**Lesson 15**

**Title of the Experiment:**  Programmable Logic Controllers
(Activity number of the GCE Advanced Level practical Guide –27)

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**Introduction**

As we introduced in the previous section microprocessors can be used to control machines and processes. For example automatic washing machines use microprocessor based control system. A *programmable logic controller* (PLC) is a special form of microprocessor based controller that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes. PLC's are designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. The term *logic* is used because programming is primarily concerned with implementing logic and switching operations. PLC's are optimized to control industrial environment.  Some advantageous of using PLC's are;

- PLC is designed to withstand vibration, temperature, noise in an industrial environment
- Inbuilt interface for input and output devices
- Programing language is based on logic and switching operations (easy to understand)

Similar to the microcontroller, PLC consists of a CPU, memory and I/O interface. A programmer (programming device) and power supply for a PLC are also attached to the system. The I/O interface in the PLC system was designed to deliver high current to operate a relay switch or similar device. Two or more PLC's can be connected using communication interface of the PLC. This helps to establish supervisory systems to monitor all processes from one place. A block diagram of PLC system is shown in figure 1.
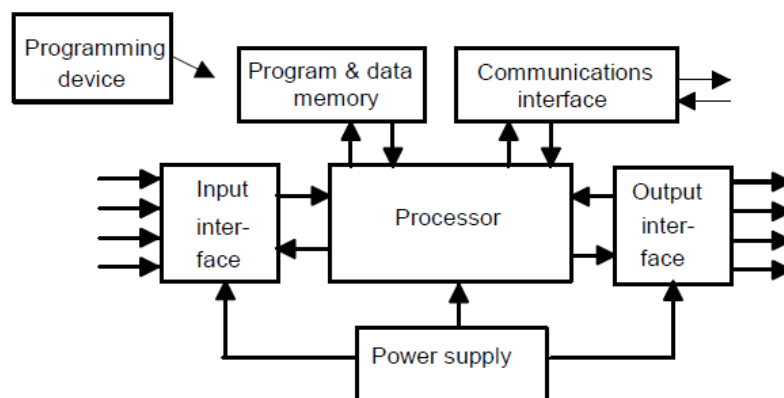


**Figure 1:** Block diagram of a PLC

Generally PLC might have 6,8,12 or 24 inputs and 4, 8 or 16 outputs with a memory. Several discrete elements can be connected to the PLC such as push buttons, selector switches, relay contacts, level switches, limit switches and various sensors.

Figures 2 and 3 illustrate respectively a photograph and a labelled diagram of the PLC that will be discussed in this class.
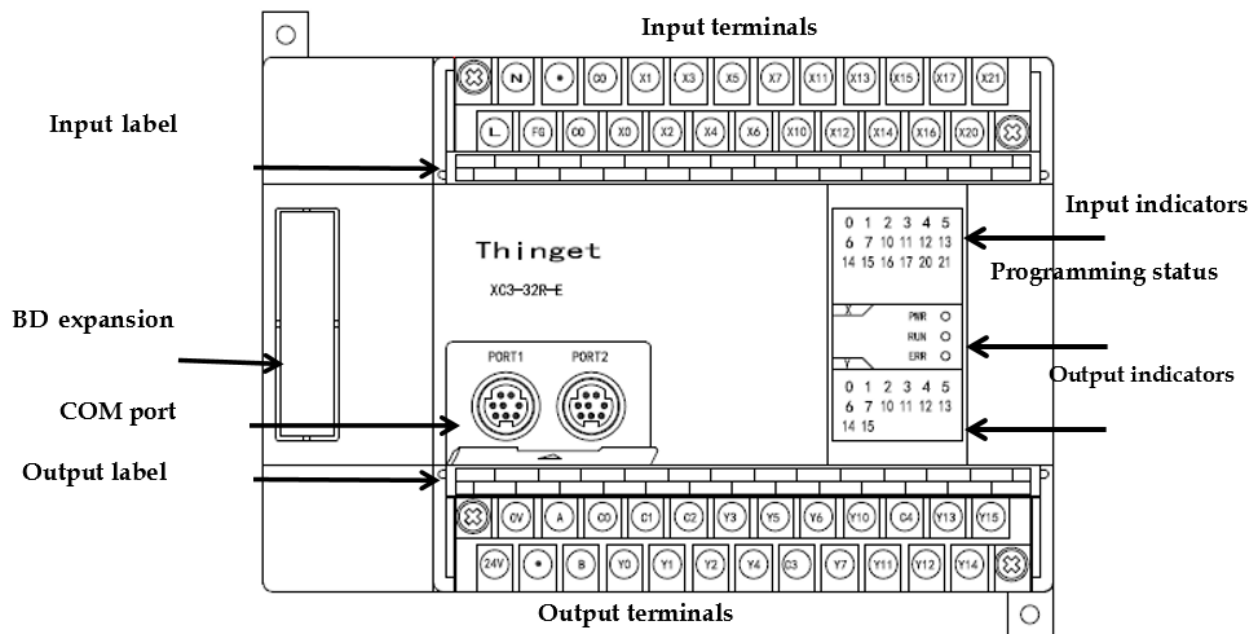
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**Figure 2:** Picture of PLC



**Figure 3:** Labeled diagram of PLC

## Introduction to Ladder Programming

The IEC 1131-3 is the international standard for ladder programming. The IEC 1131-3 programming languages are ladder diagrams (LAD), instruction list (IL), sequential function charts (SFC), structured text (ST), and function block diagrams (FBD). PLC can be programed using List or Ladder method but in this course only consider the ladder programing. In addition to that functional block programming

Ladder diagrams are specialized schematics commonly used to document industrial control logic systems. They are called "ladder" diagrams because they resemble a ladder, with two vertical rails (supply power) and as many "rungs" (horizontal lines) as there are control circuits to represent. A simple ladder diagram controlled by a hand switch is shown in figure 4.
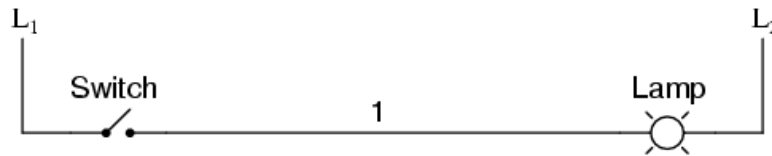
**Figure 4:** A simple ladder diagram

The $L_1$ and $L_2$ are referring to the supply rails and has no relation with the standard inductor symbol (L). In this notation $L_1$ is the live (hot) conductor and $L_2$ is the neutral (grounded) conductor. The power lines, or rails as they are often termed, are like the vertical sides of a ladder with the horizontal circuit lines like the rungs of the ladder. The horizontal rungs show only the control portion of the circuit. In this way any electrical circuit can be represented by a ladder diagram. Figure 5 illustrates analogue between these two circuits.
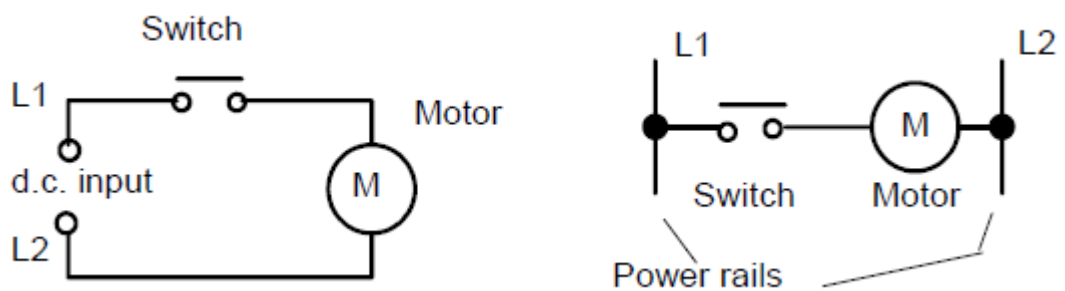


**Figure 5:** An analogue between circuit diagram and ladder diagram

A ladder diagram is read from left to right and top to bottom. PLC reading starts from left side of the first rung and after the first rung reading of the second rung starts from the left side.
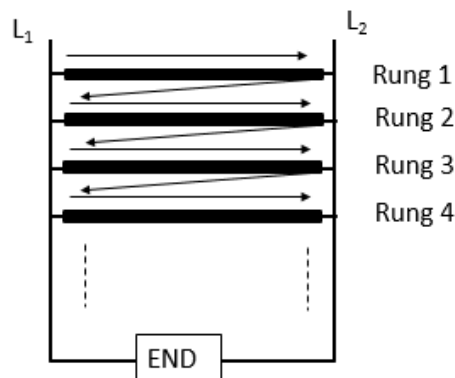


**Figure 6:** Reading pattern of ladder diagram

The reading pattern is shown in figure 6. A last or end rung is designated by "END" or "RET". The program is returned back if it is denoted as "RET". Each rung must be started with one or more inputs and end with at least one output.

In any type of PLC, input and output devices are labeled according to the IEC-1131-3 symbols as shown in figure 7.
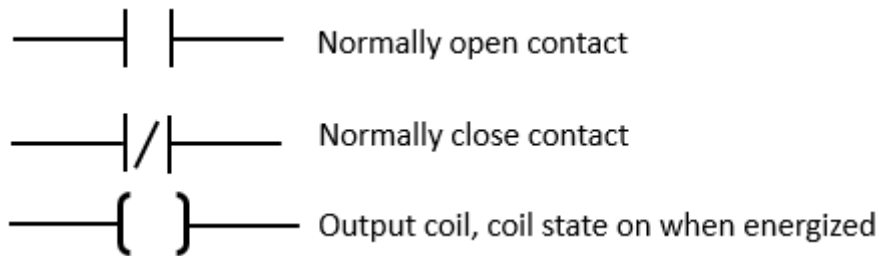
**Figure 7:** Symbols used in ladder diagrams

PLC manufacturer provides output and input labels with the product. This label represents the memory address of a particular device. The PLC module used in this experiment, input relay starts with 'X' followed by octal number (X000 to X007). First zero (MSB) explains that the system contains only a base unit. When the system contains more than one module X100 refers to the address of the first module and X200 refers the address of the second module and so on. In a similar way the output relays are denoted by symbol Y.
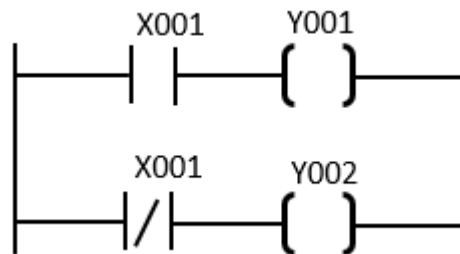


**Figure 8:** Ladder diagram with input and output devices

In the above diagram (figure 8), Y001 provides an output only when X001 is activated otherwise Y002 provides an output. Like input and output denoted by X and Y there are a few other device ID's incorporated with the PLC. Please read the following table, it shows other possible device ID's related to PLC. Specific prefix and memory address for each item. As example counters start with C and timers starts with T and the address (table 1).

Example 1

In the following example (figure 9), a program test lamp is switched on when the pump is running and the pressure is satisfactory or the test switch is closed.
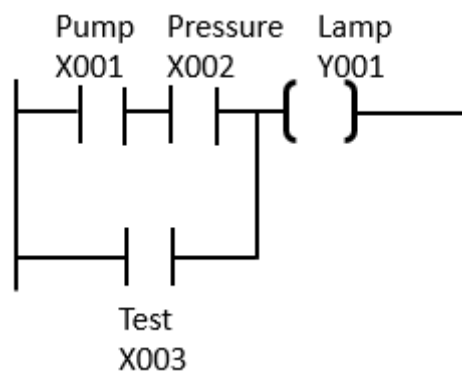


**Figure 9:** Ladder diagram for example 1

**Table 1:** Mnemonics used in ladder programing

| Mnemonic | Name | Bound | | | points | | |
|---|---|---|---|---|---|---|---|
| | | 14 points | 24\32 points | 48 \60 points | 14 points | 24\32 points | 48 \60 points |
| X | Input relay | X000~X007 | X000~X015 X000~X021 | X000~X033 X000~X043 | 8 points | 14\18 points | 28\36 points |
| Y | Output relay | Y000~Y005 | Y000~Y011 Y000~Y015 | Y000~Y023 Y000~Y027 | 6 points | 10\14 points | 20\24 points |
| M | Interior relay | M0~M2999 【M3000~M7999】 | | | 8000 | | |
| | | M8000~M8511 for special using | | | 512 | | |
| S | Flow | S0~S511 【S512~S1023】 | | | 1024 | | |
| T | Timer | T0~T99: 100ms not accumulation | | | 620 | | |
| | | T100~T199: 100ms accumulation | | | | | |
| | | T200~T299: 10ms not accumulation | | | | | |
| | | T300~T399: 10ms accumulation | | | | | |
| | | T400~T499: 1ms not accumulation | | | | | |
| | | T500~T599: 1ms accumulation | | | | | |
| | | T600~T618: 1ms with interruption precise time | | | | | |
| C | Counter | C0~C299: 16 bits forth counter | | | 635 | | |
| | | C300~C598: 32 bits forth/back counter | | | | | |
| | | C600~C634: high-speed counter | | | | | |
| D | Data Register | D0~D3999 【D4000~D7999】 | | | 8000 | | |
| | | For special usage D8000~D8511 | | | 512 | | |
| FD | FlashROM Register | FD0~FD1535 | | | 1536 | | |
| | | For special usage FD8000~FD8511 | | | 512 | | |

**Experiment 1**

**Standard logic functions**

There are many control situations requiring actions to be initiated when certain combinations of conditions are realized. Standard logic functions are the fundamental building blocks of any logic control device.

**Learning outcome**:

At the end of the experiment, the student will be able to implement logic gates and demonstrate logic operations using PLC.

**Procedure:**

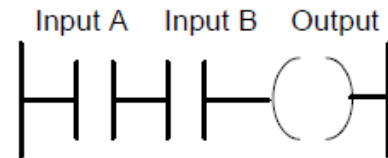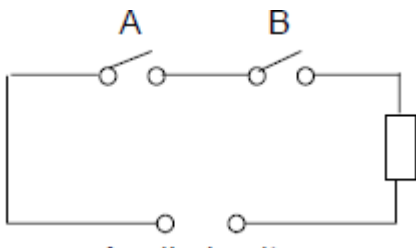Connect the PLC into the computer. Power the PLC and draw the following ladder circuits one by one.

Physical diagram                                         Ladder equivalent

(a)



(b)
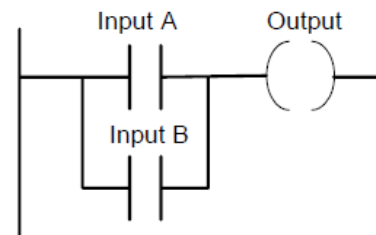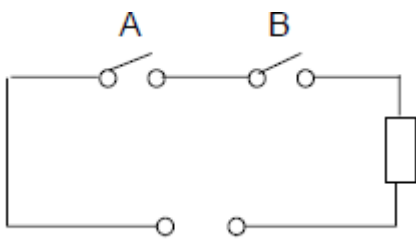


(c) Ladder circuit                                       (d) Ladder circuit

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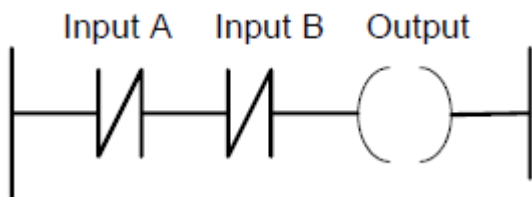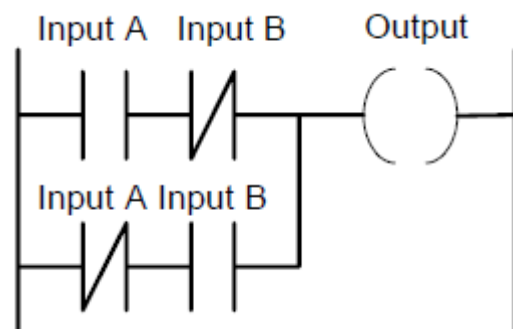
**Observations:**

(a)

| A | B | Output |
|---|---|--------|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(b)

| A | B | Output |
|---|---|--------|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(c)

| A | B | Output |
|---|---|--------|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

(d)

| A | B | Output |
|---|---|--------|
| 0 | 0 | |
| 0 | 1 | |
| 1 | 0 | |
| 1 | 1 | |

**Conclusions:**

**Circuit (a)**

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**Circuit (b)**

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**Circuit (c)**

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**Circuit (d)**

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**Experiment 2**

**Output device control**

Output is on as long as the push button is pressed.

**Learning outcome**:

At the end of the experiment, the student will be able to demonstrate skills on operating output devices attached to the PLC.

**Procedure:**

Connect the power supply to the L, N terminals. Connect "COM terminal on basic units and expansion together. Note that 24V, COM is a power supply which can deliver 400mA/DC24V therefore do not connect 24V to these terminals. Connect the push button to the input and indicator lamp to the output as shown in figure 10.
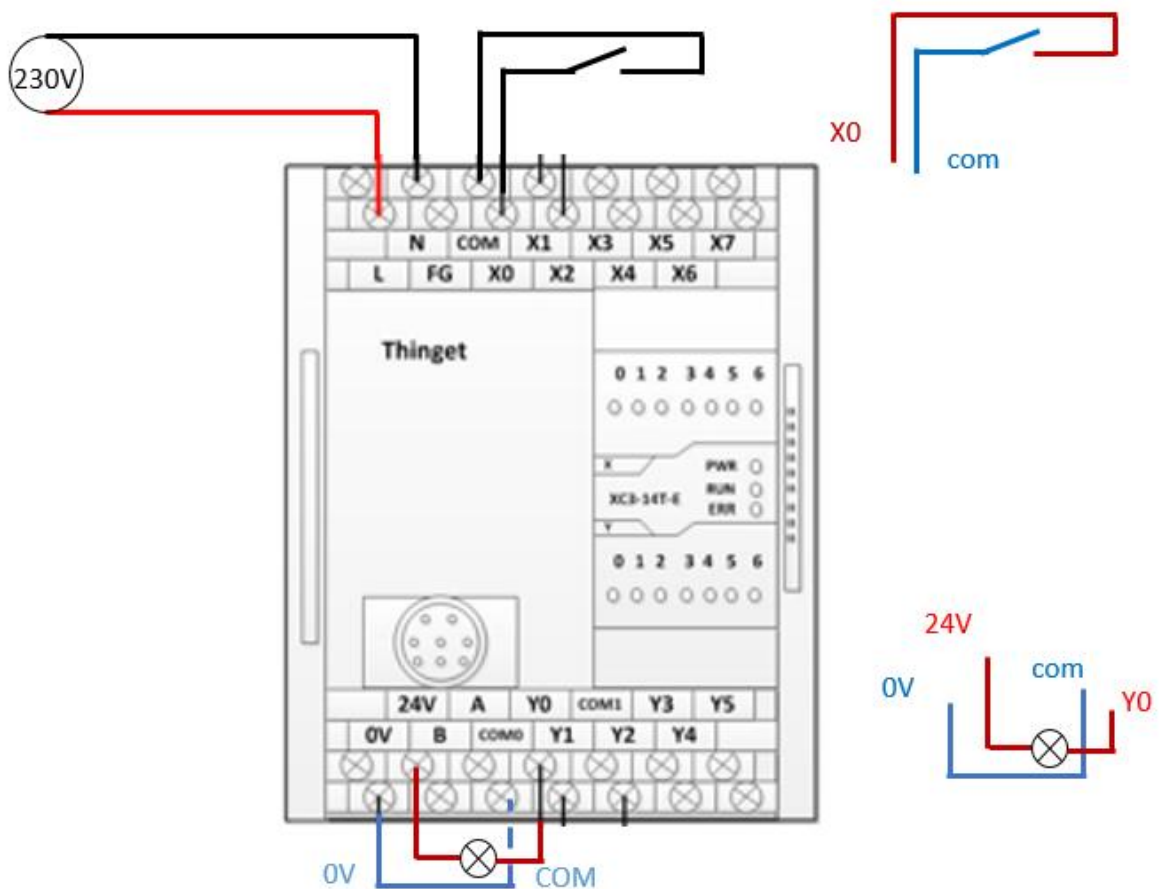


**Figure 10:** Circuit diagram for Experiment 2

Draw a ladder diagram which can light the lamp as long as you press the push button. Download the program to the PLC and run the program.

**Observations**

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**Conclusion**

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**Experiment 3**

Output device control with timer

**Objective**:

The output lamp should light 5s and switch off once the push button is pressed.

**Learning outcome**:

At the end of the experiment, the student will be able to demonstrate skills on controlling output devices with inbuilt PLC timer modules.

**Procedure**: In this practical, use the same wiring diagram used in the previous experiment. Design the ladder circuits as shown in the diagram and download it to the PLC. Change the timer values and observe the difference.

**Observations**

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**Conclusion**

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**Experiment 4**

Output device control with loop

**Objective**:

Output lamp should on and off continuously once the push button is pressed.

**Procedure**:

Do not change the wiring diagram. Design the ladder circuits as shown in figure 10 and download it to the PLC. Change the timer values and observe the difference. (Hackworth & Hackworth, 2004) (Listo, 2013) (Thinget, 2009)

**Learning outcome**:

At the end of the experiment, the student will be able to demonstrate skills on controlling output devices with closed loop program.

**Observations**

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**Conclusion**

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**References**

Hackworth, J., & Hackworth, F. (2004). Programable Logic Controllers; Programing methods and applications, ebook.

Listo. (2013). XC series PLC software manual; Listo Ltd; Nothern Ireland.

Thinget. (2009). XC series programable controler user manual; Xinje Electronic co. Ltd.

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