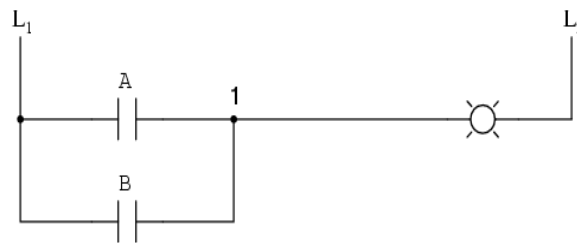




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INSTITUTE OF APPLIED TECHNOLOGY

PLC

Module 4: Programming with Ladder Logic



PREPARED BY

IAT Curriculum Unit

Jan 2010

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Module 4:

Programming with Ladder Logic

Module Objectives

Upon successful completion of this module, students should be able to:

1. Identify the ladder diagram elements.
2. Identify and define the different symbols used in ladder diagrams.
3. Draw the truth table and write the output boolean expression for the given ladder diagram.
4. Draw ladder diagrams for simple logic operations.
5. Convert the given function block diagram to ladder diagram.
6. Build simple LOGO! applications using the RS latching relay in ladder diagrams.
7. Build ladder diagrams using the On-delay and Off-delay timer to implement LOGO! timing applications.
8. Complete timing diagrams for the given timer application.
9. Convert simple electrical circuits to ladder diagrams.
10. Build simple LOGO! applications using the Up-counter and the Down-Counter in ladder diagrams.

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4.1 Introduction to Ladder Diagram (LAD)

Ladder Diagrams are special schematic diagrams that are commonly used for industrial control logic systems. They are called *ladder diagrams* (LAD) because they resemble a ladder. In this module, you will learn how to program the LOGO! using Ladder Logic or Ladder Diagrams.

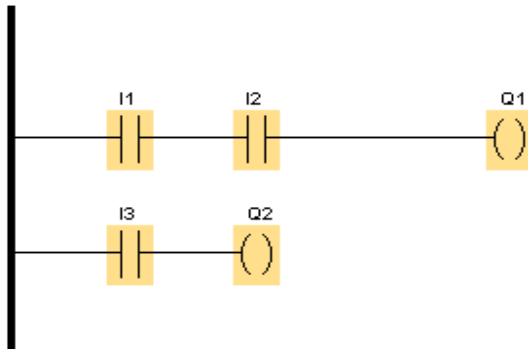


Figure 4.1 Ladder Diagram Example-1

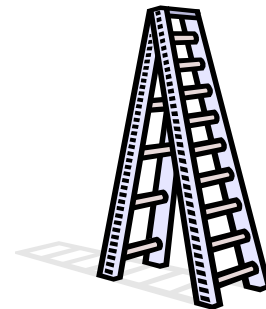


Figure 4.2 A ladder

Figure 4.1 shows an example of a ladder diagram. They have two vertical power rails on the left and on the right (not shown) that supply power, and rungs (horizontal lines) that represent each path of the circuit. The elements in a ladder diagram are contacts, coils and blocks. Ladder logic diagrams are read from left to right and from top to bottom. The example of the LAD shown in Figure 4.1 has two rungs. Each rung is connected to an independent output. The ladder diagram example shown in Figure 4.3 has only one rung.

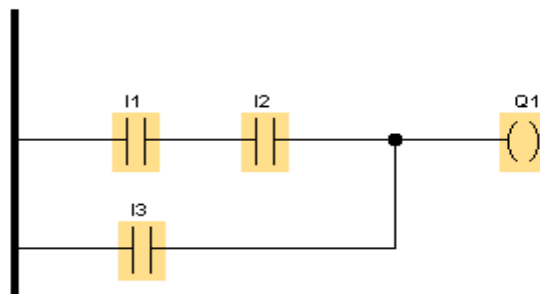


Figure 4.3 Ladder Diagram Example-2

4.2 Ladder Logic Symbols

The set of symbols which are commonly used in LAD are as follows:

A. Contacts

Contacts are of two types:

1. Normally Open (NO) Contact: It produces a HIGH output when its input is HIGH or '1'.
2. Normally Closed (NC) Contact: It produces a HIGH output when its input is LOW or '0'.

The Contact Symbols are shown in figures 4.4 and 4.5



Figure 4.4 NO Contact



Figure 4.5 NC Contact

B. Coils

Coils represent relays that are energized when power flows through them. When a relay coil is energized, it sets its output state to HIGH (1) or ON. Its output goes LOW (0) or OFF in the absence of power. Figures 4.6 and 4.7 show the symbols of the coil types that will be used in this module; they are as follows:

1. Normal Coil: Outputs the result of the logic operation.
2. Negating Coil: Outputs an inverted version of the logic operation.

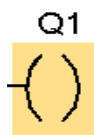


Figure 4.6 Normal Coil

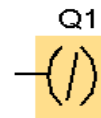


Figure 4.7 Negating Coil

C. Functions & Special Functions

Apart from the contact and coil elements, functions and function blocks can also be used within ladder diagrams as shown in Figure 4.8.

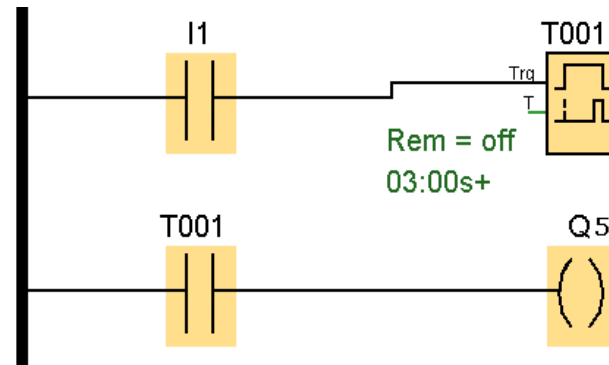


Figure 4.8 Use of Function Blocks in LAD

Example: Ladder diagram for the AND Operation

Let I1 and I2 be the two NO input contacts, and let Q1 be the normal output coil. The LAD can be drawn as shown in Figure 4.9

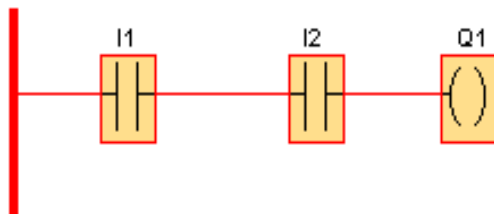


Figure 4.9 LAD for AND Operation



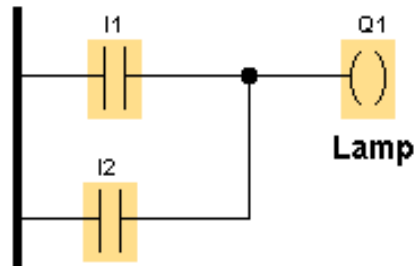
Figure 4.10 Simulating AND Operation

The output Q1 will produce a HIGH output only if both I1 and I2 inputs are HIGH. This is clear from the simulation done with LOGO! Soft Comfort software shown in Figure 4.10.

The Boolean output expression of Figure 4.9 is: $Q1 = I1.I2$

Skill 1

Identify the contact types, complete the truth table for the ladder diagram given below, and identify the logic function:



1. Identify the contact types:

Contacts	Type
I1	
I2	

2. Complete the truth table:

Truth Table

I1	I2	Q1
0	0	
0	1	
1	0	
1	1	

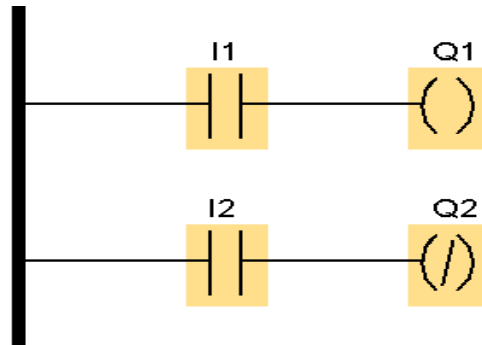
3. Write the Boolean output expression for the operation specified:

4. What operation does this ladder logic diagram represent?

Conduct Lab Activity 1 on page-19

Skill 2

Identify the output coil types in the Ladder Diagram given below, and complete the truth table for the LAD:



1. Identify the coil types:

Output	Type
Q1	
Q2	

2. Complete the truth table:

Truth Table

I1	Q1
0	
1	

I2	Q2
0	
1	

Skill 3

Draw Ladder Diagrams to implement the following operations:

1. $Q1 = I1 + I2 \cdot \overline{I3}$

2. A lamp in the corridor can be switched ON by using three switches S1, S2 and S3 as per the condition below:

The lamp will be ON only if **any two** of the three switches are pressed. Write the boolean expression, draw the truth table and the LAD.

The Boolean expression is:

The truth table	The LAD

Skill 4

Convert the FBDs shown in Figures 4.(11 and 12) to LADs:

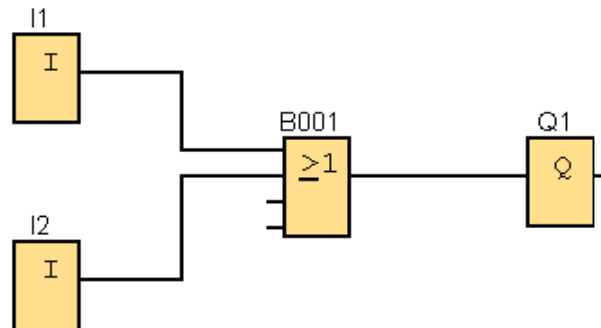


Figure 4.11 FBD

Draw the LAD Here

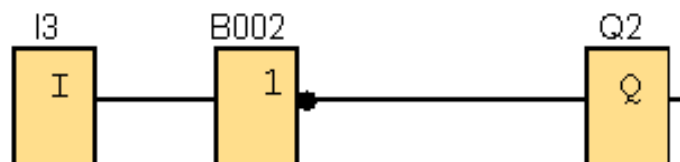
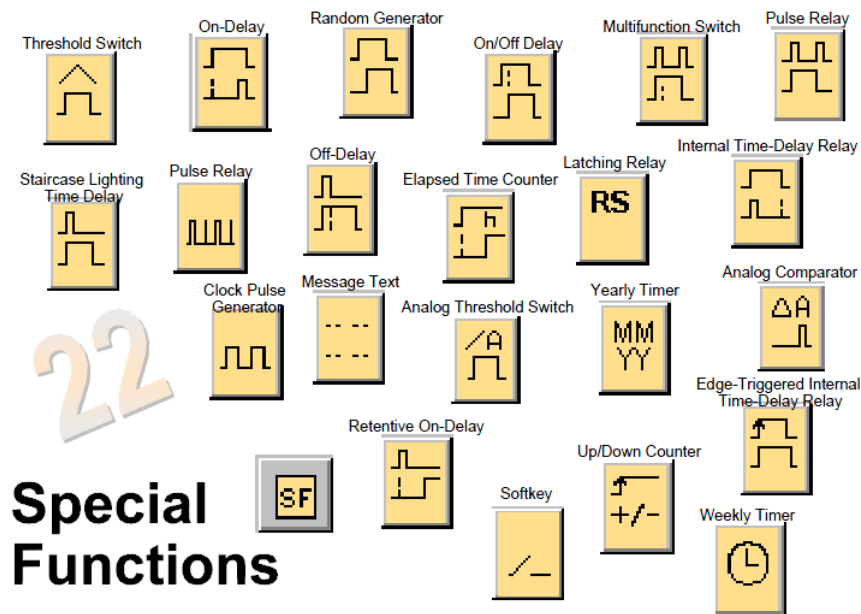


Figure 4.12 FBD

Draw the LAD Here

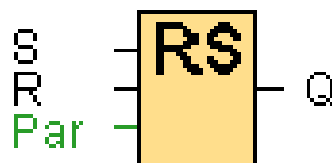
4.3 Special functions

The LOGO! PLC provides various basic and special functions such as logic functions, timers, counters, memory functions and mathematical operators. Among the special functions, the **latching relays**, **timers**, and **counters** are commonly used.



4.3.1 RS latching relay

Many PLC applications require basic memory and storage operations. The RS function block (or **RS latching relay**) is a memory function which can be used to **set** and **reset** any operation.



It has the Set (S) and Reset (R) inputs. A HIGH signal at the S input sets the output Q to 1 and a HIGH signal at the R input brings the output Q to 0.

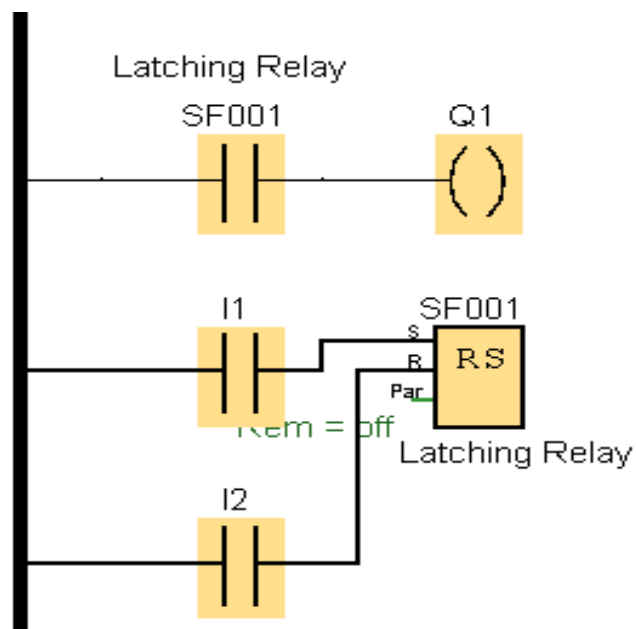
Skill 5

Follow Example-1, and **use the RS latching relay** to implement the operation specified in Example-2.

Example1:

A conveyor belt is used to transport non-metallic work pieces to the workbench. A horn has been connected to the output of the PLC and it will sound to show error when metallic work pieces are detected. A pushbutton is also connected to the input that will be used to stop the horn.

Purpose	Input	Output
Sensor to detect metallic work pieces	I1	
Horn to indicate error		Q1
Pushbutton to stop the horn/reset the latch	I2	

The LAD solution for Example-1

Example2:

The level of water in a tank is to be controlled. A start button must start the water-pump to fill the tank. The process must stop when the sensor senses the required water level. Draw the LAD using an RS latching relay to implement the function.

Purpose	Input	Output

Draw the LAD in the box given below

4.3.2 Timers

Many control tasks require the programming of time. There are different types of timers and the type used depends on the application. Only On-Delay and Off-Delay Timers will be discussed in this module.

1- **On Delay timer:** It is used to start an action after a certain time.

- **Trg** (Trigger) is used to trigger the timer.
- **T** (time) is used to set the On-delay time.

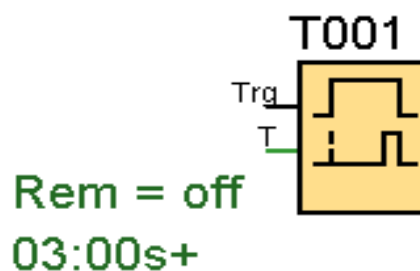


Figure 4.13 On-Delay Timer Function Block

2- **OFF Delay timer:** It is used to stop an action after a certain time.

- **Trg** (Trigger) is used to trigger the timer.
- **R** (Reset) is used to reset the off-delay timer. Reset has priority over the Trigger input.
- **T** (time) is used to set the off-delay time.

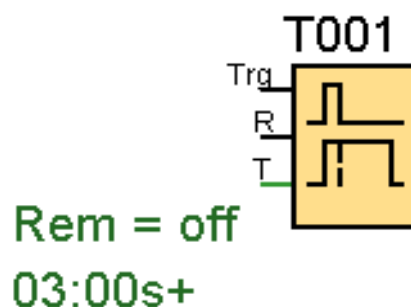


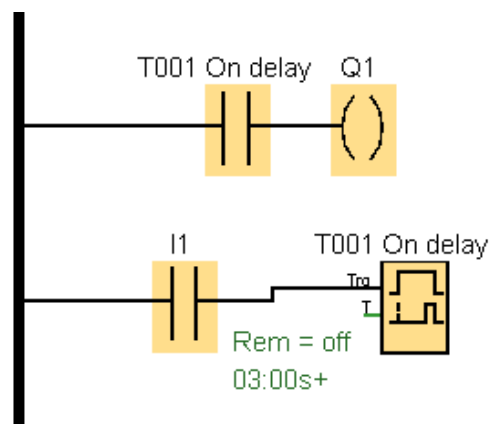
Figure 4.14 Off-Delay Timer Function Block

Skill 6

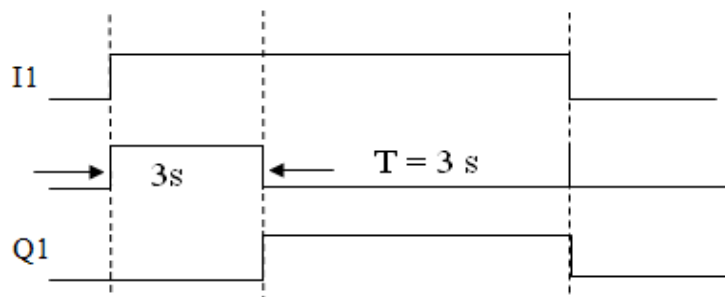
Follow example-1, and use the **timer** function block in the LAD to implement the operation specified in example-2:

Example-1:

An escalator in a certain mall is required to *Start* after a delay of *3 seconds* once the sensor senses the person. Identify the type of timer that could be used for this application. Draw the LAD and complete the timing diagram.

Ladder Diagram:

The timer used is the On-delay timer

Timing Diagram:

Example-2:

A corridor light must switch ON immediately after sensing a person and switch off 10 seconds after it turns ON. Draw the ladder diagram and the timing diagram.

Ladder Diagram:

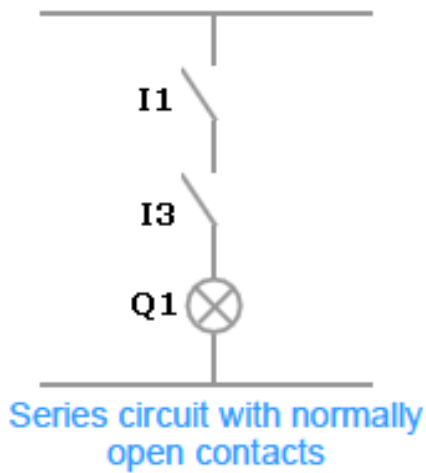
Timing Diagram:

Conduct Lab Activity 2 on page-21

Skill 7

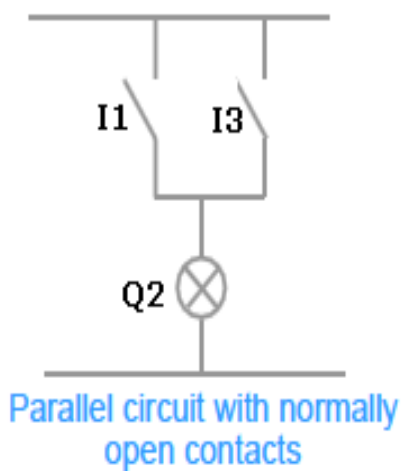
Draw ladder diagrams for the electrical circuits given below:

1) The electrical circuit



The Ladder Diagram

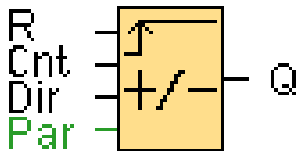
2) The electrical circuit



The Ladder Diagram

4.3.3 Counters

Counters are used for counting applications, such as counting the number of cans or cartons or work pieces. The Up/Down counter can be set as Up Counter or Down Counter by using the Dir input.



R: Resets the counter

Cnt: Counts the 0 to 1 transitions at input

Dir (Direction): it determines the direction of count.

➤ Dir = 0: count Up-counter

➤ Dir = 1: count Down-counter

Par: Specifies the range (from 0 to 999999)

Skill 8

Use the counter function block in the LAD

Figure 4.15 shows a parking area at a mall which can only take 12 cars. It is required to design a Parking System which can display the 'No spaces' message when the parking is full. Draw a ladder diagram using the counter block to count the cars entering the parking area.

Hint: Count the no of cars, and if count=12, display 'No spaces'.

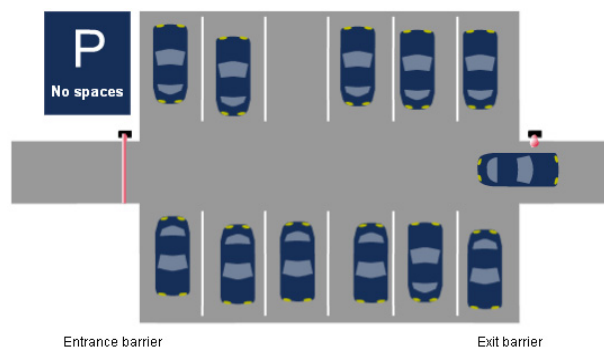


Figure 4.15 Parking System

Draw the LAD here

Conduct Lab Activity 3 on page-23

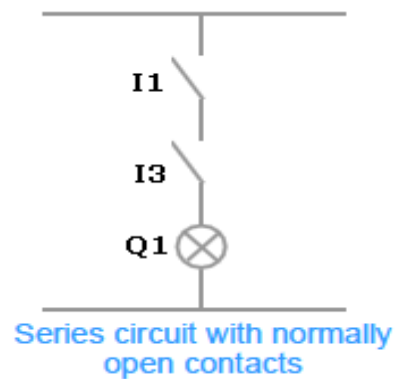
4.4 Lab Activity 1

Objectives:

To familiarize with the AND logic function in ladder language.

Procedure:

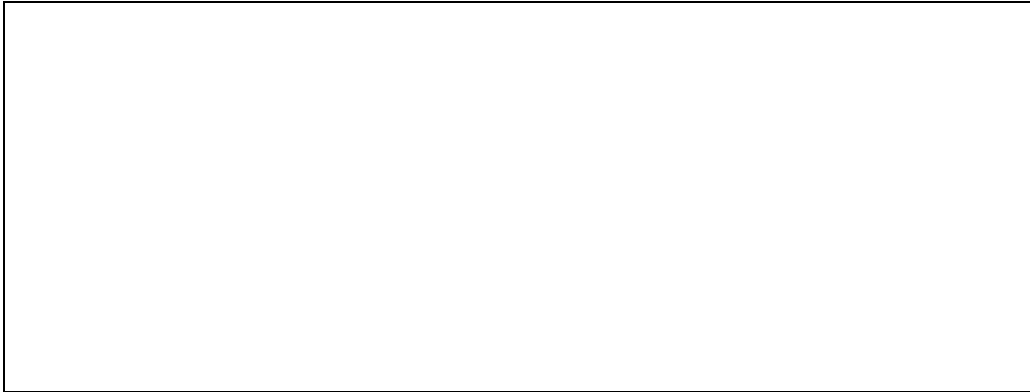
1. Write a program to turn on the Green indicator light (Q1) when the pushbuttons I1 and I3 are pressed as indicated in the electrical circuit shown.



(Use the table given below for the inputs and outputs on the LOGO! EduTrainer).

Inputs	PLC side
Green push button (N.O.)	I1
Red push button (N.C.)	I2
White push button (N.O.)	I3
Selector Switch	I4
Emergency Jumper	I5
Outputs	PLC side
Green Light	Q1
White Light	Q2

2. Draw the ladder diagram in the box provided:



3. Run the program and observe the result. Does the white light turn ON if one input only is pressed?

.....

4. Identify and indicate the Logic operation

.....

5. Modify the program by using NC contacts to switch OFF the white lamp, if I1 or I3 is pressed.

6. Draw the modified ladder diagram in the box provided:



7. Run the program and observe the result.

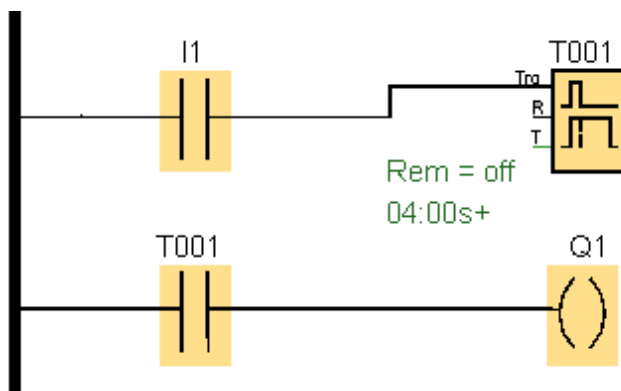
4.5 Lab Activity 2

Objectives:

To familiarize with the application of the Off-delay and On-delay timers in ladder language.

Procedure:

1. Enter the given program on the LOGO! Soft editor and run the program. (Set the time to 4 seconds).



2. Press the **green pushbutton**. Does the **green lamp** turn on? For how long does it remain on?

.....

3. Indicate the type of timer used in this application

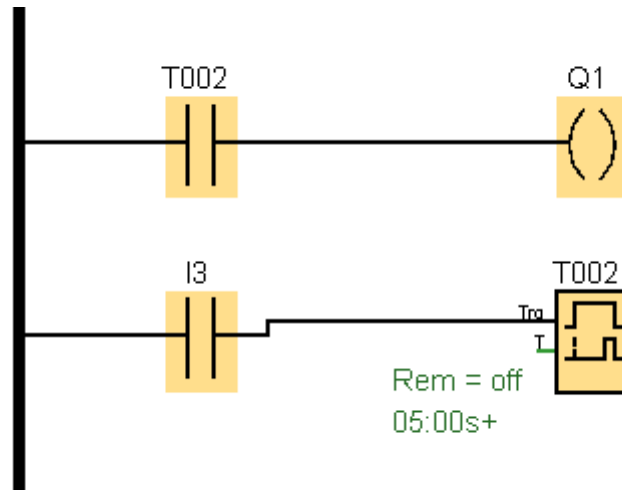
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4. Press the green pushbutton, hold it on for 2 seconds, and then release it. What is the difference observed?

.....

.....

5. Now, enter the given program on the LOGO! Soft editor and run the program. (Set the time to 5 seconds).



6. Press the **white pushbutton**. Does the **green light** turn on immediately?

.....

7. How long does it take for the green light to turn on?

.....

8. What is the type of timer used in this application?

.....

4.6 Lab Activity 3

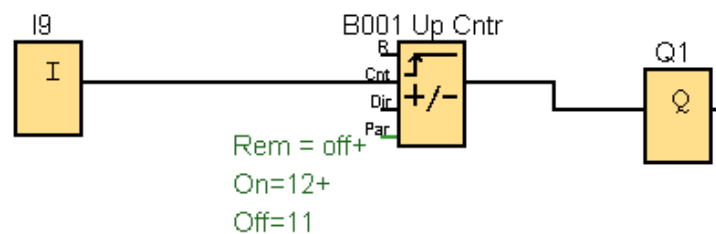
Objectives: To familiarize with the application of a Counter

Background Information

In a Chocolate Packaging Unit, it is required to count 12 chocolates to be packed in one pack. A sensor is used to sense the number of chocolates and an Up-counter must be set to count up to 12. A white indicator light is used to indicate achievement of the set target.

Procedure:

1. Build the function block diagram given below using the Up-counter.

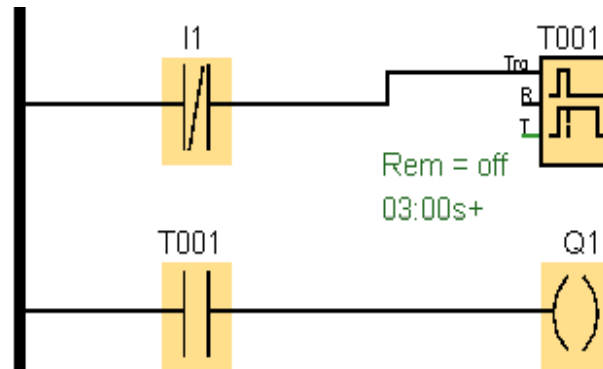


2. Use the simulation tool to test the result.
3. Convert the function block diagram to the ladder diagram. Draw the LAD in the box given below:

4. Download and run the program. Use the optical sensor to sense 12 objects. What do you observe?

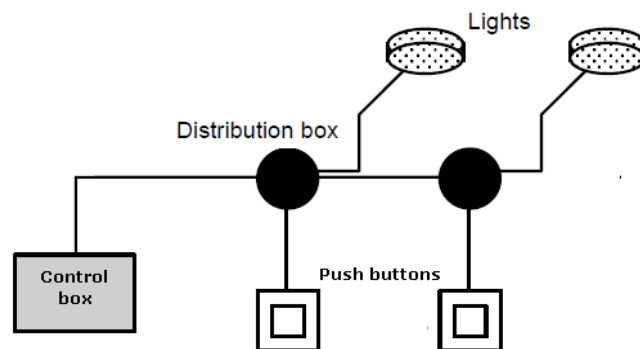
4.7 Module Exercise

1. In the ladder diagram given below, identify the type of timer used.



2. In an application, it is required to program the PLC to serve in a staircase lighting system where the basic requirements are as follows:

- When someone is using the staircase, the lights should be switched on.
- The lights should be switched off 10 seconds after it turns ON in order to save energy.

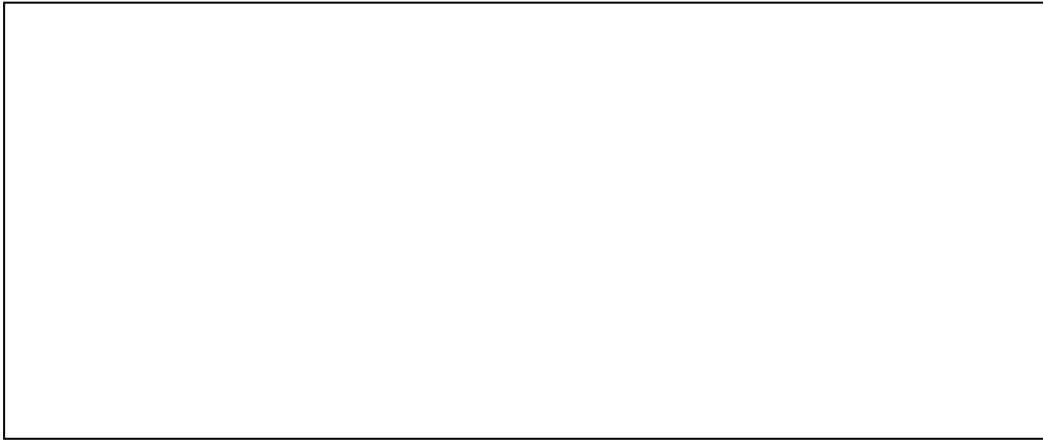


Indicate the type of timer that could be used

.....

.....

Write a program to achieve the desired task. Use I1 and I3 as input push buttons and two output indicator lights. Draw the ladder diagram in the box provided.



3. A green lamp must switch ON 2 seconds after pressing either S1 or S2. Draw a ladder diagram to implement this operation.

4.8 Assignment

Visit your **classroom Blog** created by your instructor and comment on the following topics:

TUESDAY, MARCH 9, 2010

➔ Design your Smart Home!



Imagine this as your Smart Home, and comment on what automatic control features you would prefer to have in your Smart Home?

TUESDAY, MARCH 9, 2010

Light Control System



The picture shows all three floors of a 3-storey building. Every floor has lights and switches.

Share with your friends how you would like the control system to switch ON and switch OFF the lights. Would you like to add a Special function such as the timer?