UNIT 9
INSTRUCTOR'S MANUAL

INPUTS AND OUTPUTS

1. This is the first unit in which students will be reading and entering programs from ladder logic diagrams. In this and the next several units, the keystrokes sequences will be given with the ladder logic diagram. As the students progress, they will be required to remember the keystroke sequences and use them correctly when called for in a program. You should get them into the habit of memorizing programming keystrokes, beginning with this unit.

2. The concept of normally open and normally closed input elements may be difficult for some students, especially since these inputs are independent of the type of input device used (normally open and normally closed). The significant difficulty seems to be with the normally closed input element. The students may need to be reminded that the output which is activated by an normally closed element has its own separate power supply. Thus, turning off a switch can turn on a light, and turning on a switch can turn off a light.

3. During the Experiment in this and the next several units, it is advisable to check how the students wire the input and output common connections. Mis-wiring could cause a fuse to blow.

UNIT 9

INPUTS AND OUTPUTS

Objectives

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

1. Identify normally open and normally closed input elements.
2. Identify output elements.
3. Explain the functions of input and output elements.
4. Write a simple input /output program.
5. Enter inputs and outputs into the MicroLogix.

Background

In the previous chapters you examined the basic structure of ladder logic diagrams, and compared ladder logic diagrams to electrical circuits. You were also introduced to the idea that ladder logic diagrams represent Boolean AND/OR equations. In this unit you will begin using ladder logic diagrams to program the MicroLogix 1000 for specific electrical functions. To do this you need more information about elements of circuits and their ladder logic symbols.

Remember that the two rails of the ladder logic diagram represent the electrical power source in the circuit. Each rung represents a particular condition in the circuit. Now assume that a normally open switch is wired to input terminal I:0/4 and a light bulb is wired to output terminal O:0/5 on the PLC. Assume also that proper power is supplied to the input and output devices. To turn on the light, the PLC should be programmed with the ladder logic diagram in Figure 9-1.

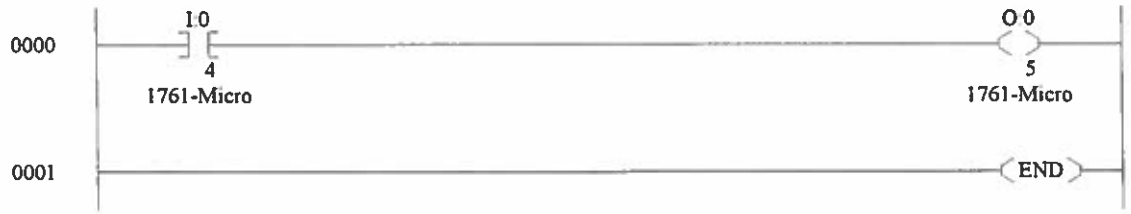


Figure 9-1
Normally Open Element Controlling Output

The program in Figure 9-1 gives the PLC very explicit instructions. It tells the PLC to activate the output element O:0/5 when the input element I:0/4 is *energized.* Since the switch connected to input element I:0/4 is normally open, the program functions as follows. When the PLC is ON and in the RUN mode, the switch and light communicate with the PLC. If the switch is pressed (closed), power is applied to input element I:0/4 and input element I:0/4 is energized. This signals the PLC to activate

output O:0/5. When output element O:0/5 is activated the light will come on. The light will stay on only as long as power is applied to I:0/4 by the switch being pressed.

The type of input element used above, is called a *normally open* or *examine if closed* element. The normally open element in Figure 9-1 tells the PLC to activate the circuit (turn light on) when input I:0/4 is energized. In some circuits a *normally closed or examine if open* input element is more useful. The normally closed element in Figure 9-2 tells the MicroLogix to activate the circuit (turn light on) when input element I:0/4 is not energized.

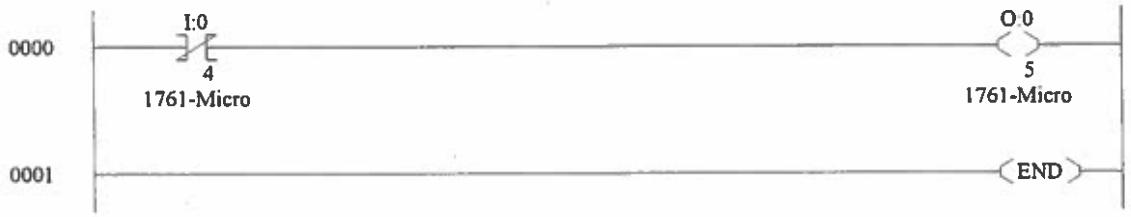


Figure 9-2
Normally Closed Element Controlling Output

There are four possible relationships among input devices, input elements, output elements and output devices. Figure 9-3 provides a graphic display of these relationships.
The input device is a switch and the output device is a light for this example. (Remember that the input LED reflects the status of the input device. The output LED reflects the status of the output element.)

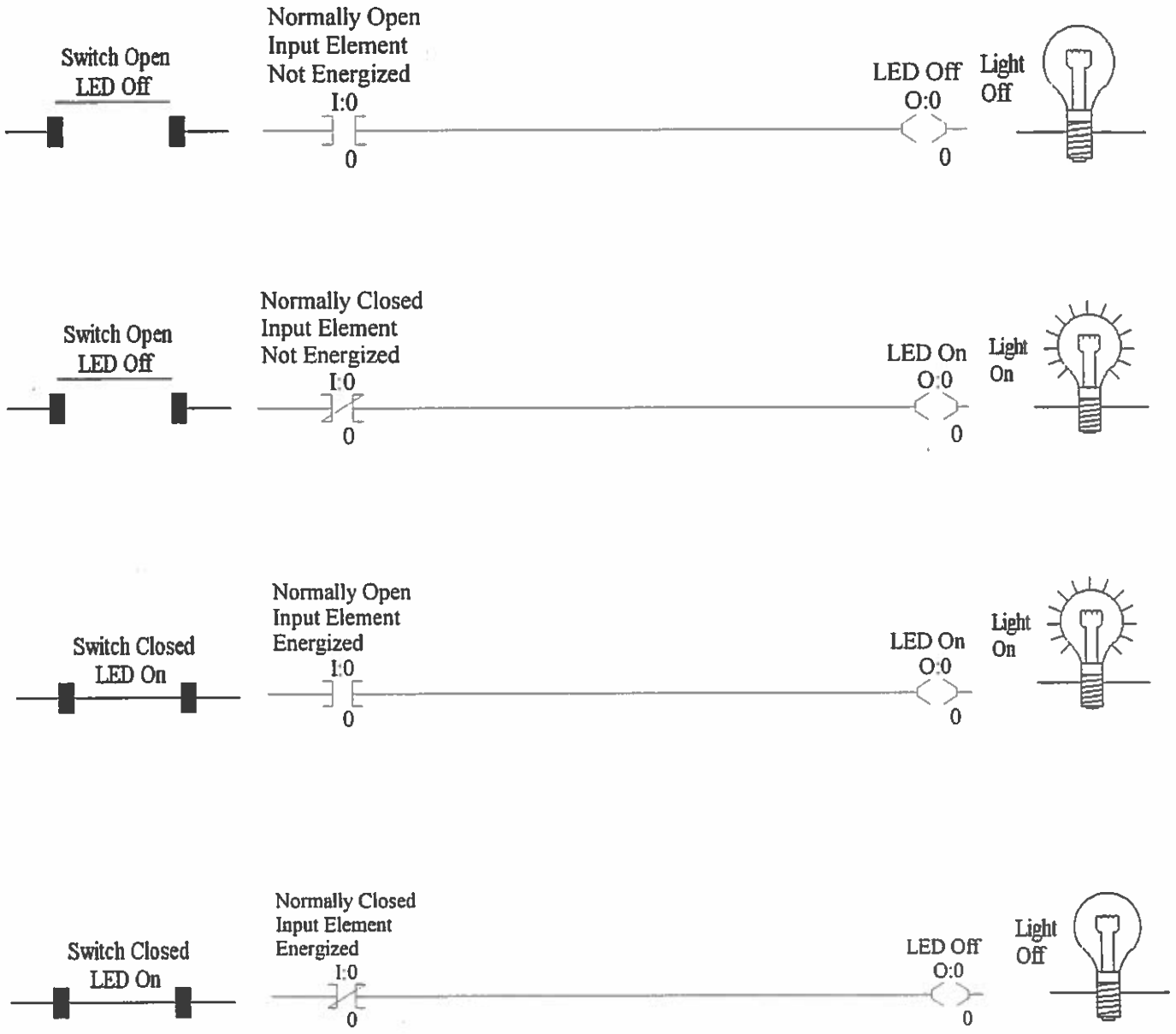


Figure 9-3
Relationships Among Input Devices, Input Elements,
Output Elements, and Output Devices

Providing power to switches and lights

Unless an experiment specifically instructs you to do something else, use the following procedure to supply power to the switches and lights on the System panel.

1. Make sure the panel ON/OFF switch is OFF.
2. Take four jumper wires and connect them as shown in Figure 9-4.

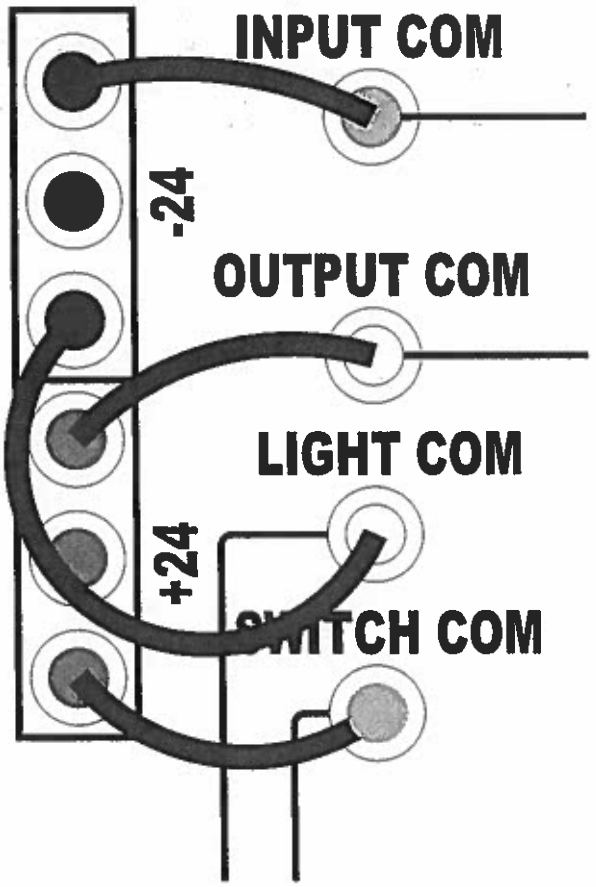


Figure 9-4
Wiring On-Board Power Supply to Switches and Lights

3. Check to make certain the wires connect

+24 VDC (red) to Output Common (left of PLC).
+24 VDC (red) to Switch Common (left of PLC).
-24 VDC (black) to Input Common (above lights).
-24 VDC (black) to Light Common (above switches).

This wiring should be used whenever you are instructed to make the common connections.

Computer Programming Keystrokes

In the MicroLogix 1000, specific keystrokes designate inputs and outputs. Note that the Allen-Bradley uses examine on when referring to a normally open contact (input element). The term examine off is used to refer to a normally closed contact (input element).

Element	Keystroke
Normally Open (Examine if Closed)	-| |-
Normally Closed (Examine if Open)	-|/|-
Output	--( )--

Table 9-1
Input and Output keystrokes

Note that the input elements are logical inverses of each other as in the Boolean NOT function. Other elements that you will study in later units also demonstrate the Boolean basis for ladder logic and PLC programming.

Address numbers are designated for input and output elements are given in Table 9-2:

Element	Address number
External Input	I:0/0 - I:0/7
External Output	O:0/0 -O:0/5

Table 9-2
External and Internal Addresses

Other address numbers are used for specialized inputs and outputs such as timers and counters will be discussed later.

A normally open contact is programmed with the keystrokes:

Examine if Closed # I:0/0 - I:0/7 rest of the rung is entered here

A normally closed input element is programmed here

Examine if Open # I:0/0 - I:0/7 rest of the rung is entered here

And an output coil uses the keystrokes:

-( )- Output Energized **# O:0/0 - O:0/5**

1. Normally open contact: Examined if Closed (XIC):

XIC is a normally open instruction used in your program to determine if a bit is on. If the bit addressed is on (1) when one of these instructions is executed, then the instruction evaluated is true. If the bit addressed is off (0) when one of these instructions is executed, then the instruction evaluated is false.

Bit Address	XIC Instruction
0	False
1	True

Table 9-3
Bit addresses for XIC instruction

Examples of devices that turn on or off include:

- a push button wired to an input;
- an output wired to a pilot light;
- a timer controlling a light;

Using XIC:

Use the XIC instruction for normally open contacts that appear first on a rung or a block.

2. Normally closed contact: Examine if open (XIO):

XIO is a normally closed instruction used in your program to determine if a bit is Off. When the instruction is executed, if the bit address is off (0), then the instruction is evaluated as true. When the instruction is executed, if the bit address is on (1) then the instructions evaluated as false.

Bit Address State	XIO instruction
0	True
1	False

Table 9-4
Bit address states of XIO instruction

Examples of devices that turn on or off include:

- motor overload normally closed (N.C) wired to an input;
- an output wire to a pilot light (addressed as O:0/4);
- a timer controlling a light (addressed as T4:4:3/DN);

Using XIO:

Use the XIO instruction for normally closed contacts that appear first on the rung or block.

3. Output Energize (OTE):

Use an OTE instruction in your ladder program to turn on an output or a bit when rung conditions are evaluated as true. An example of a device that turns on or off is an output wired to a pilot light. (addressed as O:0/4). OTE instructions are reset when:

- You enter or return to the RUN mode or power is restored;
- The OTE is programmed with an inactive or false Master Control Reset (MCR) zone;
- Rung conditions are evaluated as false;

To enter the program in Figure 9-5, the operator would use the keystrokes shown:

New Rung then Examine if Closed then I:0/0 then Examine if Closed then I:0/2 then Output Energized then O:0/4

The nomenclature used throughout the text shows the keystroke sequence below the ladder diagram.

Note that the initial 0's are not keyed in as a part of the element address but are automatically inserted when using the ladder logic programming software.

New Rung Examine if Closed I:0/0 Examine if Closed I:0/2 Output Energized O:0/4

Figure 9-5
Ladder Logic Diagram and Corresponding Keystroke Sequence

In the lab that follows, you will try some simple programming. If you should hit the wrong key anytime during programming, you can remove your error by right clicking and select delete.

EXPERIMENT

Purpose

To enter simple input and output commands into the controller.

Procedure

1. Make sure the on/off switches for the MicroLogix PLC Training System are set to OFF. Then plug the computer with interface cable into the PLC.

2. Make the following connections with the jumper wires:

   Switch 0 to Input 0
   Switch 2 to Input 1
   Output 1 to Light 0
   Output 2 to Light 4

   Do not forget to make the common connections! (Refer to Figure 9-4.)

3. Turn on the main power switch.

4. Examine the input indicator lights on the PLC. Think about the two types input devices discussed in Unit 3.

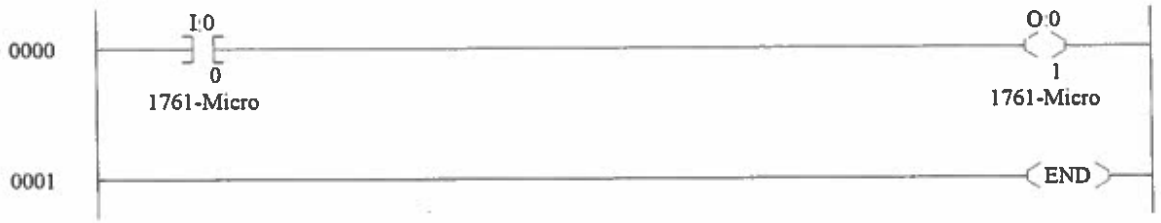
   a. Which input indicators are lit?

   Input I:0/0 indicator is off and input I:0/1 indicator is on. All other LED's are off.

   b. Explain why this is the case.

   Input I:0/0 is connected to a normally open switch which is in its normal position (off) at this time. Input I:0/1 is connected to a normally closed switch which is in its normal position (on) at this time. All other inputs are not in use. Output LED's only respond to a program which is running.

5. With the PLC in the OFFLINE mode, enter the program shown in Figure 9-6.



New Rung Examine if Closed I:0/0 Output Energized O:0/1

Figure 9-6
Program for Step 5

6. Verify Project, Save, Download Go Online, and Run.

7. Press switch 0.

   How do the output devices respond ?

   Light 0 comes on. All other lights stay off.

8. Now go OFFLINE and create a new program in Figure 9-7.

New Rung Examine if Closed I:0/1 Output Energized O:0/2

Figure 9-7
Program for Step 8

9. Verify, Save, Download, Go Online, Run, press switch 2.

a. What happens to the output devices?

Light 4, which came on when the run mode was entered, turned off when the switch 2 was pressed. All other lights, which were off, staved off.

b. Why do lights 0 and 4 operate differently?

Light 0 was controlled by a normally open switch and a normally open input element, so it came on when the switch was pressed. Light 4 was controlled by normally closed switch, so it went off when the switch was pressed.

Figure 9-8
Program for Step 10

10. Now go OFFLINE and create a new program in Figure 9-8.

New Rung Examine if Open I:0/1 Output Energized O:0/2

11. Verify, Save, Download, Go Online and Run. With the controller in RUN mode Press Switch 2.

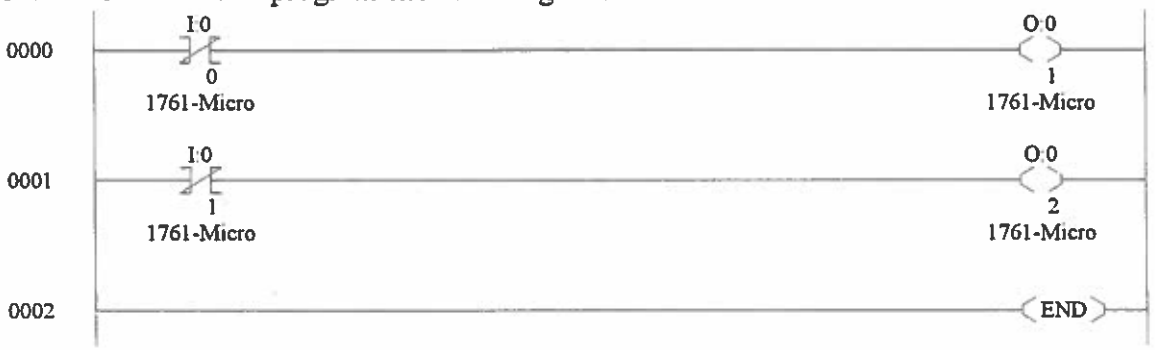
a. Now how do the output devices operate?

Light 4 stays off until switch 2 is pressed. The rest of the lights stay off.

b. Why does light 4 operate differently than before?

The normally open input element was changed to a normally closed input element. So light 4 now comes on when its switch is turned off (pressed).

12. Create a new program shown in Figure 9-9.



New Rung Examine if Open I:0/0 Output Energized O:0/1
New Rung Examine if Open I:0/1 Output Energized O:0/2

Figure 9-9
Program for Step 12

13. Verify, Save, Download, Go Online, and Run. With the controller in RUN mode, Press Switch 0.

a. How do the output devices respond?

Light 0, which came on when the Run mode was turned on, turned off when switch 0 was pressed. The rest of the lights are off and stay off.

b. Press switch 2. What happens to the output devices?

Light comes on and light 0 stays on. The rest of the lights stay off.

c. Why do light 0 and light 4 operate differently than in steps 6 and 9?

They have both been changed from being normally open input elements to having normally closed input elements. This change completely reverses their operations.

14. Study the input and output LED's on the controller as you press and release switches 0 and 2.

Describe what you observe. Also explain how the LEDs help you to understand the operations of the two switches.

The LED for switch 0 comes on and the LED for the light goes off when switch 0 is pressed. The LED for switch 2 goes off and the LED for light 4 comes on when switch 2 is pressed. The LED for switch 0 indicates that the switch 0 has power flowing through it when it is pressed. Thus switch 0 is normally open. The LED for switch 2 indicates that switch 2 has power flowing through it when switch 2 is released. Thus switch 2 is normally closed.

15. Turn off the power and set aside any loose parts. When you are satisfied that you understand the inputs and outputs, complete the questions below.

Questions

1. What are the functions of the input and output elements in a controller?

An input element receives information about the status of an input device, such as a switch, and communicates this status to the controller. An output element receives information from the controller about whether an output device should be on or off. The output element communicates status to the output device to turn the device on or off.

2. What are the two types of input elements and what are their programming keystrokes? How are they different?

Examine if Closed element: 

Examine if Open element: 

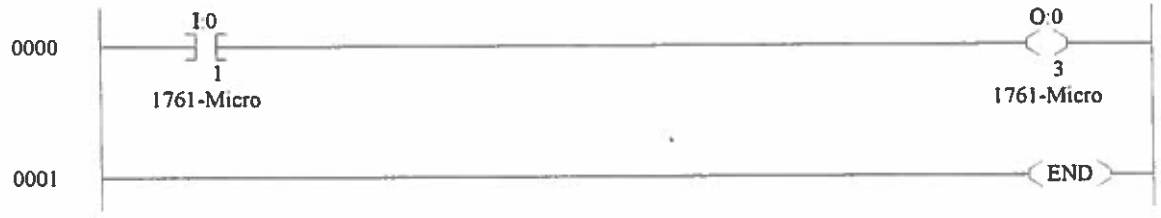
An Examine if Closed element activates its output when it is energized. An Examine if Open element activates its output when it is not energized.

3. What type of element is represented by "O:0/4" and what is its programming keystrokes?

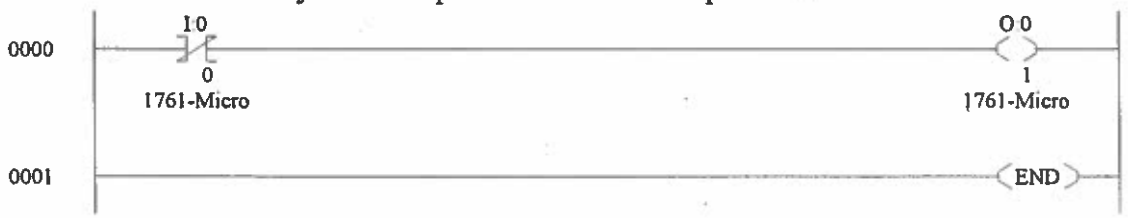
O:0/4 is an external output energized element: --( )--

4. Draw the ladder logic diagram for the following:

   a. Normally open input I:0/1 controls output O:0/3.



b. Normally closed input I:0/0 controls output O:0/1.



c. Output O:0/1 is controlled by normally open input I:0/7.

5. List the keystrokes in the correct order for the following ladder logic diagrams:

a.

New Rung Examine if Closed I:0/0 Output Energized O:0/4

b.

New Rung Examine if Open I:0/2 Output Energized O:0/1

UNIT 10
INSTRUCTOR'S MANUAL

INTERNAL RELAYS

1. The most important concept is that internal relays do not affect an output device directly. They must be used as input elements controlling external output elements in order to control an output device.

2. It would be advisable to check the common connections before the students operate their programs during the Experiment.

UNIT 10

INTERNAL RELAYS

Objectives

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

1. Explain the difference between an internal relay coil and an external relay coil.
2. Program single and multiple internal relay contacts.
3. Write a program using internal and external coils.
4. Enter into the PLC a program containing internal and external relay coils.

Background

One of the main components used in any hard-wired control circuit is the relay. A relay is an electro-mechanical device that takes a single input and converts it into many outputs. Relays are used to control other relays and output devices.

Relays typically have more than one set of contacts in them. They can have both normally open contacts and normally closed contacts. Most industrial relays have multiple sets of normally open and normally closed contacts. Use of multiple contacts in a single relay allows several devices to be turned on or off simultaneously.

Since relays are such important devices in control circuits, they had to be incorporated into PLC's. The PLC version of the relay is called an *internal relay*. An internal relay is a logical relationship within the ladder logic. It is not a physical device. It does not turn on any outputs in the output module. Instead, an internal relay is used to control other rungs of a program.

Just as the electro-mechanical relay has a coil and a set of contacts, the internal relay has a similar construction in a PLC program. The coil part looks just like the coil symbol used for the external relay. The contacts look just like normally open and normally closed input elements. The only thing that makes internal relays different is the way they are addressed. Figure 10-1 shows a ladder logic program with an internal relay coil controlling a normally open and normally closed contact.

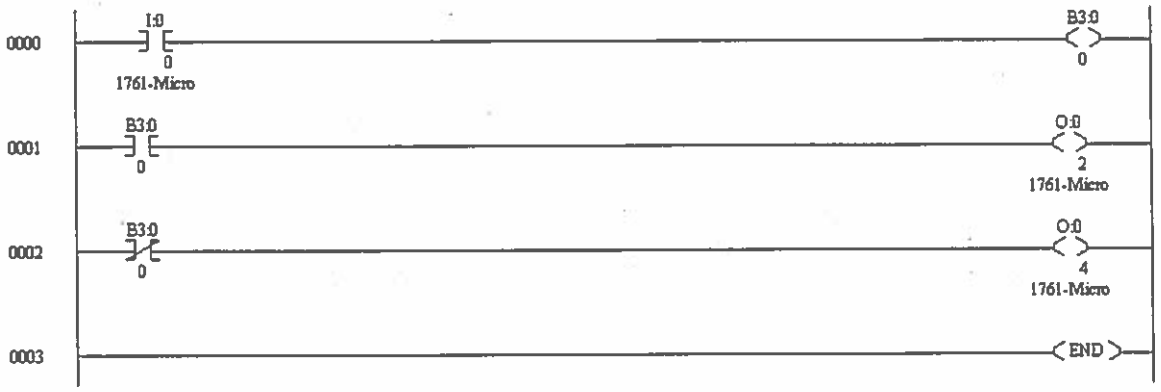


Figure 10-1
Relay Controlling Two Outputs

The coil element on rung 0 is labeled B3:0/0. It is the internal relay element. The normally open and normally closed contacts on rung 1 and 2 are both controlled by the internal relay with the same address. So the program in Figure 10-1 operates as follows:

1. When input I:0/0 turns on, internal relay coil B3:0/0 is activated.
2. This causes the normally open contact with the same addresses on rung 1 to close, turning on output O:0/2.
3. At the same time, the normally closed contact on rung 2 opens up, causing output O:0/4 to turn off.

Notice that the relay coil B3:0/0 does not cause a direct output, as do coils O:0/2 and O:0/4. This is because B3:0/0 is an internal relay and cannot directly control the switches in the output module.

A more complex problem is shown in Figure 10-2. It is an example of how a relay coil and contacts can be used to turn off outputs that are turned on by other inputs. In this program two input switches are used. One switch is used to turn on output O:0/2. The other switch is used to turn off the output O:0/2 and turn on output O:0/3 at the same time.

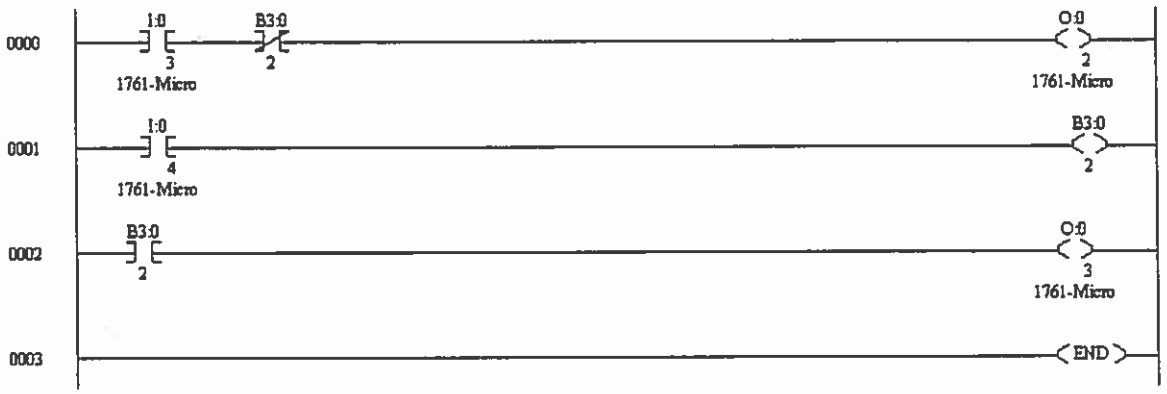


Figure 10-2
Relay Used to Break an Existing Circuit

The program operates as follows:

1. When input I:0/3 is energized it completes a path to normally closed contact B3:0/2.

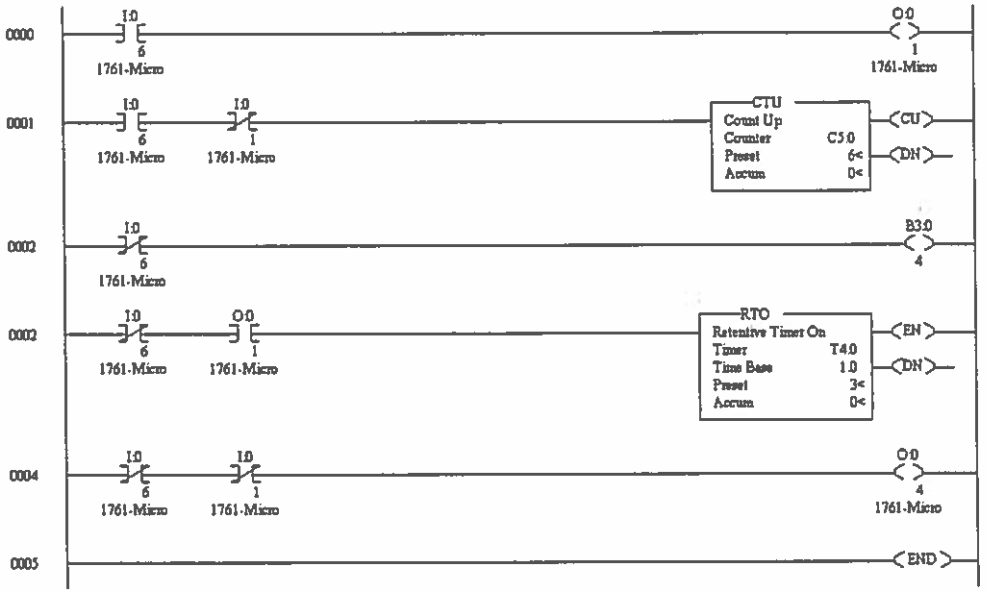
2. B3:0/2 being normally closed automatically completes the path to output coil O:0/2, and O:0/2 is activated.

3. When input I:0/4 is energized it completes a path directly to internal relay B3:0/2.

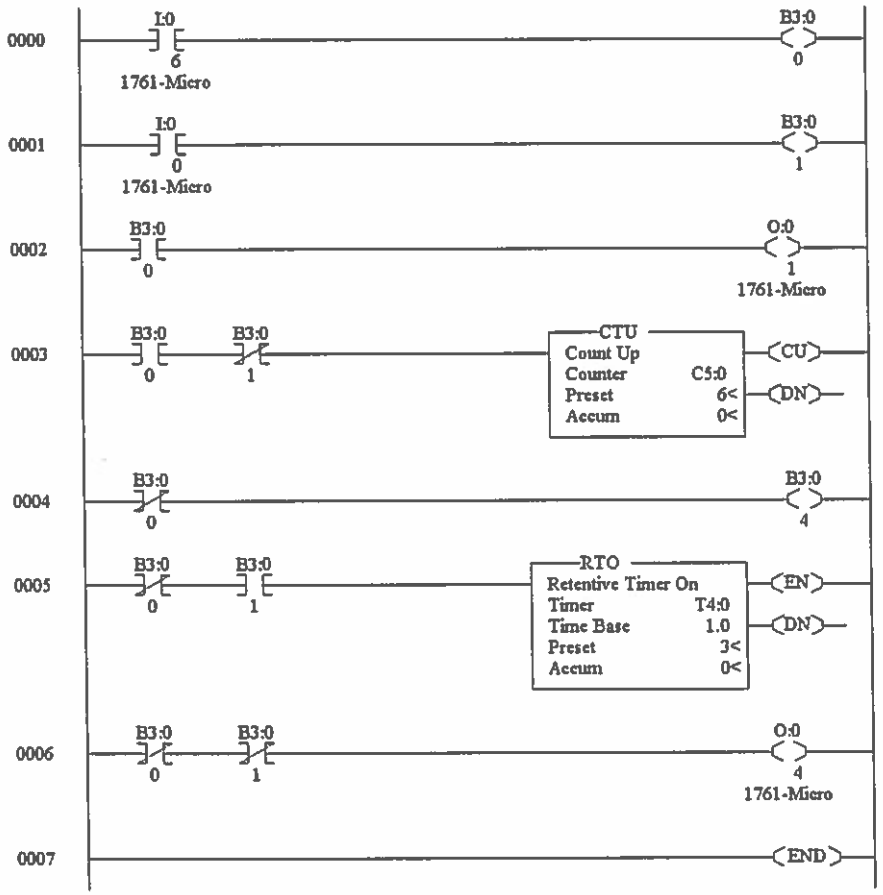
4. When coil B3:0/2 is activated it causes input elements B3:0/2 on rungs 0 and 2 to go to their energized states. Then:

    a. The normally closed B3:0/2 on rung 0 opens, breaking the connection between I:0/3 and O:0/2, turning off O:0/2.
    b. The normally open B3:0/2 on rung 2 closes, completing the path to O:0/3, turning on O:0/3.

Sometimes the advantage of using an internal relay coil is hard to see. Below is a brief example of how an internal relay coil can save programming time, especially if the program must be modified. Assume that a variety of coils are all controlled in some way by input I:0/6. The program segment can be written in two ways, as given in Figure 10-3.



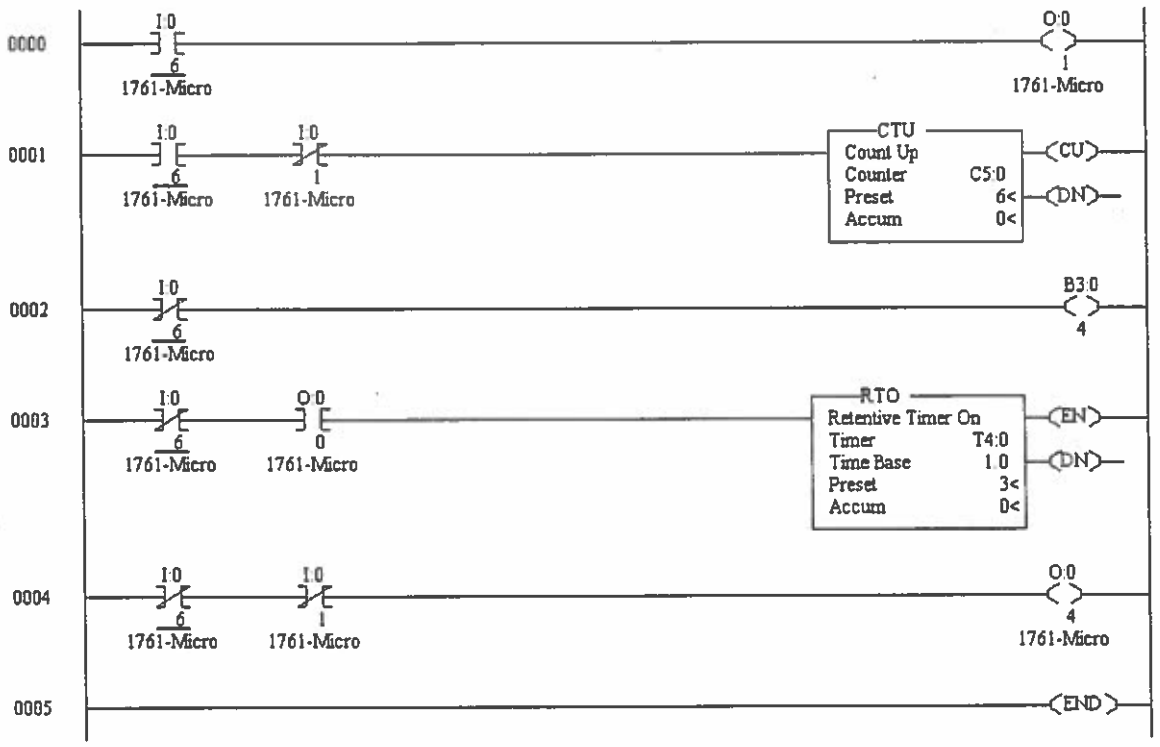
(A)



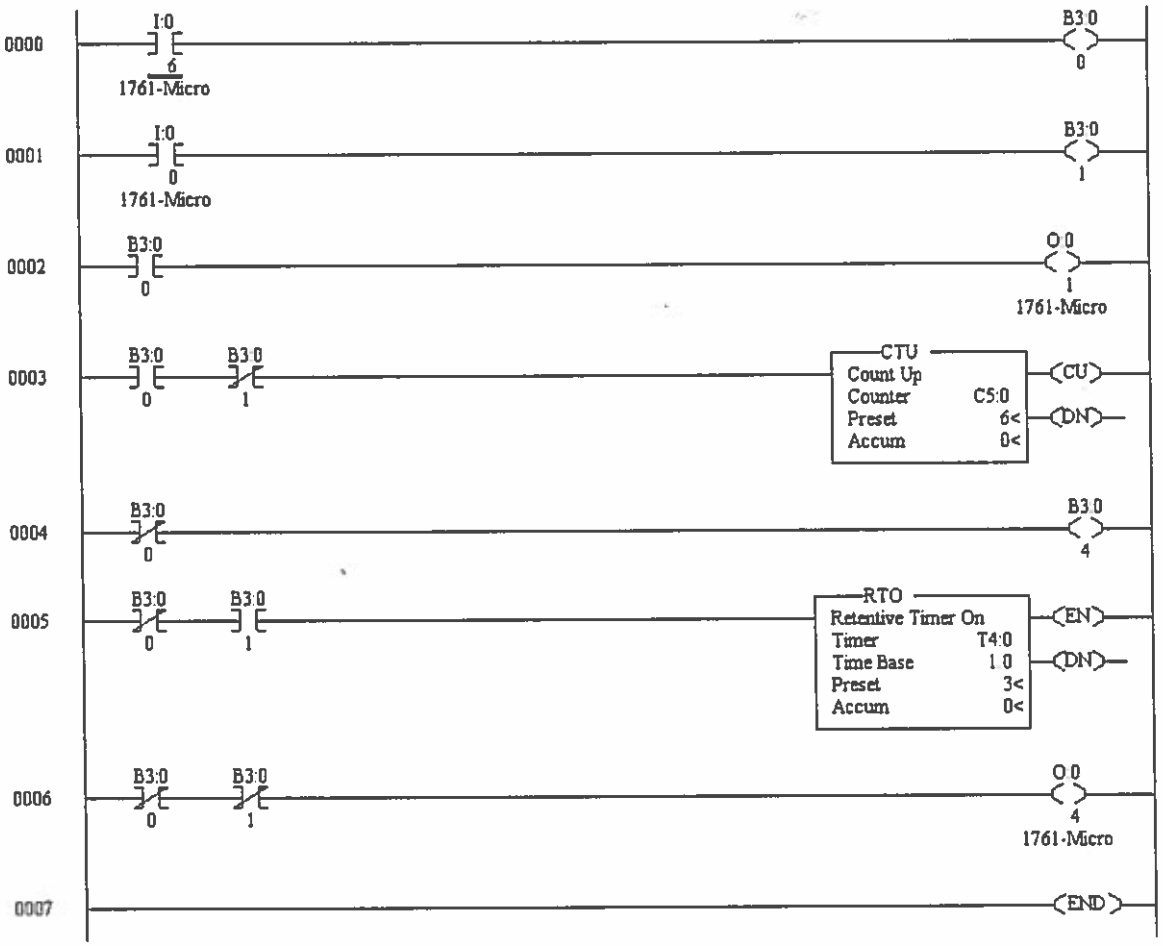
(B)

Figure 10-3
Multiple Output Program With and Without Internal Relay

Suppose the program must be modified to reverse the operation of input I:0/6. In the program without a relay, five elements of the program must be changed, as indicated by the ___ beneath the changed elements in Figure 10-4 (A). The program with the relay requires that only one element can be modified to reflect the change in the input element.



(A)



(B)

Figure 10-4
Input Editing With and Without Relays

The use of relays is key to efficient and easily changeable PLC programs. Without relays, editing and rewriting programs could take as long as rewiring the hard-wired circuits the programs represent.

It is important to understand relays and how they operate within a program. They are essential to just about all of the other internal control devices (counters, timers, sequencers) to be studied in future units.

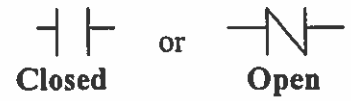
Computer Programming Keystrokes

The addresses assigned to PLC internal relays by Allen-Bradley represented as a BIT data File (B3:0/0 through B3:31/15) for a total of 512 available addresses. To enter an internal relay coil at the end of the rung, use the following keystrokes:

Output Energized then the address (B3:0/0 through B3:31/15)

To program a normally open or normally closed input contact for an internal relay, using the keystroke:

Examine if **Examine if**



Closed **Open** **Corresponding Relay Number** **rest of the rung entered here**

EXPERIMENT

Purpose

To enter and examine the operation of internal relays in a program.

Procedure

1. Make sure power is off to the MicroLogix PLC Training System, and plug the interface cable into the controller body.

2. Make all common switches to the controller, switches and lights.

3. Select two switches, numbers 0, 1, 4 or 5 and enter the switch numbers into Table 10.1.

Switch	Input	Light	Output
1	2	0	0
4	4	7	1

Table 10-1
Connections for Procedures

4. Make all the connections between switches, inputs, lights and outputs as indicated in Table 10-1.

5. Turn on the MicroLogix PLC power, using the RSLogix500 Software, create a new program.

6. Examine the program in Figure 10-6.

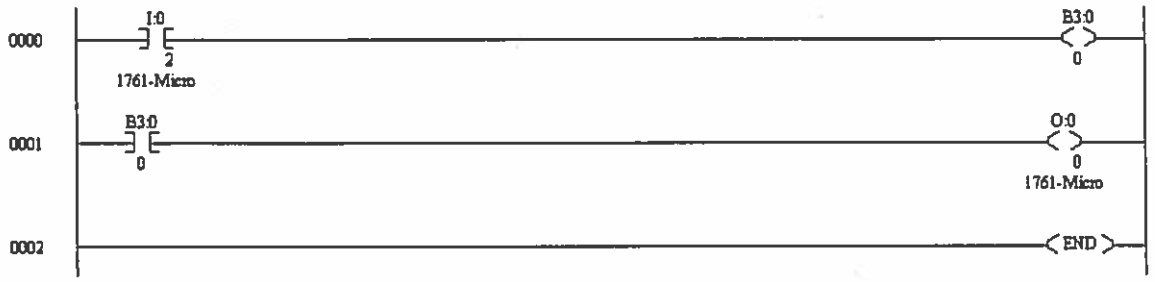


Figure 10-6
Program for Step 6

Explain what the program would do.

Input I:0/2 turns on the relay B3:0/0. Relay B3:0/0 turns on output O:0/0. Input I:0/2 is activated by the switch designated in the Table 10-1. Output O:0/0 Controls light 2.

7. With the computer in the OFFLINE mode, enter this program into the computer with the keystrokes.

New Rung	Examine if Closed I:0/2	Output Energized B3:0/0
New Rung	Examine if Closed B3:0/0	Output Energized O:0/0

8. Verify, Download, Go Online and Run. Operate the switch connected to the input I:0/2.

   a. How does the switch connected to input 2 control the light?

   The program should have operated as described in Step 6 above.

   b. Compare this answer to your answer to Step 6.

   The student should compare his answer to Step 6 above. They should reenter the program into the controller and test its operation to be sure they understand it. Errors should be noted in the answer space.

Go OFFLINE. Then enter the program shown in Figure 10-7.

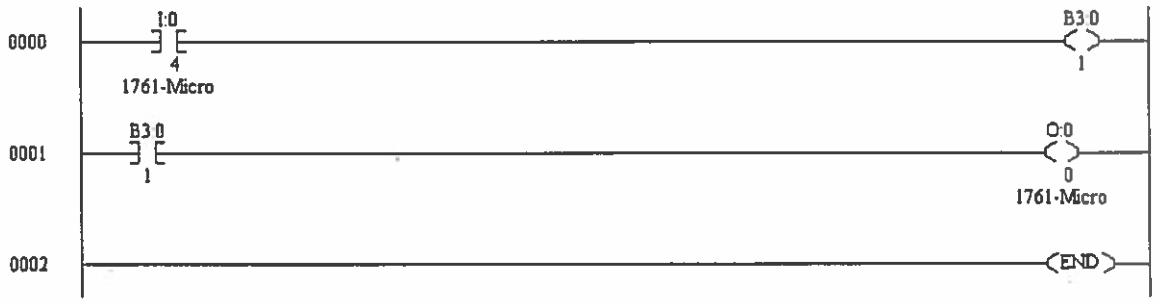


Figure 10-7
Program for Step 9

Explain what the program will do.

When the input I:0/4 is energized, relay B3:0/1 is activated. Relay B3:0/1 turns on output O:0/0. Input I:0/4 is controlled by the switch in the Table 10-1. Output O:0/0 controls light 0.

9. Put the computer again in OFFLINE mode. Enter the program into the computer using the following keystrokes:

New Rung	Examine if Closed I:0/4	Output Energized B3:0/1
New Rung	Examine if Closed B3:0/1	Output Energized O:0/0

10. Verify, Download, Go Online, and Run and operate the switch. Compare the operation of this program with the program in Figure 10-6.

In the first program, the relay is used to activate an output device. In the second program, the relay is used to deactivate the output device.

11. Add a rung to the program in Step 6 so that it will activate output O:0/1 when the input I:0/2 is deactivated. Draw the complete ladder logic diagram in the space below.

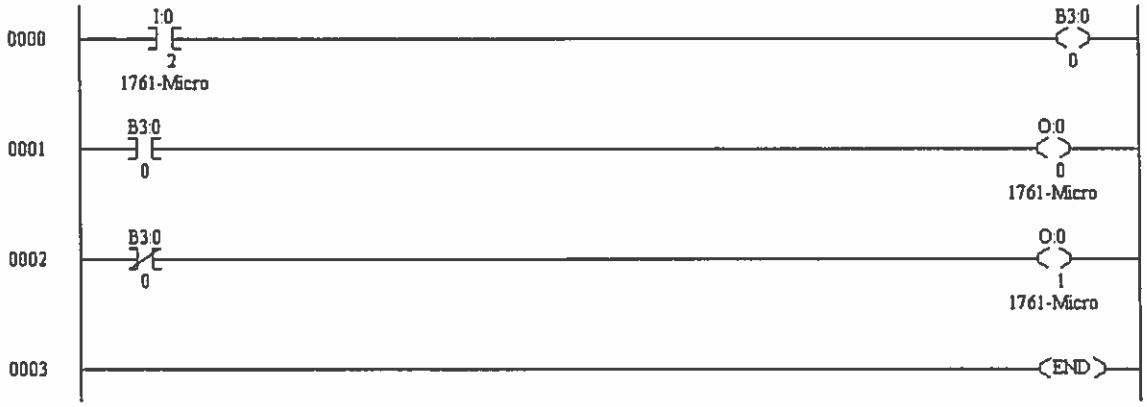


Figure 10-8
Program for Step 12

12. Display the keystrokes for the revised program on these lines.

New Rung	Examine if Closed I:0/2	Output Energized B3:0/0
New Rung	Examine if Closed B3:0/0	Output Energized O:0/0
New Rung	Examine if Open B3:0/0	Output Energized O:0/1

13. Enter and test the operation of your program.

Did it operate like it was supposed to? *Answers will vary.*

If not, check your program and your wiring and try again. If you still have not succeeded after a second try, consult with your instructor.

14. Turn off the power, remove all jumper wires. Put away all the materials and complete the following questions.

Questions

1. What is an internal relay used for?

   An internal relay is used to convert a single input into multiple outputs, controlling operation of multiple devices simultaneouslv.

2. How are internal relay coils addressed in a MicroLogix 1000?

   Relay coils are addressed by pressing Output Energized -- ( ) -- and numbers B3:- - -.

3. Respond to the following as either TRUE or FALSE.

   a. *False* Internal relay elements make a program harder to change.

   b. *True* A relay coil element will energize any input element with the same address.

   c. *False* Internal relays may only have normally open contacts.

   d. *False* Internal relays are rarely used in PLC programs.

4. Explain the operation of the program in Figure 10-9.

   When contact B3:0/11 on rung 0 is not energized, energizing input I:0/4 activates internal relay B3:0/10. When coil B3:0/10 is activated it energizes contact B3:0/10, turning on output O:0/2. As long as internal relay B3:0/11 is not activated output O:0/3 is turned on. Energizing input I:0/9 activates internal relay B3:0/11 energizing contact B3:0/11 on rung 3. This turns off output O:0/3. At the same time, it energizes contact B3:0/11 on rung 0, deactivating B3:0/10 and turning off output O:0/2.

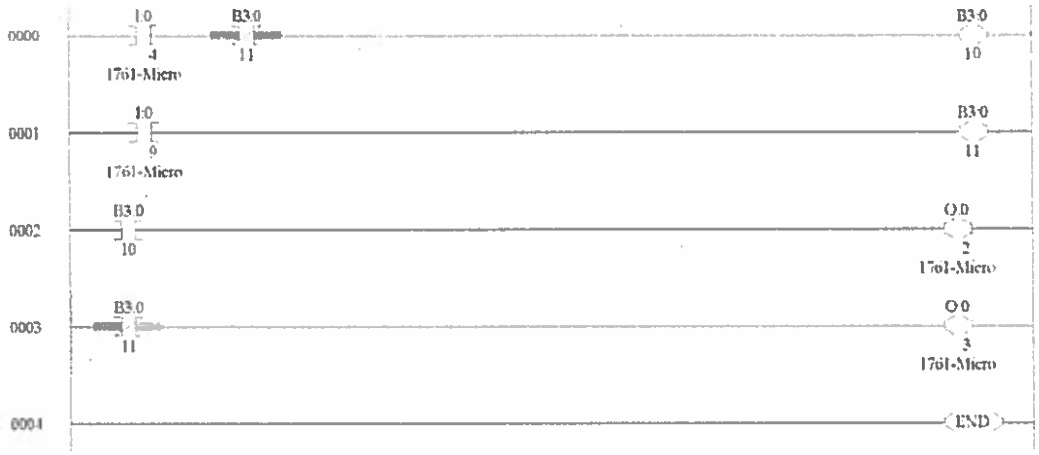
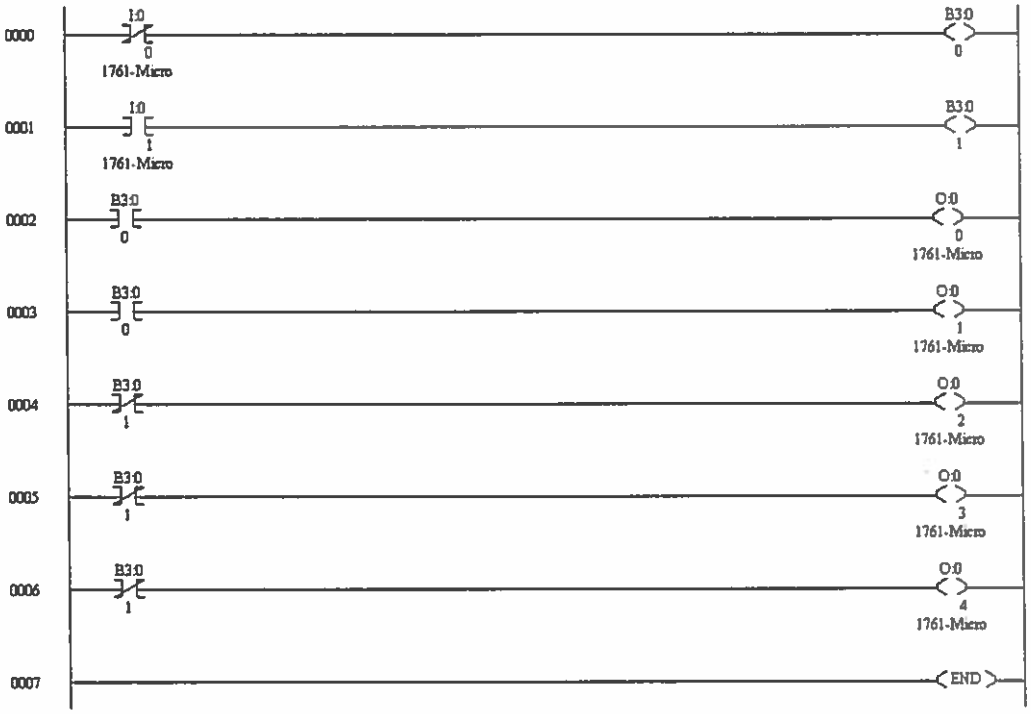


Figure 10-9

5. Write a program in which a normally closed input, when energized, turns on two lights. Also a normally open input, when energized must turn off three lights. All outputs must be controlled by the relay elements. Provide both the ladder logic diagram and the programming keystrokes.



New Rung	Examine if Open I:0/0	Output Energized B3:0/0
New Rung	Examine if Closed I:0/1	Output Energized B3:0/1
New Rung	Examine if Closed B3:0/0	Output Energized O:0/0
New Rung	Examine if Closed B3:0/0	Output Energized O:0/1
New Rung	Examine if Open B3:0/1	Output Energized O:0/2
New Rung	Examine if Open B3:0/1	Output Energized O:0/3
New Rung	Examine if Open B3:0/1	Output Energized O:0/4