p & o/p interface modules. For large PLC systems, this power supply does not normally supply power to the field devices. With larger systems, power to the field devices is provided by external AC or DC supplies. For some small micro PLC systems, the power supply may be used to field devices.

The processor (CPU) is the brain of the PLC. A typical processor consists of a microprocessor for implementing the logic program & controlling the communications among the modules. The processor requires memory for storing the results of the logical operations performed by the µp. The processor interprets the I/p signals & carries out the control actions according to the program stored in its memory, communicating the decisions as actions signals to the O/ps.

A programming device is used to enter the desired program into the memory of the processor. The program can be entered using relay ladder logic, which is one of the most popular programming languages. A program in ladder logic is similar to a schematic for a relay control ckt. It is a special language written to make it easy for people familiar with relay logic control to program the PLC.

Hand held programming devices are sometimes used to program small PLCs because they are inexpensive & easy to use. Once plugged into the PLC, they can be used to enter & monitor programs.

A personal computer (PC) is the most commonly used programming device. Most brands of PLCs have software available so that a PC can be used as the programming device. This software allows the users to create, edit, document, store & ~~to~~ troubleshoot ladder logic programs.

A <u>program</u> is a user-developed series of instructions that directs the PLC to execute actions. A programming language provides rules for combining the instructions so that they produce the desired actions. <u>Relay Ladder Logic</u> (RLL) is the std programming Language used with PLCs.

The <u>memory unit</u> is where the program containing the control actions to be exercised by the µp is stored & where the data is stored from the i/p for processing & for the o/p.

Principles of Operation.

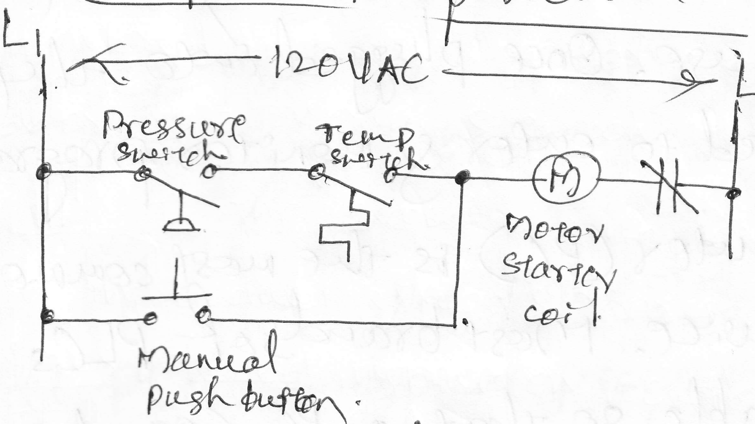


fig 1

Relay Ladder Diagram.

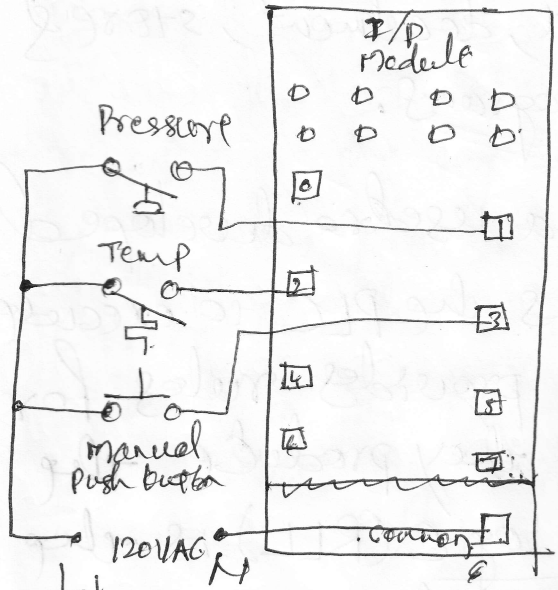


fig 2

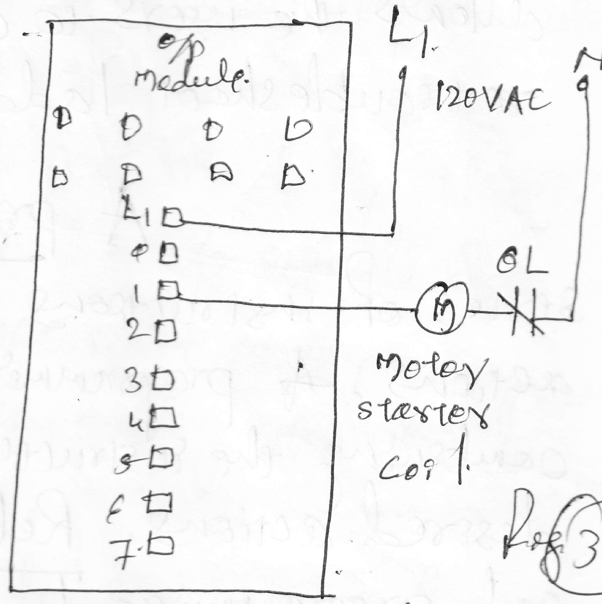


fig 3

120VAC Modular configured I/P Module. 120VAC Modular configured O/P Model

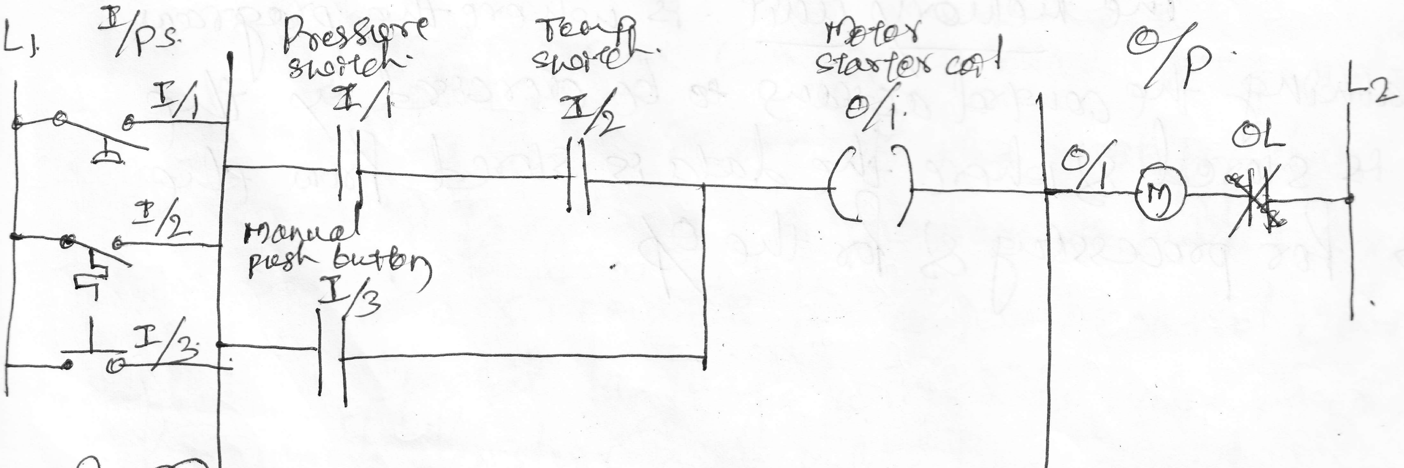


fig 4

PLC Ladder Logic Program with typical addressing scheme

To get an idea of how a PLC operates, consider the simple process control problem. Here a mixer motor is to be used to automatically stir the liquid in a vat when the temp & pressure reach preset values. In addition, direct manual operation of the motor is also provided by means of a separate push button station. The process is monitored by with temp & pressure sensor switches that close their respective contacts when conditions reach their present values.

The control problem can be solved using the relay method for motor control shown in fig ①. In the relay ladder diagram. The motor starter coil 'M' is energised when both the pressure & temp switches are closed or when the manual push button is pressed.

Now let's see how a PLC might be used for this application. The same i/p field devices (pressure switch, temp switch, push button) are used. These devices were hardwired to an appropriate i/p module according to the manufacturer's addressing location scheme. Typical wiring connection of the same is shown in fig ②

The same o/p field device (Motor starter coil) is used. This device is hardwired to an appropriate o/p module according to the manufacturer's addressing location scheme. Typical wiring connection of the same is shown in fig ③

Next, the PLC ladder logic program is constructed & entered into the memory of the CPU. A typical ladder logic program is shown in fig (4). The format used is similar to the layout of the hardwired relay ladder ckt. The individual symbols represent instructions, & numbers represent the instruction location addresses.
Each i/p & o/p device is given an address, which lets the PLC know where it is physically connected.
During program scan the controller monitors the i/ps, executes the control program & changes the o/p accordingly.

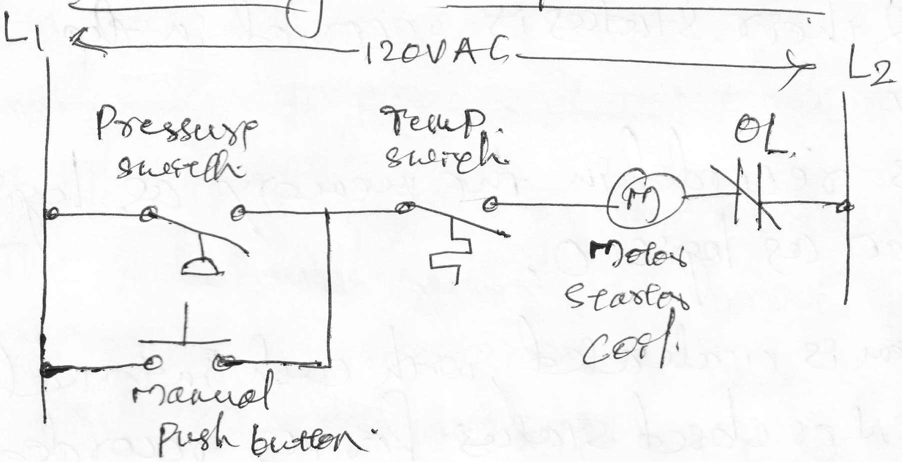
For the program to operate, the controller is placed in the RUN mode, or operating cycle. During each operating cycle, the controller examines the status of i/p devices, executes the program & changes the o/ps accordingly. Each -| |- symbol represents a set of normally open contacts. The -( )- symbol is considered to represent a coil that, when energized, will close a set of contacts.

In LLP, the coil O/1 is energized when contacts I/1 & I/2 are closed or when contact I/3 is closed. Either of these conditions provides a continuous logic path from left to right a/c the rung that includes the coil.

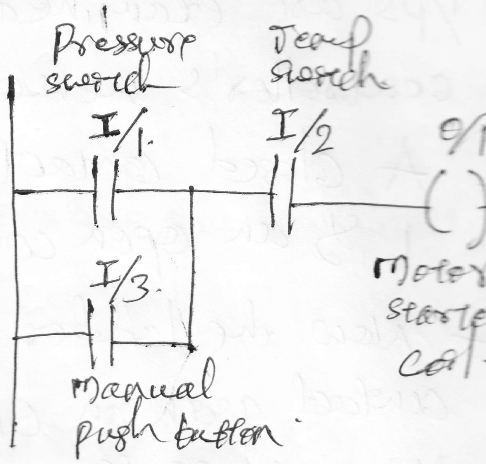
The run operation for the process control scheme can be described by the following sequence of events:

- First, the pressure switch, temp switch & push button i/ps are examined & their states is recorded in the controller's memory.
- A closed contact is recorded in the memory as logic 1, & an open contact as logic 0.
- Now the ladder dgm is evaluated, with each internal contact given an OPEN or closed status for its recorded 1 or 0 state.
- When the states of the i/p contacts provide logic continuity from left to right a/c the rung, the o/p coil memory location is given a logic 1 value & the o/p module interface contacts will close.
- When there is no logic continuity of the program rung, the o/p coil memory location is set to logic 0 & the o/p module interface contacts will be open.
- The completion of one cycle of this sequence by the controller is called scan. The scan time, the time reqd for one full cycle provides a measure of the speed of response of the PLC.

Modifying the Operation



Relay Ladder Diagram
fig 1



PLC LLP. fig 2

One of the important features of PLC is the ease with which the program can be changed. For eg. assume that the original process control ckt for mixing operation is modified as shown in RLD in fig 1. The change requires that the manual push button control be permitted to operate at any pressure but not unless the specified temp. setting has been reached.

If a relay system is used, it would require some rewiring of the ckt shown in fig 1 to achieve the desired change. However, if PLC is used, no rewiring would be necessary. The i/ps & o/ps are still the same. All that is reqd is to change the PLC LLP as shown in fig 2

PLCs versus Computers

- Industrial environment.
  - wide range of temp & humidity.
  - electrical noise.
- Easily learned language i.e, relay ladder logic.
- Program language is built into memory.
- No permanent keyboard, CD drive, or monitor.
- It has terminals for i/p & o/p field devices.
- PC executes several programs simultaneously.
- PLC executes single program in sequential manner.
- PLC can be easily installed & maintained.
- Troubleshooting is simple.
- I/p & o/p modules can be easily connected & replaced.
- PAC (Programmable Automation Controller.)

PLC size & Application

- Nano PLC (less than 15 I/O points.)
- Micro " (~~less than~~ 15 – 128 I/O points.)
- Medium " (128 – 512 I/O points)
- Large " (over 512 I/O points).

Three major types of PLC applications:

1) – Single ended or stand-alone PLC: One PLC controlling one process.

– require small PLC as it is not used for communication with other computers or PLCs.

2) Multitask PLC application: One PLC controlling several processes.

– Adequate I/O capacity is reqd.

3) Control management PLC: One PLC controlling several others.

– Large I/O capacity to communicate with other PLC's & computer.

Memory

– stores data, instructions & control programs.

– size is expressed in K values: 1K, 6K, 12K, etc.

– 1K means 1024 bits. ~~or 1024 words.~~

– eg: PLC with 8-bit words has 49,152 bits of storage with 6K word capacity (8X6X1024=49,152)

– Amount of memory reqd depends on applications.

Factors affecting the memory size reqd for a particular PLC include.

- No. of I/O points used
- Size of control program.
- Data collecting requirements.
- Supervisory functions reqd
- Future expansion.

Instruction set.

- Lists different types of instructions supported.
- ranges from 15 instructions on smaller units upto 100 instructions on larger units.

PLC Hardware Components

The I/O Section

- The I/O section of a PLC is the section to which all the field devices are connected & providing the interface btw them & CPU.
- I/O arrangements are built in into a fixed PLC while modular types use external I/O modules that plug into the PLC.

The fig. illustrates a rack-based I/O section made up of individual I/O modules.

- I/p interface modules accept signals from the m/c or process devices & convert them into signals that can be used by the controller.
- O/p interface modules convert controller signals into external signals used to control the m/c or process.
- Each slot in the rack is capable of accomodating any type of I/O module.

Discrete I/O Modules

The most common type of I/O interface module is the discrete type. This type of interface connects field i/p devices of the ON/OFF nature such as selector switches, push buttons & limit switches. III^ly o/p module connects to field devices such as lights, relays, solenoids & motor starters that require ON/OFF switching.

The classification of discrete I/O covers bit oriented i/ps & o/ps. In this type each bit of i/p or o/p represents the status of i/p or o/p.

Each discrete I/O module is powered by some field supplied voltage source. Since these voltages can be of different magnitude or type, I/O modules are available at various AC & DC voltage ratings as listed in table.

The modules themselves receive their voltage & C^t for proper operation from the backplane of the rack enclosure into which they are inserted as shown.

Backplane power is provided by the PLC module power supply & is used to power the electronics that reside on the I/O module ckt board. Module supplies ltres typically may be rated for 3A, 4A, 12A or 16A depending on type & no of modules used.

The fig. shows the block dgm for one i/p of a typical AC discrete i/p module.

The i/p ckt is composed of two basic sections: The power section & the logic section. An optical isolator is used to provide electrical isolation betn the field wiring & the PLC backplane internal circuitry.

The i/p LED turns ON or OFF indicating the status of the i/p device. Logic ckts send the digital signal to the processor. PLC backplane internal circuitry typically operates at 5VDC or less.

A simplified dgm for a single i/p of a discrete AC i/p module is shown in the fig. The operation of the ckt can be summarized as follows:

*) The i/p noise filter consisting of the capacitor & resistor R_1 & R_2 removes false signals that are due to contact bounce or electrical interference.

*) When the push button is closed, 120V AC is applied to the bridge rectifier i/p.

*) This results in a low-level DC o/p voltage that is applied a/c the LED of the optical isolator.

*) The zener diode (Z_D) sets the minimum threshold level of voltage that can be detected.

*). When light from the LED strikes the photo-
-transistor, it switches into conduction & the status of the push button is communicated in logic to the processor.

*). The optical isolator not only separates the higher AC i/p voltage from the logic ckts but also prevents damage to the processor due to line voltage transients. In addition, this isolation also helps reduce the effects of electrical noise, common in the industrial environment, which can cause erratic operation of the processor.

*). For fault diagnosis, an i/p state LED indicator is ON when the i/p pushbutton is closed. This indicator may be wired on either side of the optical isolator.

*). A PLC i/p module will have either all the i/ps isolated from each other with no common i/p connections or groups of i/ps that share a common connection.

Discrete i/p modules perform 4 tasks in the PLC control system. They:

*). Sense when a signal is received from a field device.
*). Convert the i/p signal to the correct voltage level for the particular PLC
*). Isolate the PLC from fluctuations in the i/p signals voltage or C^t.

*) Send a signal to the processor indicating which sensor originated the signal.

The fig. shows the block dgm for one o/p of a typical discrete o/p module. Like the i/p module, it is composed of two basic sections: The power section & the logic section, coupled by an isolation ckt. The o/p interface module can be thought of as an electronic switch that turns the o/p load device on & off. Logic ckts determine the o/p status. An o/p LED indicates the status of the o/p signal.

A simplified dgm for a single o/p of a discrete AC o/p module is shown.

The operation of the ckt can be summarized as follows:

*) As part of its normal operation, the digital logic ckts of the processor sets the o/p status according to the program.

*) When the processor calls for an o/p load to be energized a voltage is applied a/c the LED of the opto-isolator.

*) The LED then emits light, which switches the phototransistor into conduction.

*/. This ~~is~~ in turn triggers the Triac AC semiconductor switch into conduction allowing C^n to flow to the o/p load.

*/. Since, the triac conduces in either direction, the o/p to the load is AC.

*/. The Triac rather than having ON & OFF states, actually has low & high res. levels, resp. In its OFF state (high res), a small leakage C^n of few milliamp still flows through the trial.

*/ As with i/p ckts, the o/p interface is usually provided with LEDs that indicate the status of each o/p

*/ Fuses are normally req^d for the o/p module ~~dues~~ allowing for each ckt to be protected & operated separately

*/. The triac cannot be used to switch a DC load.

*/ For fault diagnosis, the LED o/p status indicator is on whenever the PLC is commanding that the o/p load ~~is~~ be switched on.

To protect the o/p module ckts, specified C^n ratings should not be exceeded. For controlling larger loads, such as large motors, a std control relay is connected to the o/p module. The contacts of the relay can ~~b~~ then be used ~~to~~ control a larger load or motor starter. When a control relay is used this manner, it is called an interposing relay.

Discrete o/p modules are used to turn field o/p devices either on or off. These modules can be used to control any two states. They are available in AC & DC versions & in various voltage & C^n ranges. O/p modules can be purchased with transistor, triac or relay o/p as shown in fig.

Triac o/ps can be used only for control of AC devices. Transistor o/ps can be used only for control of DC devices. The discrete relay contact o/p module using electromechanical switching can be used with AC or DC devices, but they have much slower switching time compared with solid state devices.

There are two types of DC I/O modules: Current sourcing I/O module & Current-sinking I/O module as shown in fig.

Sinking & sourcing are the terms used to describe a C^n signal flow bet^n I/O field devices & their power supply.

Field devices connected to +Ve side of the field power supply are classified as sourcing field devices. Conversely, field devices connected to the -Ve side or DC common of the field power supply are sinking field devices

If the module is a C^r sourcing module, then I/o devices must be C^r sinking devices. Conversely, If the module is specified as C^r sinking, then the connected device must be C^r sourcing.

Analog I/O Modules:

Earlier PLCs were limited to discrete or digital I/O interfaces, which allowed only on/off type devices to be connected. Today, however, a complete range of both discrete & analog interfaces are available that will allow controllers to be applied to practically any type of control process.

Discrete ~~devices are~~ I/O devices have only two states: on & off. Analog ~~I/o~~ devices represent physical quantities that can have an infinite no. of values. Common physical quantities measured by a PLC analog module include temp, speed, level, flow, wt, pressure, position, etc. Typical analog I/Os vary from 0 to 20 mA, 4 to 20 mA or 0 to 10V.

Fig. 2.22 illustrates how PLC analog I/O modules are used in measuring & displaying the level of fluid in a tank. The analog i/p interface module contains circuit necessary to accept an analog volt or C^r signal from the level transmitter field device. This i/p is converted from analog to a digital value for use by the processo

The circuitry of the analog o/p module accepts the digital value from the processor & converts it back to an analog signal that drives the field tank level meter.

Analog i/p modules normally have multiple i/p channels that allow 4, 8 or 16 devices to be interfaced to the PLC. The two basic types of analog i/p modules are <u>voltage sensing</u> & <u>C^m sensing</u>. Analog sensors measure a varying physical quantity over a specific range & generate a corresponding voltage or C^m signal.
For eg., a sensor may measure temp. over a range of 0 to 500°C & o/p a corresponding voltage signal that varies bet^n 0 & 50 mV.

Fig. 2.23 illustrates an example of a voltage sensing i/p analog i/p module used to measure temp. The connection dgm applies to an Allen-Bradley Micro Logic 4-channel analog thermocouple i/p module. A varying DC voltage in the low mV range, proportional to the temp. being monitored, is produced by the thermocouple. This voltage is amplified & digitized by the analog i/p module & then send to the processor on command from a program instruction. Because of the low volt level of the i/p signal, a twisted shielded pair cable is used in wiring the ckt to reduce unwanted electrical noise signals that can be induced in the conductors from other wiring. When using an undergrounded thermocouple, the shield must be connected to ground at the module end.

The transition of an analog signal to digital values is accomplished by an A/D converter, the main element of the analog i/p module.

Analog volt. i/p modules are available in two types: Unipolar & Bipolar.

Unipolar modules can accept an i/p signal that varies in the +Ve direction only. eg. if the field devices o/ps 0V to +10V, then unipolar modules would be used.

Bipolar signals swing b/w a max. -Ve values & max. +Ve value. Eg, if the field device o/ps -10V to +10V a bipolar module can be used.

The resolution of an analog i/p channel refers to the smallest change in i/p signal value with the per unit change in the i/p physical quantity.

-Table

When using voltage sensing analog i/p module the length of wire is important to minimize signal degrading & the effects of electromagnetic noise interference induced along the connecting conductors.

Current sensing analog i/p module, which are not as sensitive to noise as voltage signals, are typically not distance limited. C^n sensing i/p modules typically accept analog data over the range of 4mA to 20mA, but can accomodate signal ranges of -20mA to +20mA.

The analog o/p interface module receive the digital data from the processor and are converted into proportional voltage or C^n analog signals to control analog field device. The conversion of a digital signal to an analog signal is accomplished by D/A converter, the main element of the analog o/p module.

An analog o/p signal is a continuous & changing signal. Common devices controlled by a PLC analog o/p module include instruments, control valves, electronic drives, etc. that respond analog signals.

Fig. 2.25 gives the use of analog I/O modules in a typical PLC control system. Here, PLC controls the amount of fluid placed in a holding tank by adjusting the % of the valve opening. The analog o/p from the PLC is used to control the flow by controlling the amount of the valve opening. The valve is initially open 100%. As the fluid level in the tank approaches the present value, the processor adjusts the valve.

Special I/O Modules.

Many different types of I/O modules have been developed to meet special needs. They are

1) **High speed Counter module:**

The high speed counter module is used to provide an interface for applications requiring counter speeds that surpass the capability of the PLC ladder program. High speed counter modules are used to count pulses from sensors, encoders & switches that operate at very high speeds. They have the electronics needed to count independently of the processor. A typical count rate available is 0 to 100 KHz i.e the module would be able to count 1,00,000 pulses per sec.

2) **Thumbwheel Module:**

The thumbwheel module allows the use of thumbwheel switches for feeding information to the PLC to be used in the control program.

3) **TTL Module:**

The TTL module allows the transmitting & receiving of TTL (Transistor-Transistor Logic) signals. This module allows devices that produce TTL-level signals to communicate with the PLCs processor.

4/. Encoder Counter Module:-

An encoder counter module allows the user to read the signal from an encoder on a real time bases & stores this information so it can be read later by the processor.

5/ BASIC or ASCII Module:- ASCII - American Standard Code for Information Interchange

The BASIC or ASCII module runs user written BASIC & C programs. These programs are independent of the PLC processor & provide an easy, fast interface bet^n remote foreign devices & the PLC processor. Typical applications include interfaces to bar code readers, robots, printers & displays.

6/ Stepper Motor module:-

The stepper motor module provides pulse trains to a stepper motor translator, which enables control of a stepper motor. The commands for the module are determined by the program in the PLC.

7/ BCD O/p module:-

The BCD o/p module enables a PLC to operate devices that require BCD coded signals such as seven segment displays.

Intelligent I/O Modules:-

1) PID Module

2) Motion & Position Control Module.

3) Communication Modules

I/O Specifications:

Typical Discrete I/O Module Specifications:

1) Nominal I/p voltage.

2) I/p Threshold Voltages.

3) Nominal Current per ~~O~~ I/p.

4). Ambient Temperature Rating

5) I/p ON/OFF Delay

6) O/p Voltage

7) O/p Current

8) Inrush Current

9) Short Circuit Protection

10) Leakage Current

11) Electrical Isolation

12) Points per Module.

13) Backplane Current Draw.

Typical Analog I/O Module Specifications

1. Channels per Module
2. I/p Current/Voltage Ranges
3. O/p Current/Voltage Ranges
4. I/p Protection
5. Resolution.
6. I/p Impedance & Capacitance.
7. Common Mode Rejection.

Central Processing Unit (CPU)

CPU is built into a single unit in Fixed PLCs and in modular PLCs they are in the form of modules plugged into the rack.

CPU, controller & processor are all the terms used by different manufacturers to denote the same.

Processors vary in processing speed & memory options.

A processor module can be divided into two sections: The CPU section & the memory section as shown in fig. 2.36.

The CPU section executes the program & makes the decisions needed by the PLC to operate & communi with other modules.

The memory section ~~ele~~ stores the PLC program along with I/p & O/p data.

The PLC power supply provides the necessary power to the processor & I/O modules plugged into the backplane of the rack as shown in Fig. 2.37. Power supply converts 115V AC or 230V AC into the usable DC volt. reqd by the CPU, memory & I/O circuitry. PLC power supplies are normally designed to withstand momentary losses of power without affecting the operation of the PLC. <u>Hold-up time</u> which is the length of time a PLC can tolerate a power loss, typically ranges from 10 msec. to 3 sec.

The CPU contains the similar type of μP found in a PC. The CPU executes the operating system, manages memory, monitors i/ps, evaluates the user logic & turns the o/p.

The CPU of a PLC system may contain more than one processor. One advantage of using multiprocessor is that the overall operating speed is improved. Each processor has its own memory & programs, which operate simultaneously & independently. In such PLCCs, the total response time is reduced. Dual processor CPU allows transfer of control to the second processor in the event of a processor fault.

There are three modes of operation of PLC as shown in Fig. 2.38 i.e RUN, PROG & REM.

RUN Position

- Places the processor in run mode
- Executes the ladder program & energizes o/p devices
- Prevents you from performing online program editing in this position
- Prevents you from using a programmer interface device to change the processor mode.

PROG position

- Places the processor in the program mode.
- Prevents the processor from scanning or executing the ladder program & the controller o/ps are de-energized.
- Allows to perform program entry & editing.
- Prevents from using a programmer interface device to change the processor mode.

REM Position

- Places the processor in the Remote mode; either the remote run, remote program or remote test mode
- Allows to change the processor mode from a programmer interface device.
- Allows to perform online program editing

The processor module also contains circuitry to communicate with programming device. The processor performs other functions such as timing, counting, latching comparing, motion control & math functions.

Memory Design

Memory is the element that stores information, programs, & data in a PLC. Data are stored in memory locations by a process called writing. Data are retrieved from memory by what is referred to as reading.

The complexity of the program determines the amount of memory req'd. Memory elements store individual pieces of information called bits (binary digits)

The program is stored in the memory as 1's & 0s. Memory location refers to an address in the CPU's memory where a binary word can be stored. A word usually consists of 16 bits & 8 bits make up 1 byte as shown in Fig. 2.40.

Memory sizes are commonly expressed in thousands of words that can be stored in the systems. Thus 2K is a memory of 2000 words & 64K is memory of 64000 words. & 1K = 1024 bytes. Thus memory size varies from 1K to 32MB.

Memory utilization refers to the no. of memory locations reqd to store each type of instruction. One memory location is for one coil or contact. i.e., 1K of memory will allow a program containing 1000 coils & contacts to be stored in memory.

The memory of a PLC may be broken into sections that have specific functions. Sections of memory used to store the status of i/ps & o/ps are called i/p status files or tables & o/p status files or tables as shown in fig. 2.41.

These terms simply refer to a location where the status of an i/p or o/p device is stored. Each bit is either a 1 or 0, depending on whether the i/p is open or closed. A closed contact would have binary 1 stored in its respective location on the i/p table, whereas an open contact would have a '0' stored. A lamp that is ON would have a 1 stored in its respective location in the o/p table, whereas a lamp that is OFF would have a '0' stored. I/p & o/p image tables are constantly being revised by the CPU. Each time a memory location is examined, the table changes if the contact or coil has changed state.

Memory Types:

Memory can be placed into two general categories - Volatile & non-volatile.

Volatile memory will lose its stored information if all power is lost or removed.

Non-volatile memory has the ability to retain stored information when power is lost or removed. As the name implies, PLC have programmable memory that allows users to develop & modify control programs. This memory is made non-volatile, so that if power is lost, the PLC holds its programming.

- ROM (Read Only Memory):
- RAM (Random Access Memory) or Read/Write (R/W) Memory
- EPROM (Erasable Programmable Read-Only Memory).
- EEPROM (Electrically Erasable " " " ")
- Flash EEPROM (" " " " ").

Programming Terminal Devices:

A programming terminal device is needed to enter, modify & troubleshoot the PLC program.

- Handheld type programming device
- Personal Computer (PC) in conjunction with manufacturer's programming software.

Recording & Retrieving Data.

- Printers.
- LCD or LED window screen
- memory cartridge.

Human Machine Interfaces (HMIs)

HMI can be connected to communicate with a PLC & to replace push buttons, selector switches, pilot lights, thumb wheels, & other operator control panel devices.

Luminescent touch-screen keypads provide an operator interface that operates like traditional hardwired control panels.

HMIs give the ability to the operator & to management to view the operation in real time. Through PC-based setup software, you can configure display screens to:

- Replace hardwired push buttons & pilot lights with realistic-looking icons. The m/c operator need only touch the display panel to activate the push buttons.
- Show operations in graphic format for easy viewing.
- Show alarms, complete with time of occurrence & location.
- Display variable as they change over time.

Eg: Allen-Bradley Pico GFX-70 controller

Number Systems & Codes

1) Decimal System

- Has a base 10.
- Base represents total no. of different symbols or digits used by the system.
- Symbol with largest value (9) is 1 less than base.

eg:

2) Binary System:

- Has a base 2.
- No. of digits 0 & 1.
- Table 3.1.
- eg: Conversion of binary to decimal.
- Bit.
- word (16 bits or 32 bits)
- Byte → 8 bits.
- eg.
- 1K word = 1024 words = 1024 x 16 bits = 16,384 bits using 16 bit
  = 1024 x 32 bits = 32,768 using 32 bit words
- Conversion of decimal to binary.
- eg: 47 = 101111.

→ Fig. 3.7: O/p status file for Allen bradley SLC500.

— Negative Numbers

3) Octal System

- Base 8.

4) Hexadecimal System

- Base 16.

5) Binary Coded Decimal (BCD) System:

→ 4 bits for each decimal digit (0-9).

→ eg:- 7863

6) Gray Code:

- Type of binary code.

- eg:

7) ASCII Code: (American Standard Code for Information Interchange).

- Alphanumeric code.

- 10 numerics, 26 lower & upper case letters, 25 special characters

Parity Bit:

- Additional bit.

- 0 or 1

- Odd parity & Even parity.

- eg.

Binary Arithmatic

- Addition
- Subtraction
- Multiplication
- Division

Fundamentals of Logic

Binary concept

- Binary principle.
- Logic gate
- ~~A~~ Ex: AND, OR.

AND, OR & NOT Functions:

AND:-

OR:

NOT:

Basics of PLC Programming

Processor Memory Organization:

WKT, even though the fundamental concepts of PLC programming are common to all manufacturers because of differences in memory organization, I/O addressing & instruction set, PLC programs cannot be interchangeable among PLC's of different makers.

Alen-Bradley PLCs have two different memory structures: Rack based systems & tag based systems. Let's discuss only ~~Rack based~~ memory organization of rack based system in this chapter.

Memory organization tells information about the way a PLC divides the available memory into different sections.

The memory space can be divided into two broad categories: Program files & data files.

Program files are the part of the processor memory that stores the user ladder logic program. The program covers the most of the total memory of a given PLC system. It contains the ladder logic that controls the m/c operation.

The data files store the information needed to carry out the user program. This includes information such as the status of i/p & o/p devices, timer & counter values, data storage & so on.

Contents of the data table can be divided into two categories: status data & numbers or codes. Status is ON/OFF type of information represented by 1's & 0's, stored in unique bit locations. Number or code information is represented by groups of bits that are stored in unique byte or word locations.

Fig. 5.1 shows the program & data file organization for the SLC500 controller. The contents of each file are as follows:

Program Files

Program files are the areas of processor memory where ladder logic programming is stored. They include:

*) System functions (file 0) - This file is always included & contains various system related & user-programmed information such as processor type, I/O configuration, processor file name & password.

*) Reserved (file-1): This file is reserved by the processor & is not accessible to the user.

*) Main ladder program (file-2) - This file is always included & contains user programmed instructions that define how the controller is to operate.

*) Subroutine ladder program (file 3-255) —

These files are user created & are activated according to subroutine instructions in the main ladder program file.

Data Files:

The data file portion of the processor's memory stores i/p & o/p status, processor status, the status of various bits & numerical data.

The data files include.

*) Output (file 0.)

*) Input (file 1.)

*) Status (file 2.)

*) Bit (file 3.)

*) Timer (file 4.)

*) Counter (file 5.)

*) Control (file 6.)

*) Integer (file 7.)

*) Reserved (file 8.)

*) Network communications (file 9.)

*) User-defined (files 10-255)

The I/O address format for SLC family of PLC is as shown in Fig 5.2. It consists of 3 parts:

Part-1:

Part-2

Part-3.

In Allen Bradley PLC5-controller, there are 1000 program files. They are set up ~~in two ways~~ as follows.

i. Main LLP is stored in file 2 & file 3-999 are assigned to subroutines.

~~ii~~

Fig. 5.3 shows a typical data file memory organization for an Allen Bradley PLC-5 controller.

Typical addressing formats for the PLC-5 controller is as follows.

*) O/P data file & I/P data file.

*) Status data file.

*) Bit data file.

*) Timer file.

*) Counter file.

*) Control file.

iv) Integer file.
v) Floating point file.
vi) Data files 9-999

The i/p image ~~data~~ table file. is that part of memory allocated to store on/off status of connected discrete i/ps. Fig. 5.4 shows the connection of an open & closed switch to the i/p image table file through the i/p module. Its operation is as follows:

The o/p image table file. is that part of memory allocated to storing the actual on/off status of connected discrete o/p's. Fig. 5.5 shows a typical connection of two pilot lights to the o/p image table file through the o/p module. Its operation ~~is~~ can be summar[ized] as follows:

Program Scan

During each operating cycle, the processor reads all the i/ps, takes these values & energizes or deenergizes the o/ps according to the user progr[am]. This process is known as a <u>program scan cycle</u>.

Fig.5.7 shows a single PLC operating cycle consisting of i/p scan, program scan, o/p scan & house keeping duties.

Since, the i/ps can change at any time it constantly repeats this cycle as long as the PLC is in RUN mode.

The time it takes to complete a scan cycle is called the <u>scan cycle time</u> & indicates how fast the ~~cotto~~ controller can react to changes in i/ps. The time reqd to make a single scan varies from 1 ms to 20 ms.

If the i/p status changes ~~before~~ within its scan cycle time, then processor will not respond to such ~~can~~ change until its scan time completes.

For eg: If it takes 8 ms for the CPU to scan a program & i/p contact is opening & closing every 4 ms, then the program will not respond to the contact changing sta[te]

The scan time is a function of the following

* The speed of the processor module.
* The length of the ladder program.
* The type of instructions executed.

The actual scan time is calculated & stored in the PLCs memory.

The scan is normally a continuous & sequential process of reading the status of i/ps, evaluat the control logic & updating the o/ps.
Fig. 5.8 shows an overview of the data flow during the scan process.
For each rung executed, the PLC processor will:
Refer P.No 77.

Fig. 5.9 shows the scan process applied to a simple single rung program. The operation of the scan process can be summarized as follows:
Refer. P.No. 77-78.

Ladder programs process inputs at the beginning of a scan & o/ps at the end of a scan as shown in Fig. 5.10. For each rung executed the PLC processor will:

Refer. P.No 78.

There are two types of scan pattern as shown in fig 5.11.: Horizontal scan & vertical scan.

PLC Programming Languages

The term PLC programming language refers to the method by which the user communicates information to the PLC.

The std IEC 61131 was established to standardize the multiple languages associated with PLC programming by defining the following four std. languages as shown in Fig. 5.12.

*) Ladder Diagram (LD)

*) Function Block Diagram (FBD)

*) Sequential Function Chart (SFC)

*) Instruction List (IL)

*) Structured Text (ST)

Relay type instructions

The ladder dgm language is basically a symbolic set of instructions used to create the controller program. These ladder instruction symbols are arranged to obtain the desired control logic that is to be entered into the memory of PLC. Since the instruction set is composed of contact symbols, ladder diagram language is also referred to as contact symbology.

Representations of contacts & coils are the basic symbols of the ladder logic diagram instruction set.

The three fundamental instructions that are used to translate relay control logic to contact symbol logic are Examine If closed (XIC), Examine If Open & Output Energize (OTE).

The symbol for the Examine If closed (XIC) instruction is shown in fig. 5.18.

The XIC instruction, which is also called the Examine-on instruction, looks & operates like a normally open relay contact. Each XIC instruction is associated with a memory bit ~~to~~ linked to the status of an i/p device or an internal logical condition on a rung. This instruction asks PLC's processor to examine if the contact is closed. It does this by examining the bit at the memory location specified by the address in the following manner: Refer p.No. 81.

The symbol for the Examine If Open (XIO) instruction is shown in Fig. 5.19. The XIO instruction, which is also called Examine Off instruction looks & operates like a normally closed relay contact. Each XIO instruction is associated with memory bit linked to the status of an i/p device or an internal logical condition in a rung. This instruction asks PLCs processor to examine if the contact is open. It does this by examining the bit at the memory location specified by the address in the following manner. Ref P.No. 82.

The symbol for the O/P Energize (OTE) instruction is as shown in Fig. 5.20. The OTE instruction looks & operates like a relay coil & is associated with a memory bit. This instruction signals the PLC to energize & de-energize the o/p.

~~The processor makes this instruction true~~

The operation of the o/p energize instruction can be summarized as follows:

Refer P.No. 82.

As shown in Fig. 5.21 the action of the PL[C] with NO & NC can be observed.

For an o/p to be activated or energized, at lea[st] one left to right true logical path must exist, as illustrated in Fig. 5.23.

Instruction Addressing

To complete the entry of a relay-type instruction, we must assign an address to each instructi[on]. This address indicates what PLC i/p is connected to what i/p device & what PLC o/p will drive what o/p devi[ce].

The addressing of real i/ps & o/ps, int[ernal] depends on the PLC model used. Addressing formats can vary from one manufacturer to other. These addresses can be represented in binary, decimal, octal or hexadeci[mal] depending on the number system used by the PLC.

Fig. 5.24 shows the addressing format for a[n] Allen Bradley SLC 500 controller.

Addresses contain the slot number of the module where the i/p or o/p devices are connected. Addresses are formatt[ed] as file type, slot number & bit.

Fig. 5.25 shows the I/O connection diagram in which i/ps & o/ps are typically represented by squares & diamonds resp.