# UNIT 20
# INSTRUCTOR'S MANUAL

## PLC INTERNAL OPERATIONS

1. Virtually all of the information contained in the background section cannot be observed directly because the PLC's operations take place within the enclosed controller body. Indirect evidence of the PLC's internal operations can be gained by monitoring programs as they are run.

2. Throughout this unit it is appropriate to draw on the students' knowledge of personal computers, DOS systems and the like. The operation of the PLC is directly analogous to that of PCs. The PLC has more specifically defined (and limited) functions.

# UNIT 20

# PLC INTERNAL OPERATIONS

## Objectives

Upon completion of this unit the student will be able to:

1. Describe the operation and use of an opto-isolator.
2. Explain the internal operations of input and output modules.
3. Describe the function of the processor.
4. Describe the sections and functions of memory.
5. Describe the sequence of events for a single program scan.

## Background

The three components of a PLC are the input module, the output module, and the controller or processor. The input and output modules are the controller interfaces to the outside world.

### Input and Output Modules

Input Modules. There are two types of input modules, the A.C. type and the D.C. type. Both of these input modules use *opto-isolators* to keep the voltage coming to the inputs separate from the processor's circuit boards.

An opto-isolator is an optical relay which takes an incoming electrical signal and turns it into a light beam. The light beam then travels across a small gap and activates a light-sensitive switch, called a *photo-transistor*. The switch connects to the processor. So with opto-isolators the only connections between the input and output modules and the processor are light beams. Opto-isolators are used to protect the processor from the high voltages connected to the input and output modules, for these high voltages will destroy the circuit boards in the controller.

Figure 20-1 shows the components of an opto-isolator. The *LED* (*light emitting diode*) is the component which creates the light beam. The photo-transistor is the light-activated switch. When power is applied to the LED it lights up. The light from the LED shines on the photo-transistor, causing it to conduct electricity.

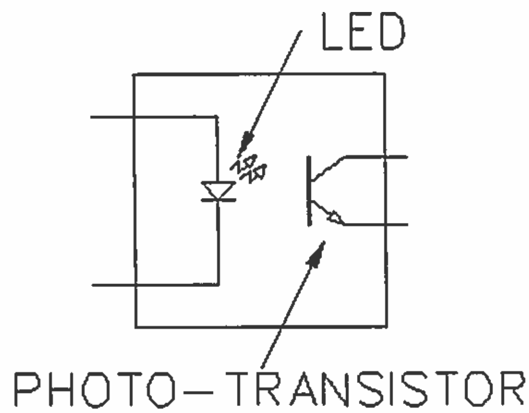



Figure 20-1
Internals of an Opto-Isolator

Figure 20-2 shows how an opto-isolator can be used to make a connection between a switch and a light bulb. Notice that both the switch and the light bulb have their own power supplies. Two power sources are necessary to isolate one side of the opto device from the other.

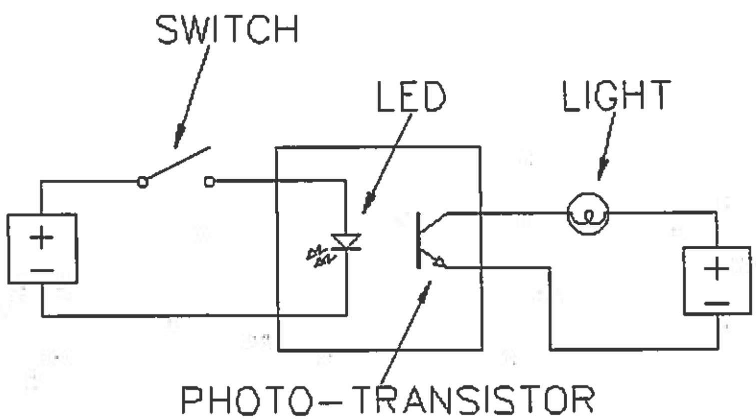
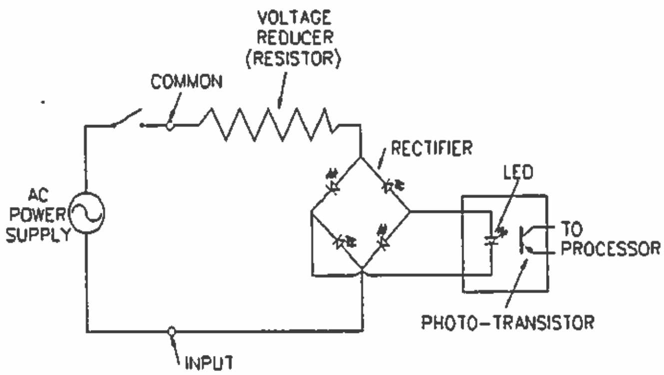



Figure 20-2
Simple Opto Circuit

The LEDs in the opto-isolator can only be activated by a D.C. voltage. So, for the terminals on an A.C. input module there must be a circuit to turn the A.C. voltage into D.C. voltage. This circuit is called a *rectifier*. The rectified voltage is then reduced to a level that the opto-isolator can use (2 VDC to 5 VDC).

In a D.C. input module the voltage does not need to be rectified. It only needs to be reduced to a usable level. So only a voltage reducer (a *resistor*) is needed. Figure 20-3 shows simplified examples of the circuits inside A.C. and D.C. input modules.



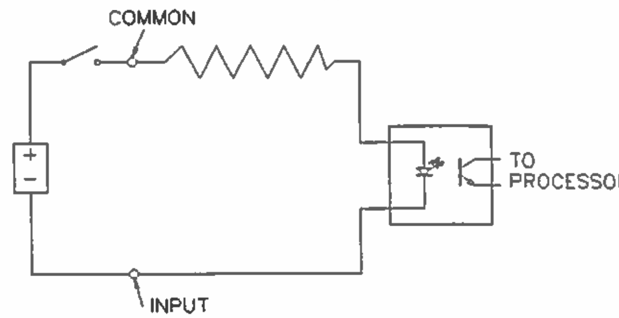




Figure 20-3
Simplified A.C. and D.C. Input Circuitry

<u>Output Modules with Relays</u>. In most PLCs the output module uses electro-mechanical relays instead of opto-isolators to communicate with the output devices. Electro-mechanical relays are chosen because they can carry larger currents than solid state devices.

The three main parts of an electro-mechanical relay are the coil, the armature, and the contacts, as shown in Figure 20-4. When voltage is applied to the coil, it produces a magnetic field which attracts the armature. The movement of the armature causes the set of contacts (a switch) to close.

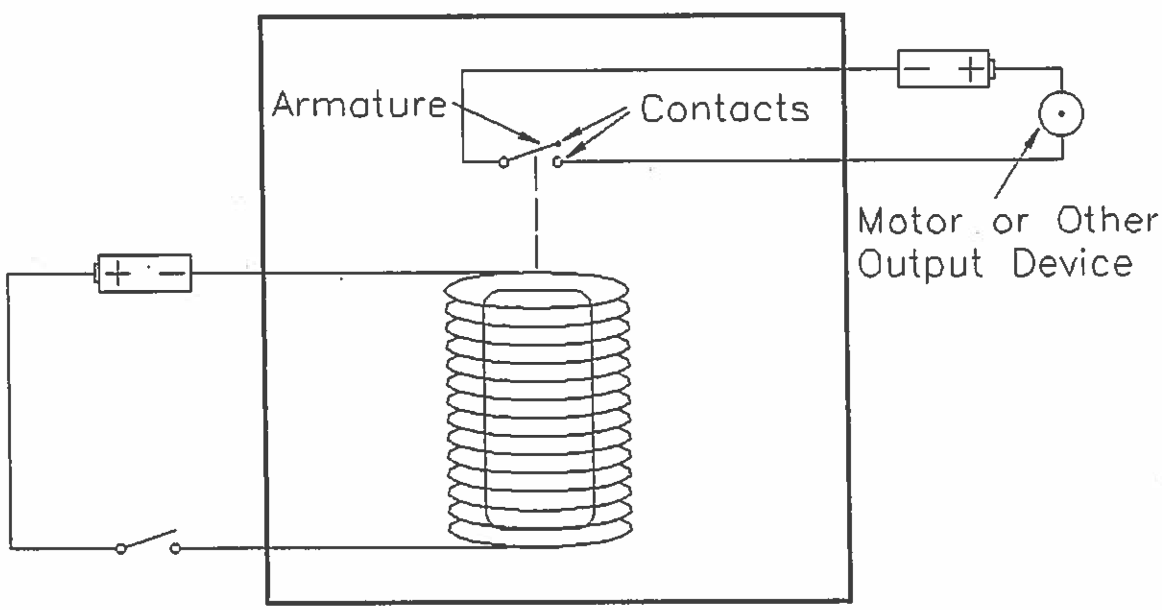



Figure 20-4
Electro-Mechanical Relay

Output Modules with Opto-Isolators. Some PLC output modules also use opto-isolators. The opto-isolators work on the same principles as the input modules. In output modules the controller turns on the LED; the photo-transistor is used to turn on the output device. Figure 20-5 shows a simplified version of an output module.

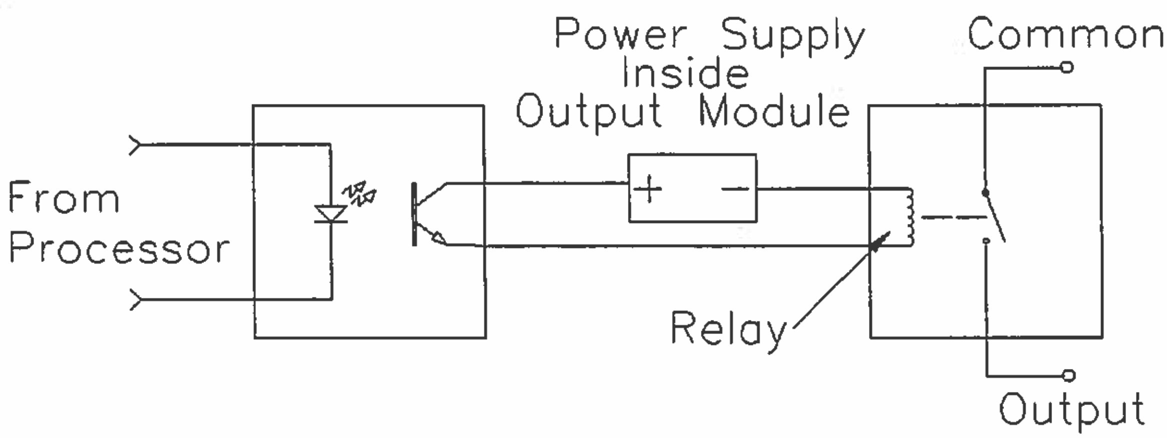



Figure 20-5
Simplified Output Module Circuit

Processor

The processor which sits in between the input and output modules is nothing more than a computer. It works along the same principles as the computer boards in personal computers. However, the processor performs a more specific function. The processor must examine the *status* (on/off condition) of the inputs connected to it and turn outputs on or off in response to those inputs.

The processor, depending on the size of the PLC, may be a single physical unit or may be divided into several physical unit within the PLC body. No matter how it is structured physically, the processor is dedicated to three discreet functions, the *central processing unit* (*CPU*), the *arithmetic logic unit* (*ALU*), and the *memory*. The connections between the input, output, CPU, ALU and memory are shown in Figure 20-6. The arrows indicate the direction in which information flows.

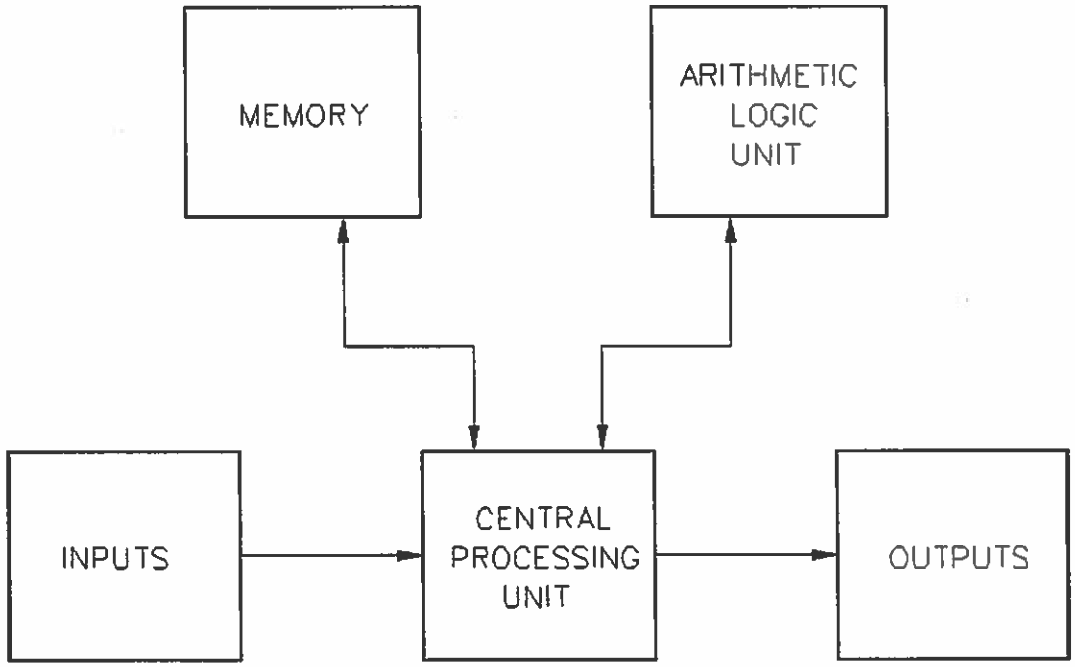



Figure 20-6
System Connections

The CPU is the brain behind the processor. Its functions are to make all decisions and to direct tasks for ALU and memory processing. The CPU determines, based on its program, what should be done in ALU and memory and when it should be done. The ALU function is to perform mathematical and logical calculations.

The memory is sub-divided into two functions, the *Random Access Memory* (*RAM*) and the *Read Only Memory* (*ROM*). The ROM is a permanent set of instructions which can not be erased. It is the information that the processor uses to understand the *commands* it receives from the operator and to test for errors in a program. If you are familiar with computers, you can think of the ROM in the processor as the DOS disk you must first put in the computer to get it running.

The RAM is erasable. It is the area in which programs are written. The RAM is made up of thousands of locations used to store information in either the *user memory* or the *register table*.

The register table is the area of memory which stores the status of the inputs and outputs. It also holds information such as internal relay status, and the times and unit counts related to timers and counters, respectively. The register table is divided into two sections, the input register and the output register. The terminal connections on the input and output modules connect through an opto-isolator directly to spaces within the register tables (see Figure 20-7). Each of the spaces in the tables has a number associated with it, called an *address*.

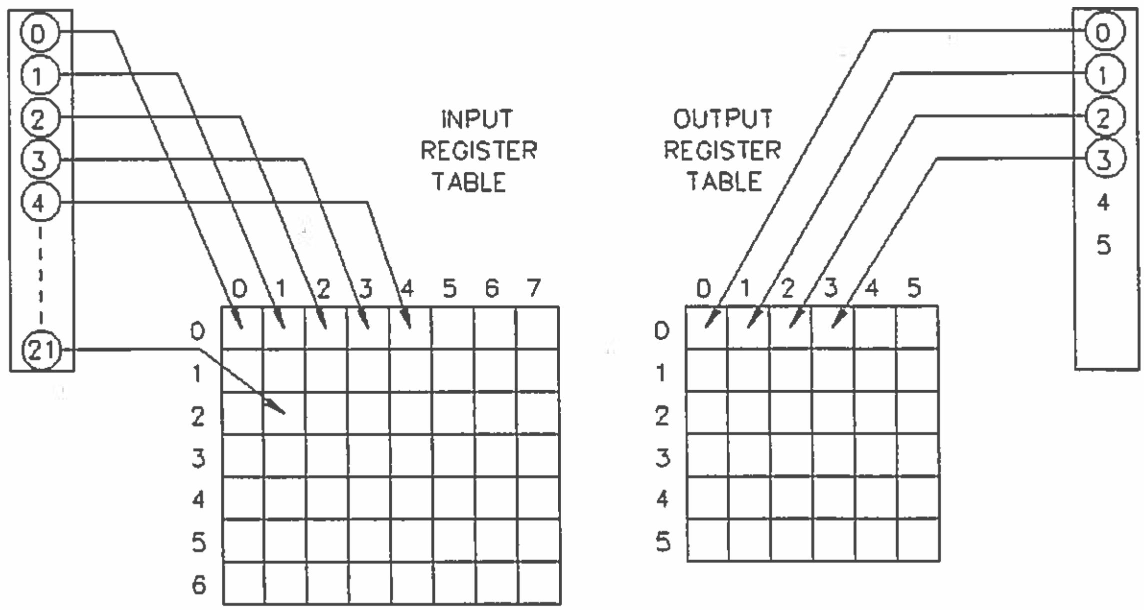



Figure 20-7
Register Tables

The user memory is the area in which programs are stored. It holds the set of instructions used by the processor to link the input and output modules together. Each register table and the user memory are hooked together through the processor, as in Figure 20-8.

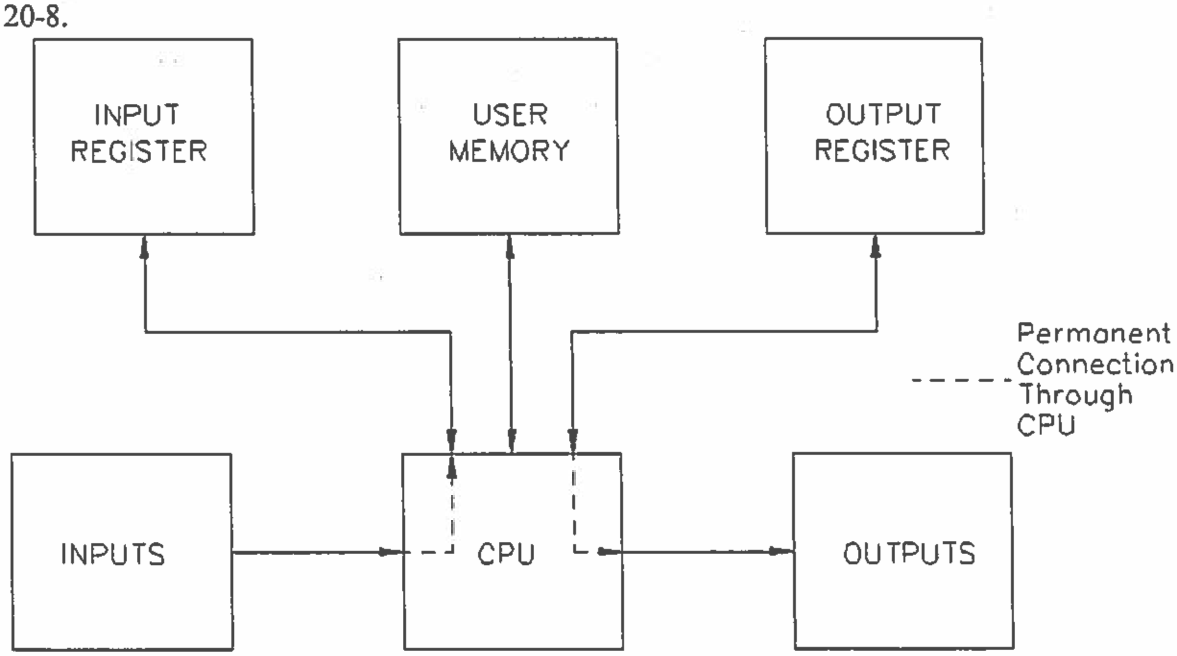



Figure 20-8
Memory Connections

Figure 20-9 shows the connections in the controller from input module to output module. This diagram can be used to trace PLC operation from input device to output device.

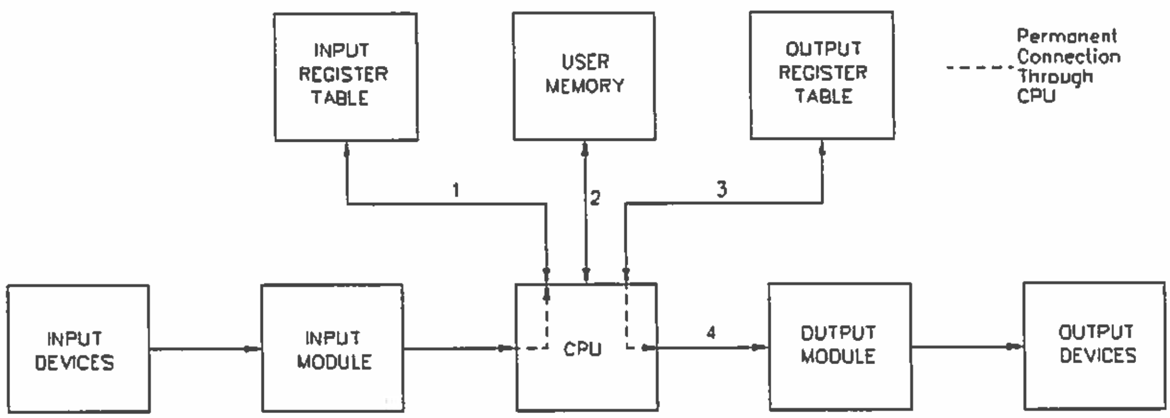



Figure 20-9
Controller Operation

The controller completes three basic operations in a fraction of a second.

1. Reads status of inputs from input register table.
2. Executes user program step by step, in order entered, changing output settings (on/off) according to input status and program instructions.
3. Updates output register table so status of outputs matches any new settings.

These three operations together make up the *scan* cycle of the PLC. This cycle is repeated several thousand times per second.

The cycle time is a very important aspect of precision control situations. For example, a flywheel spins at such a high speed that it activates a sensor every 30 milliseconds. To keep track of the rotations of the flywheel with a PLC, the scan cycle must be less than 30 milliseconds long so as not to miss a count. The scan time of a PLC can be measured by a special PLC program. You will learn how to measure *scan time* later in your studies of the PLC.

Once you have completed your study of the Background materials, please complete the following Questions as a self-check of your understanding.

**Questions**

1. What is an opto-isolator and how does it work?

*An opto-isolator consists of an LED and an photo-transistor. The LED, when activated, emits a small amount of light. This light is detected by the photo-transistor, which is then activated. The opto-isolator takes an electrical input and turns it into an electrical output without allowing any electrical contact between the two devices it is connecting.*

2. Explain the functions of the three parts of a processor.

*A processor is made up of a central processing unit (CPU), an arithmetic logic unit (ALU), and the memory (RAM and ROM). The CPU directs the ALU and memory how and when to act on inputs. The ALU does mathematical calculations and solves logic problems. In memory, RAM stores the changeable operating information, such as programs. ROM stores the information which allows the CPU to interpret the operator's commands and to determine the correctness of a program.*

3. Switch 0 is connected to input 001 on a PLC and output 015 on the PLC is connected to light 3. The PLC's program instructs the controller to turn off light 3 when switch 0 is turned on.

Describe the sequence of events which occur in the PLC when switch 0 is turned on.

*Switch 0 activates input 001. Input 001 supplies power to an opto-isolator whose photo-transistor is activated. This sends an electrical signal to the input register table to change the status of input 001 from off to on. The processor, on its next scan of the input register table, recognizes the status change for input 001. The CPU, knowing that output 005 should be off when input 005 is on, changes the status of output 005 to off. This in turn de-activates the electro-mechanical relay for the output itself. When output 005 is de-activated, light 3 turns off.*

4. How are the operations of input and output modules the same? Different?

*Input and output modules connect the CPU to input and output devices, respectively. Both modules use opto-isolators to separate the CPU from the relatively high voltages used to run input and output devices. Both modules are connected to register tables which hold the information indicating input and output statuses. The input module responds to input status changes. The output module responds to CPU controlled status changes.*

5. Define the following terms:

a. RAM: *Random access memory - holds programs and other data which are changeable in memory.*

b. ROM: *Read only memory - stores permanent memory for such things as keystroke meanings and erroneous commands.*

c. LED: *Light emitting diode - an electrical element which emits light; some LEDs are parts of opto-isolators.*

d. CPU: *Central processing unit - reads status of inputs, executes programs, checks output status against output register table and updates register table.*

e. User Memory: *The part of the memory available to the user to store programs.*

f. Register Table: *Used to store status information about each specific input or output address on a PLC.*

6. What are the main parts of an electro-mechanical relay and how do they work together?

*Coil, armature, contacts. When the coil is activated, it creates an electro-magnetic field which attracts the armature. As the armature moves, it touches the two electrical contacts, bridging the gap between them. This bridge allows electricity to flow through the relay. In a normally closed relay, the coil attracts the armature away from the contacts, breaking the flow of electricity.*