UNIT 11
INSTUCTOR'S MANUAL

"AND" AND "OR" CIRCUITS

1. This unit employs Boolean relationships to describe ANDed and ORed inputs in a ladder logic diagram. If you elected to omit the unit on Boolean Algebra, you will need to find an alternative way to present the background information presented in this unit.

2. Since outputs cannot be ANDed and ORed, you may need to re-emphasize to the students that each program rung can hold only a single output, even though it can have many inputs and can have branched inputs.

3. It would be a good idea to check the common connections one last time before the students run their programs. After this unit the students should be familiar enough with the wiring set up to do the wiring on their own.

4. During the Experiment the students are asked to record all occurrences of particular events. You may need to remind them to check for all possible answers to a question, to try all possible combinations of switches and the like.

5. In Question 3 of the Questions the solution will come more easily if the students try to program for one line of conditions at a time. Trying to do both lines at once may prove confusing.

6. If you have omitted the material on Boolean Algebra, you should omit Question 5 of the Questions section.

UNIT 11

"AND" AND "OR" CIRCUITS

Objectives

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

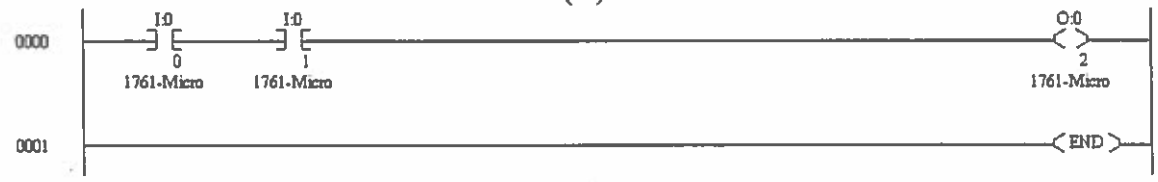
1. Identify an AND circuit.
2. Identify an OR circuit.
3. Open and close an OR branch on a ladder logic diagram.
4. Develop AND/OR combination circuits.
5. Enter AND, OR and combination AND/OR circuits into the controller.

Background

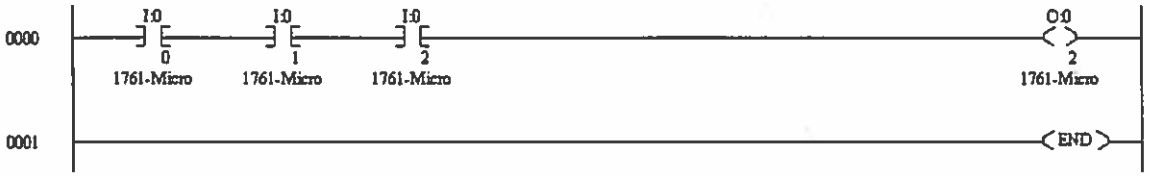
AND and OR logical relationships were first presented in Unit 6., Boolean Algebra. You were shown how Boolean equations can be used to describe electrical circuits. This unit will focus on how these ANDs and Ors apply to the ladder logic diagrams and how they are entered into the controller.

The best way to describe AND and OR logic circuits is by using examples of ladder logic diagram. In the MicroLogix 1000 a new rung is begun by pressing the "New Rung" key. Rung A shows a single input element I:0/0 controlling output element O:0/2. When input element I:0/0 is energized, output O:0/2 will be turned on.

(A)



(B)



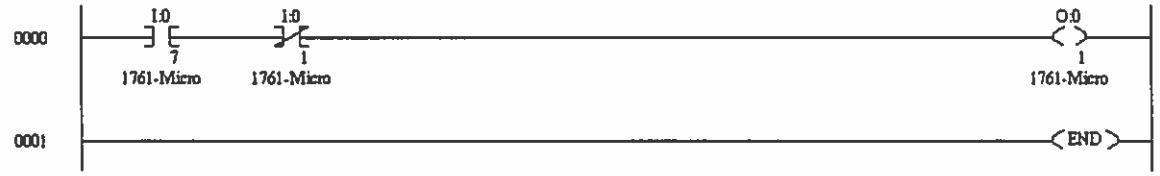
(C)

Figure 11-1
ANDed Input

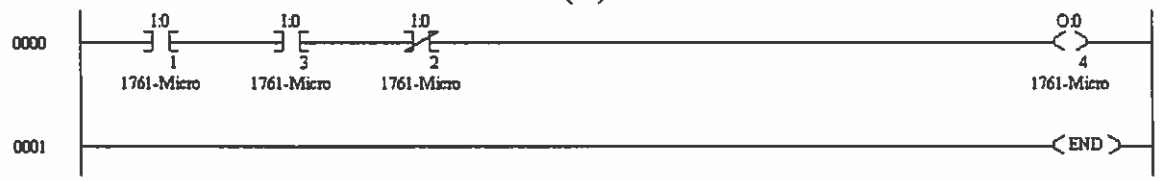
On rung B in Figure 11-1, two input elements I:0/0 and I:0/1 control output element O:0/2. Elements I:0/0 AND I:0/1 must both be energized before output O:0/2 will be turned on. Inputs I:0/0 and I:0/1 are considered ANDed together.

On rung C of Figure 11-1, three input elements, I:0/0, I:0/1 and I:0/2 control output element O:0/2. These three elements as shown are ANDed together. All three input elements must be energized at the same time in order for the output element O:0/2 to be turned on. Notice that in ANDed circuits more than one input elements must be passed through to reach the output element. That is, the input elements are in series.

In Figure 11-1 only normally open inputs were used. When normally closed input elements are placed in series, they create AND NOT or AND-inverse relationships. For example, rung A in Figure 11-2 states that input I:0/7 must be energized AND input I:0/1 must NOT be energized for output O:0/1 to turn on. If the element I:0/1 is energized, output element O:0/1 cannot be turned on.



(A)



(B)

Figure 11-2
Input Elements in AND NOT Relationships

In the rung B of Figure 11-2, both an AND and an AND NOT (AND-inverse) relationships are used. Rung B that input I:0/1 AND I:0/3 must be energized AND I:0/2 must NOT be energized for output O:0/4 to be activated. Once input I:0/2 is energized, output O:0/4 cannot be turned on.

The rung in Figure 11-3 has input elements which are ORed together. It shows two input elements I:0/0 OR input I:0/3 ORed together at the beginning of the rung. This means that if input I:0/0 OR input I:0/3 is energized, output O:0/1, will turn on. The vertical line that connects the right side of the element I:0/3 back up to the top line of the rung is called a branch. A branch in a ladder logic diagram indicates that the connected lines contain an OR circuit, that is, the elements are in parallel.

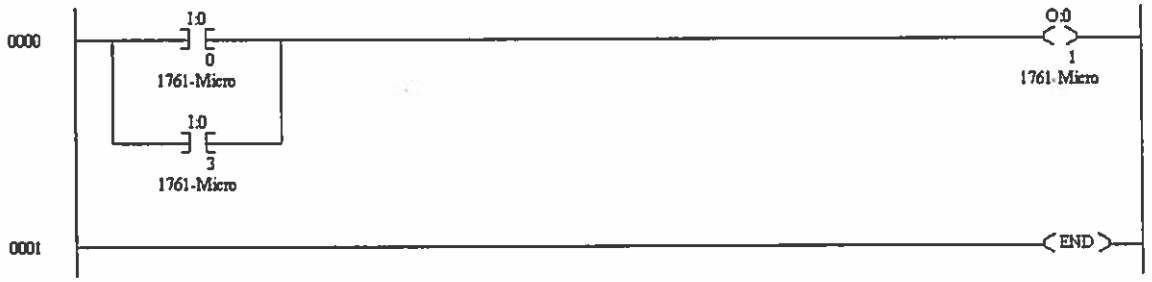


Figure 11-3
ORed Elements

Like AND NOT, OR NOT is used when a normally closed input is placed in an OR relationship. The rung in Figure 11-4 illustrates how a normally closed input can be used in an OR circuit.

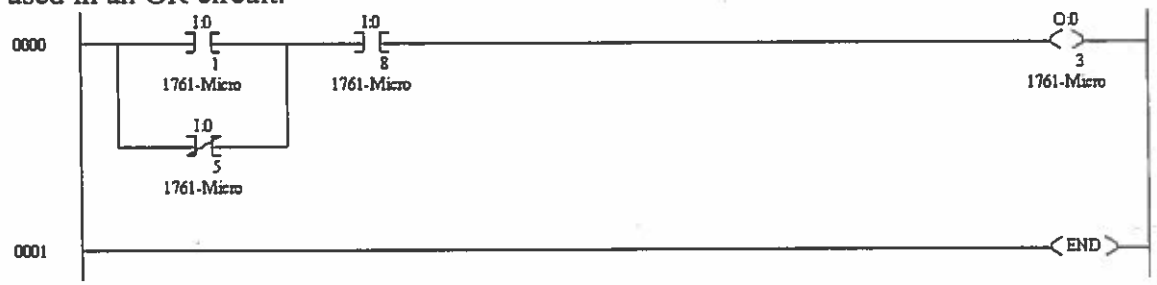


Figure 11-4
Inputs in OR NOT Relationship

AND and OR circuits can be combined into the same rung of a program as in Figure 11-4. Input element I:0/8 in the rung is not part of the OR circuit. Input I:0/8 is actually ANDed together with the ORed pair of inputs I:0/1, I:0/5. So if I:0/1 is energized OR I:0/5 is NOT energized, AND I:0/8 is energized, then O:0/3 will turn on. Single branches should always appear at the end of the rung. It is also possible to have multiple branches on a rung. Figure 11-5 is an example of two ORed switches ANDed together. Note that a branch is needed on each side of the I:0/2 element to connect it to the main rung. The left-hand branch is called the opening branch; the right-hand branch is called the closing branch.

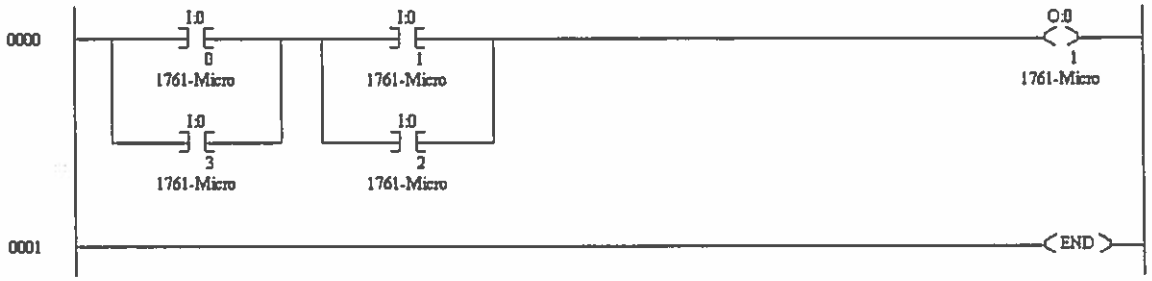


Figure 11-5
Two ORed Pairs, ANDed Together

Here inputs I:0/0 and I:0/3 are ORed together and inputs I:0/1 and I:0/2 are ORed together. These two ORed pairs and then ANDed together along the main rung. Figure 11-6 shows the four possible paths to output element O:0/1.

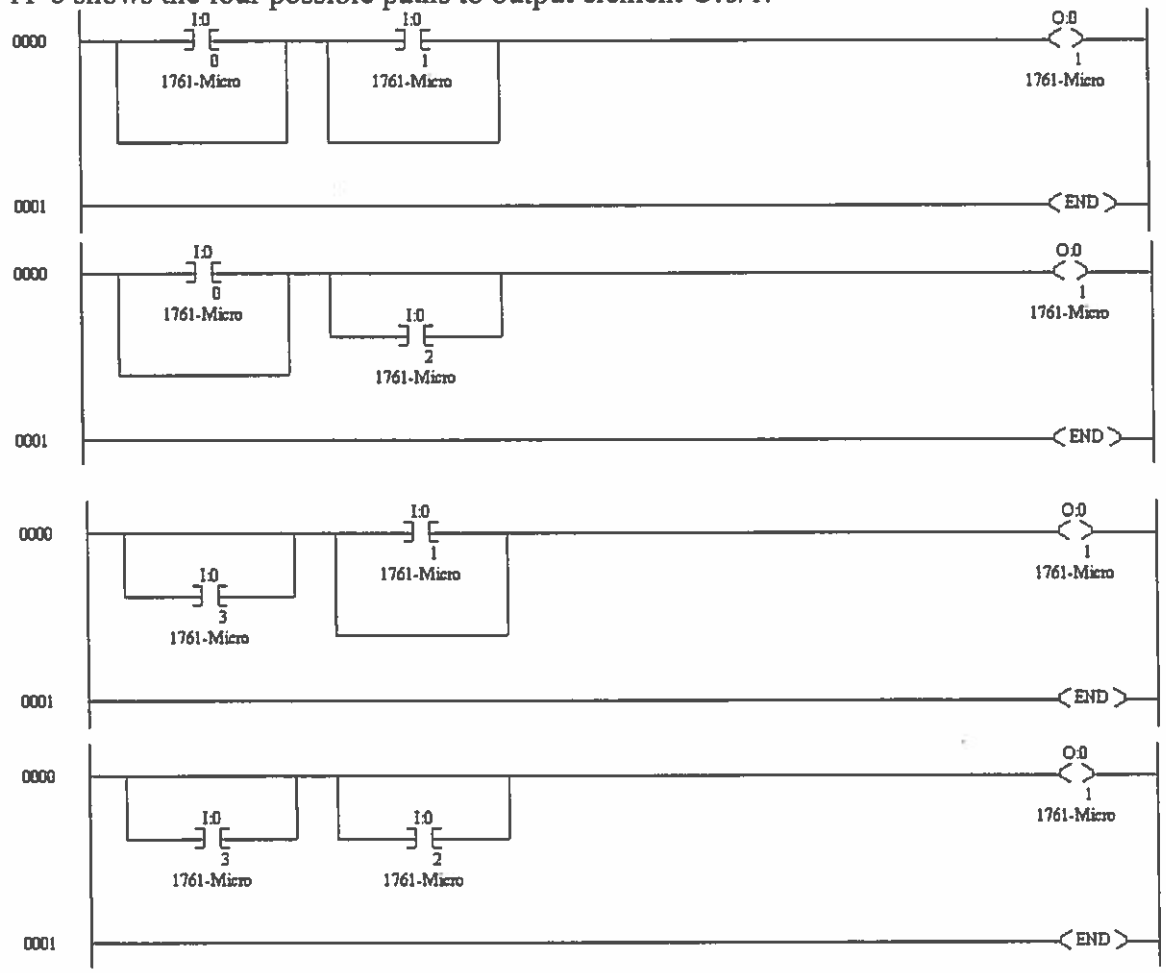
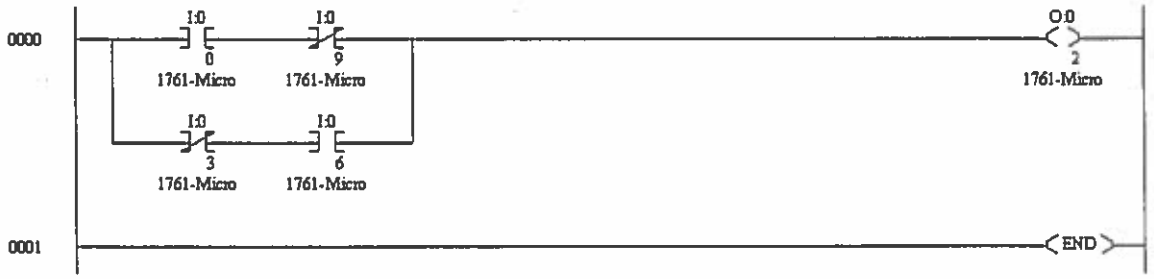


Figure 11-6
Paths to Output when Two ORed Pairs are ANDed Together

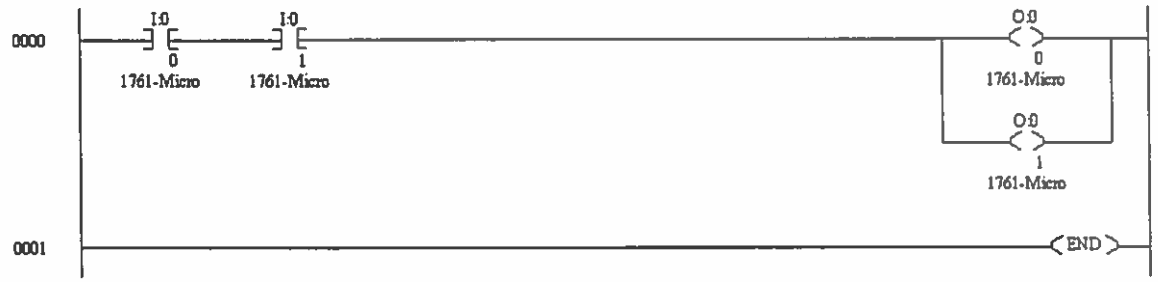
It is also possible to have a set of several elements ANDed together, then ORed with a set of several other ANDed elements in Figure 11-7. Whenever the ORed sets have unequal quantities of inputs, the set with larger quantity should be placed on the main rung.



New Rung
Examine if Closed I:0/0
Examine if Open I:0/9
Output Energized O:0/2
Rung Branch
Move rung branch to before I:0/0 and after I:0/9
Examine if Open I:0/3
Examine if Closed I:0/6

Figure 11-7
Multiple Inputs in an ORed Circuit

Branches can be placed just about anywhere in the program. In the PLC you can program parallel outputs on a rung to allow a true logic path to control multiple output.

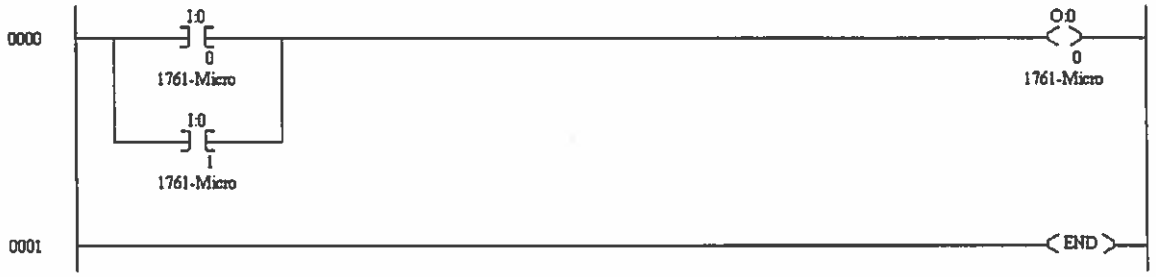


New Rung
Examine if Close I:0/0
Examine if Close I:0/1
Output Energized O:0/0
Rung Branch
Move rung branch to before O:0/0 and after O:0/0
Output Energized O:0/1

Figure 11-8
Multiple Outputs

Computer Programming Keystrokes

To enter the program shown in Figure 11-9, use the keystrokes shown.



New Rung
Examine if Close I:0/0
Rung Branch
Move rung branch to before I:0/0 and after I:0/0
Examine if Close I:0/1
Output Energized O:0/0

Figure 11-9
Branching Program and Keystroke Sequence

Notice that each rung must have its own command. A more complex branching is given in Figure 11-10.

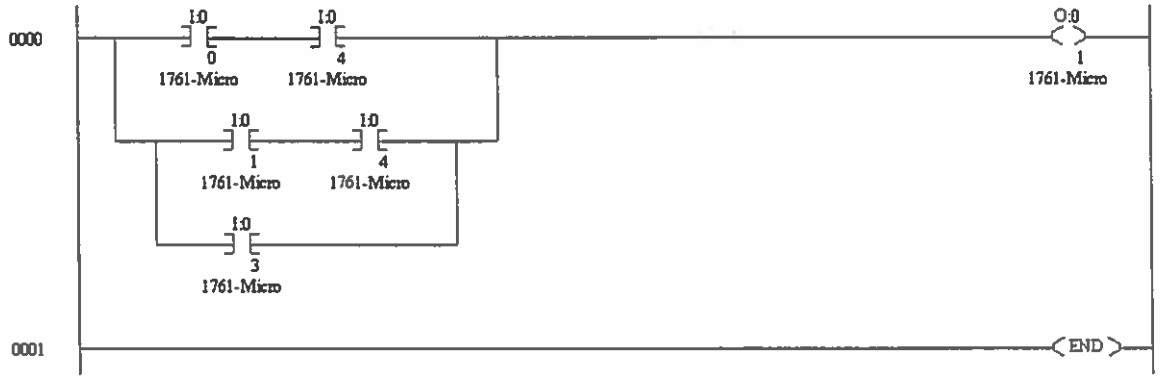


Figure 11-10
The programming keystrokes:

New Rung
Examine if Close I:0/0
Examine if Close I:0/4
Rung Branch
Move rung branch to before I:0/0 and after I:0/4
Examine if Close I:0/1
Examine if Close I:0/4
Rung Branch
Move rung branch to before I:0/1 and after I:0/4
Examine if Close I:0/3
Output Energized O:0/1

EXPERIMENT

Purpose

To write AND/OR programs and enter them using appropriate keystrokes sequences.

Procedures

1. Make sure the Interface Cable is plugged in.
2. Attach the common leads to the controller and the switch/light commons.
3. Make the connections given in the table below between the lights, switches, inputs and outputs.

Switch	Input	Light	Output
5	I:0/0	0	O:0/0
4	I:0/1	7	O:0/1
0	I:0/3	1	O:0/2
1	I:0/4	--	--

Table 11-1
Connections for Procedures

4. Turn on the MicroLogix PLC power, using the RSLogix500 Software, create a new program and enter the example program in Figure 11-9.

Verify, Download, Go Online, and Run the program, testing the appropriate switches.

Does the program operate in the way explained in the background information? Explain your answer.

The program should operate as follows: Switch 5 when pressed, turns on light 0. When pressed a second time, switch 5 turns off light 0. Switch 4 when pressed also turns on light 0. When pressed a second time, switch 4 turns off the light.

5. Study Figure 11-11. This ladder logic diagram activates output O:0/0 when inputs I:0/0 and I:0/1 are energized. It also activates output O:0/1 if input I:0/0 is not energized or if input I:0/4 is energized.

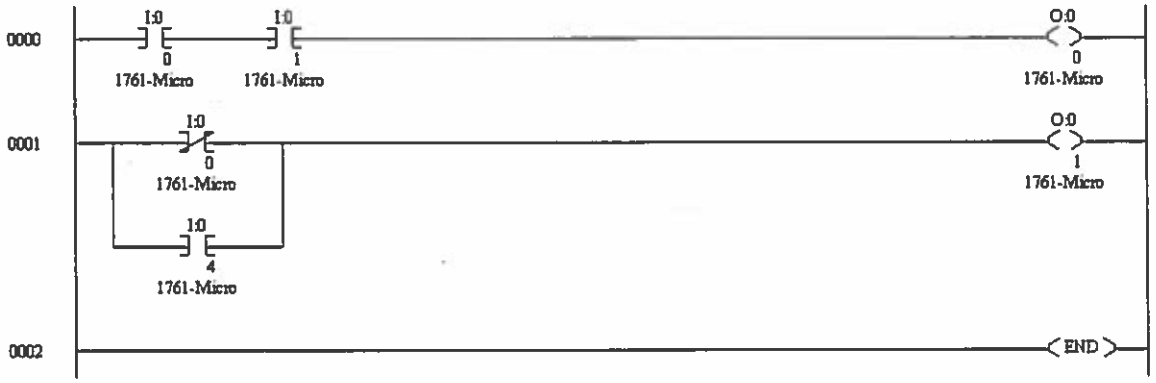


Figure 11-11
Program for Step 6

Explain which switches, on or off, control which lights.

Switches 4 and 5, when depressed, turn on light 0. When switch 5 is off (not depressed) light 7 is on. When switch 5 is on (depressed) pressing switch 1 turns on light 7.

6. List the keystrokes for the program in Figure 11-11.

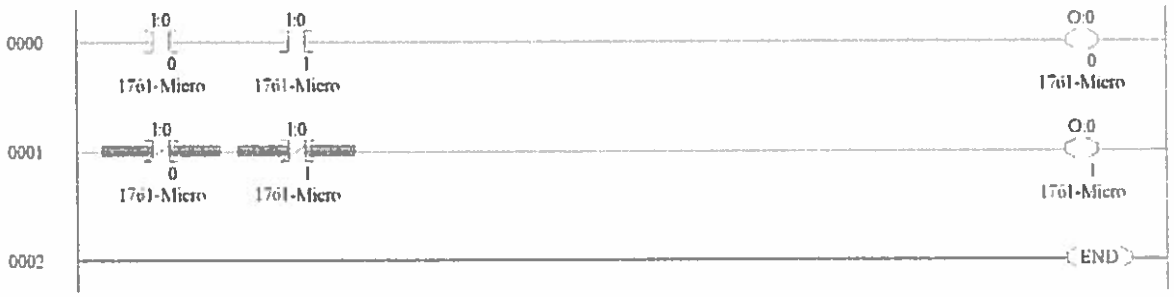
New Rung
Examine if Close I:0/0
Examine if Close I:0/1
Output Energized O:0/0
New Rung
Examine if Open I:0/0
Rung Branch
Move rung branch to before I:0/0 and after I:0/0
Examine if Close I:0/4
Output Energized O:0/1

7. Enter the program and test its operation.

Was your explanation correct? If not, why not.

Answers will vary. The student should identify where his explanation differed from actual program operation.

8. Modify the program in Figure 11-11 so that light 0 comes on if switches 4 and 5 are on. Also, when switches 4 and 5 are off light 7 comes on. Draw the entire ladder logic diagram and list the entire keystroke sequence in the space provided. (Remember that all of the switches you are using are normally open.)



The key stroke sequence:

Delete Rung Branch
After Examine if Open I:0/0 add Examine if Open I:0/1

9. Run your modified program.

Why are lights 0 and 7 never on at the same time?

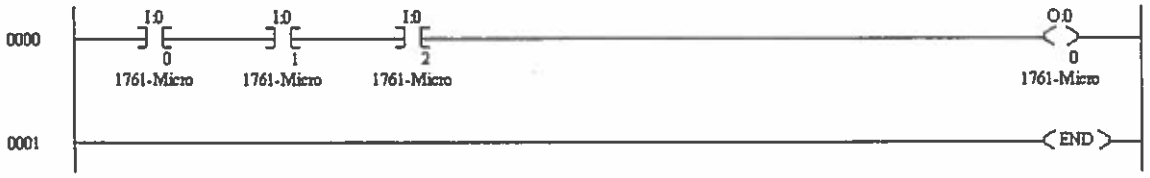
Output O:0/1 requires a switch status opposite to that of output O:0/0. When output O:0/0 is activated, output O:0/1 must be deactivated and vise versa.

(If lights 0 and 7 did come on at the same time, check your ladder logic diagram and keystroke sequence in Step 9. Re-enter the program and run it. If you still have problems, consult with your instructor.)

10. Turn off the power and set aside all of the equipment, then complete the Questions which follow.

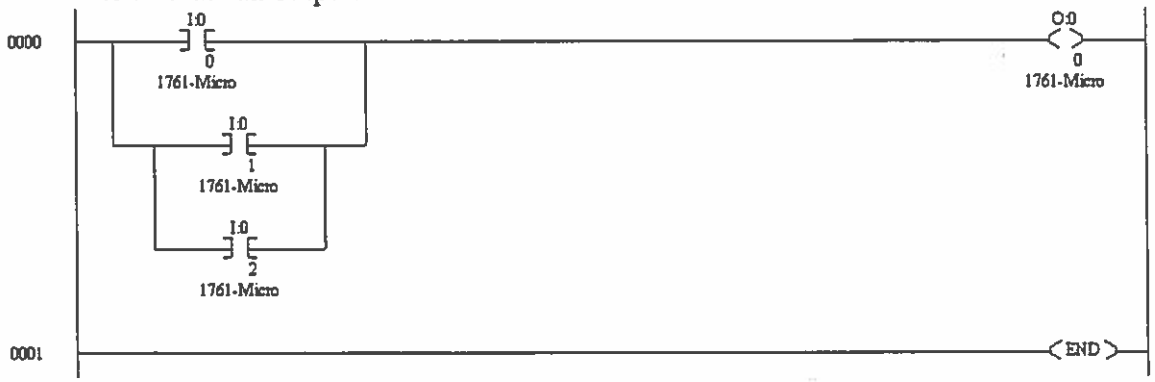
Questions

1. Draw a ladder logic diagram that has three normally open input elements ANDed together to activate an output.



(Element addresses may vary within their acceptable ranges.)

2. Draw a ladder logic diagram which has three normally open inputs ORed together to activate an output.

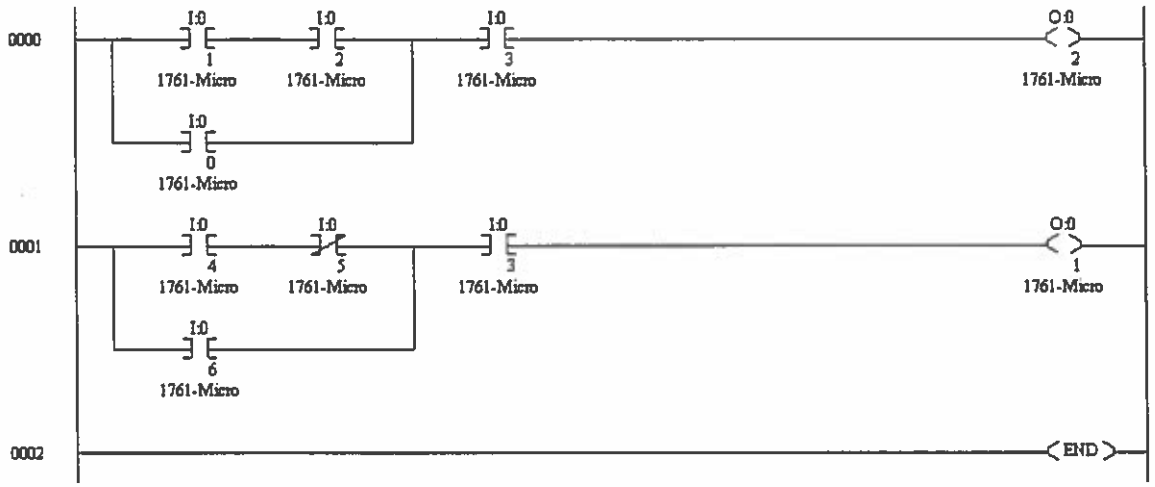


(Element addresses may vary within their acceptable ranges.)

3. Draw a single ladder logic diagram and give the keystroke sequence for the operations described below.

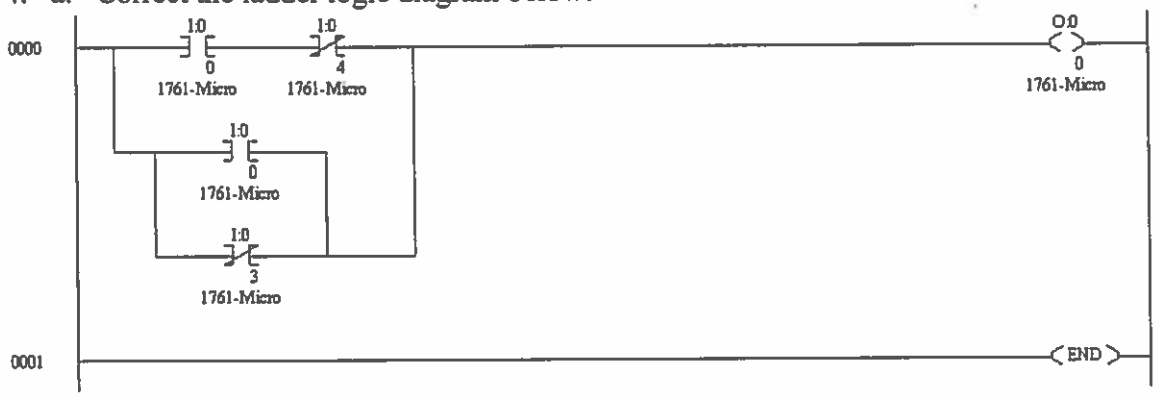
   a. Input element I:0/0 or input elements I:0/I and I:0/2 and input elements I:0/3 turn on output element O:0/2.

   b. Input elements I:0/3 and I:0/6 or input elements I:0/3 and I:0/4 and not input elements I:0/5 turn on output element O:0/I.

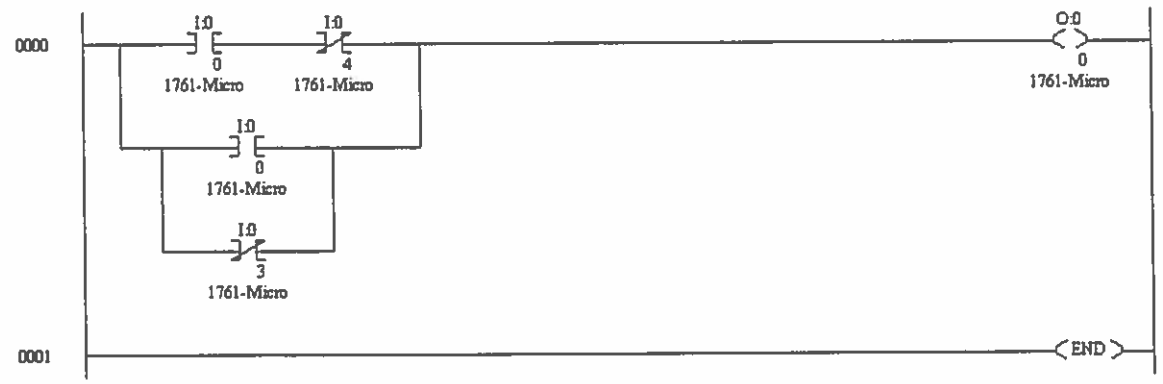


New Rung
Examine if Close I:0/1
Examine if Close I:0/2
Rung Branch
Move rung branch to before I:0/1 and after I:0/2
Examine if Close I:0/0
Examine if Close I:0/3
Output Energized O:0/2
New Rung
Examine if Close I:0/4
Examine if Open I:0/5
Rung Branch
Move rung branch to before I:0/4 and after I:0/5
Examine if Close I:0/6
Examine if Close I:0/3
Output Energized O:0/1

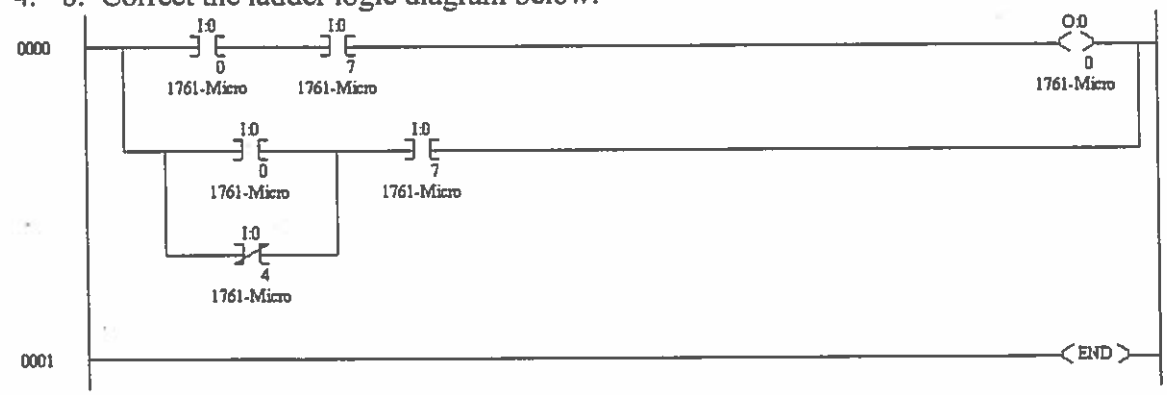
4. a. Correct the ladder logic diagram below:



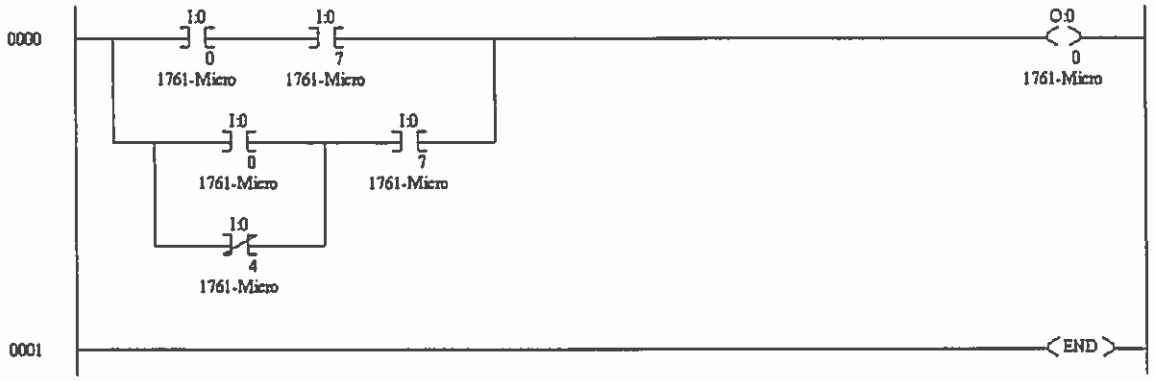
a. Corrected Ladder Diagram



4. b. Correct the ladder logic diagram below:

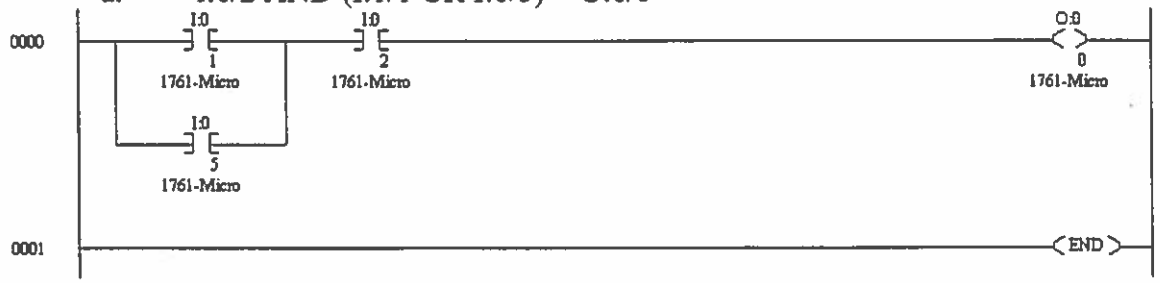


b. Corrected Ladder Diagram



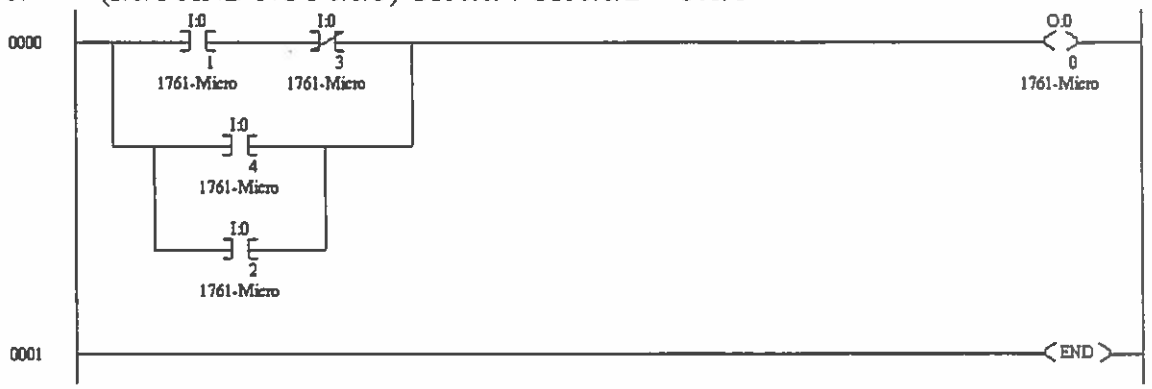
5. Draw the ladder logic diagrams and give keystroke sequences for the following equations.

a. I:0/2 AND (I:1/1 OR I:0/5) = O:0/0



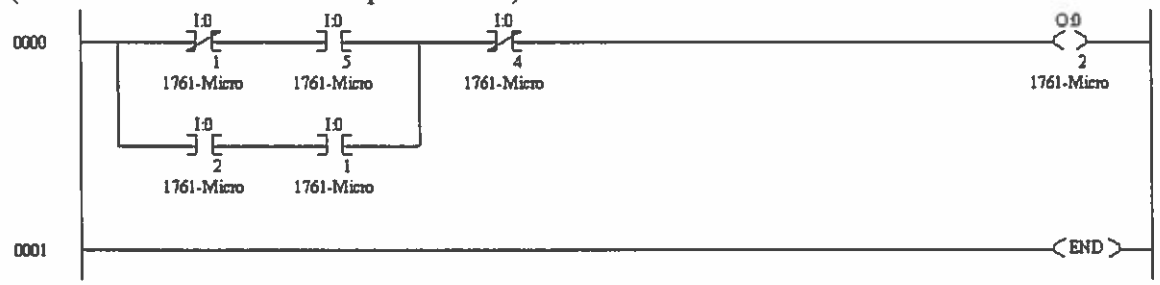
New Rung
Examine if Close I:0/2
Examine if Close I:0/1
Rung Branch
Move rung branch to before I:0/2 and after I:0/1
Examine if Close I:0/5
Output Energized O:0/0

b. (I:0/1 AND NOT I:1/3) OR I:0/4 OR I:0/2 = O:0/0



New Rung
Examine if Close I:0/1
Examine if Open I:0/3
Rung Branch
Move rung branch to before I:0/1 and after I:0/3
Examine if Close I:0/4
Rung Branch
Move rung branch to before I:0/4 and after I:0/4
Examine if Close I:0/2
Output Energized O:0/0

c. ((NOT I:0/1 AND I:0/5) OR (I:0/2 AND I:0/1))AND NOT I:0/4 = O:0/2
(Be careful with the double parenthesis)



New Rung
Examine if Open I:0/1
Examine if Closed I:0/5
Examine if Open I:0/4
Rung Branch
Move rung branch to before I:0/1 and after I:0/5
Examine if Close I:0/2
Examine if Close I:0/1
Output Energized O:0/2

UNIT 12
INSTRUCTOR'S MANUAL

LATCHING RELAYS

1. The students are expected to know the keystroke sequences for inputs, outputs and relays. These keystrokes will not be reviewed in this and later units, unless directly relevant to entering a new function.

2. Question 3 of the Questions gives switch and light numbers. The students will have to decide on correct input and output addresses, so they may vary slightly from those given in the answer.

UNIT 12

LATCHING RELAYS

Objectives

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

1. Describe latching and unlatching rungs.
2. Compare a latching relay to the latching instruction.
3. Compare an unlatching relay to the unlatching instruction.
4. Write and key in a program which uses a parallel input element to latch a rung.
5. Write and key in a program using latch/unlatch instructions.

Background

In previous units the electrical circuits typically consisted of a momentary switch and a light. When the switch was pressed, the light came on. Releasing the switch turned off the light. There are some situations in which the light or other output device must stay on when the momentary switch is released. A *latching relay* can be used to keep the output device activated. Figure 12-1 is the ladder logic diagram of a typical *latching circuit* or *operation holding circuit*.

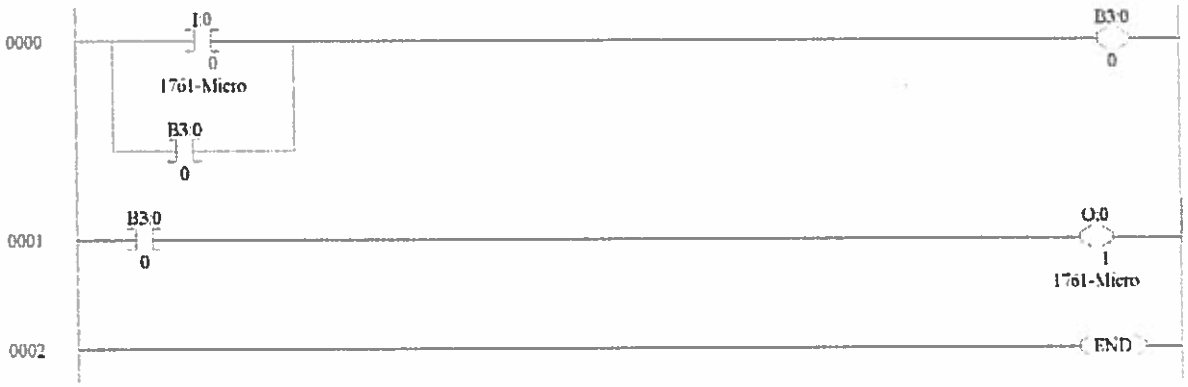


Figure 12-1
Latching Circuit

In this latching circuit the internal relay B3:0/0 is activated when input I:0/0 is energized. When B3:0/0 comes on its normally open contact on rung 1 is energized, activating output O:0/1. The normally open contact B3:0/0 which is ORed with input I:0/0 is also energized. This completes a circuit in parallel with input I:0/0. Parallel input B3:0/0 is the *latching element*. Even when input I:0/0 is no longer energized, the B3:0/0 contacts will be held in their energized state by coil B3:0/0.

In the circuit in Figure 12-1, output O:0/1 will stay on once turned on. To turn off the latching circuit, the program must be modified to incorporate an *unlatching element*, as in Figure 12-2.

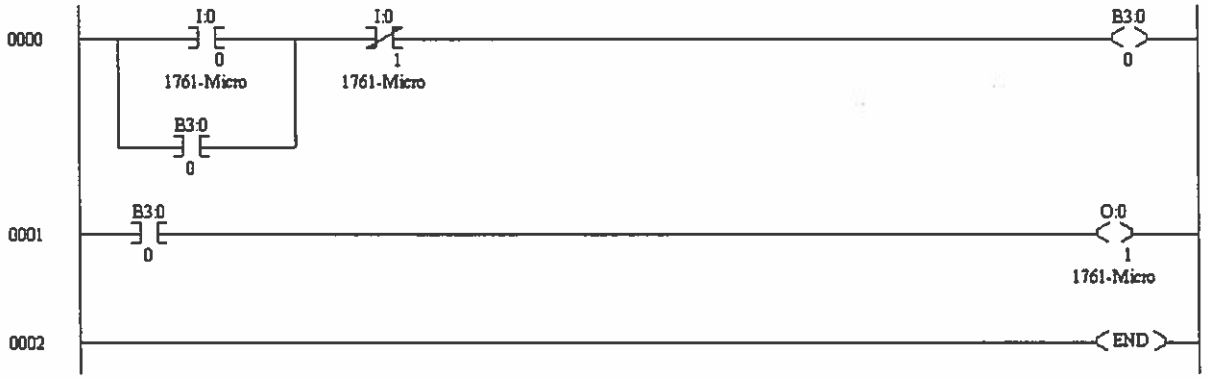


Figure 12-2
Latching Circuit with Unlatching Input Element

Input I:0/1, when energized, de-activates B3:0/0, unlatching the latched rung and turning off output O:0/1. Because all input elements are checked numerous times each second, the response is nearly instantaneous when input I:0/1 is energized. The circuit in Figure 12-2 is the basic circuit for the start and stop push-buttons on machines controlled by PLCs.

It is also possible to unlatch a rung with an unlatching relay, as in Figure 12-3.

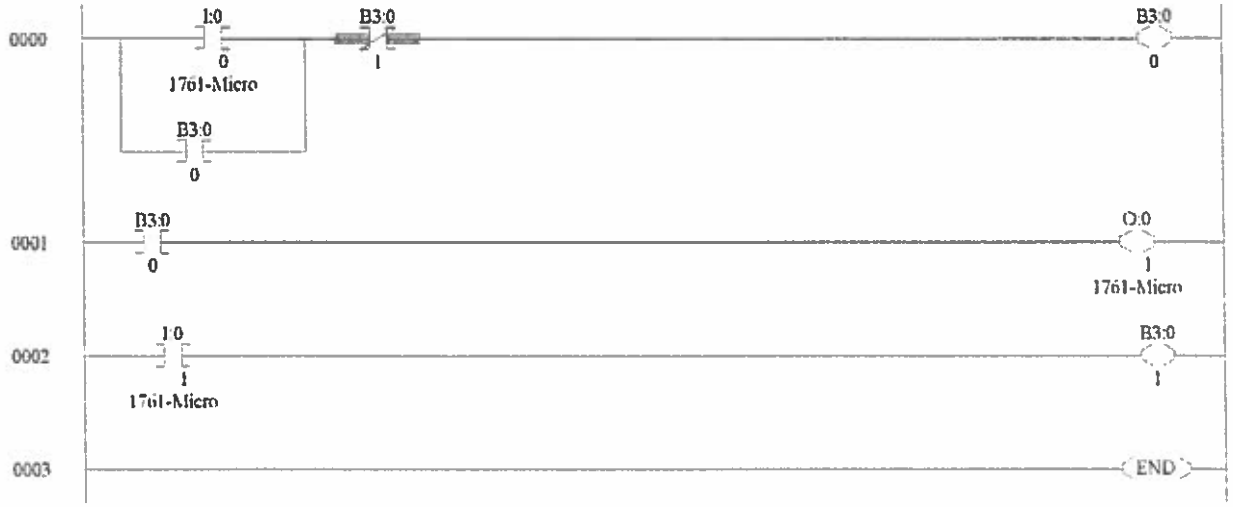


Figure 12-3
Latching Circuit with Unlatching Rung

In Figure 12-3 the internal relay B3:0/1 is used to unlatch the latching circuit. The normally closed contact B3:0/1 is placed on the latching rung in series with inputs I:0/0 and B3:0/0. Input I:0/1 is energized to activate coil B3:0/1. When coil B3:0/1 is activated it opens the normally closed contacts on the latching rung, de-activating coil B3:0/0. De-activating coil B3:0/0 opens both normally open contacts B3:0/0, turning off output O:0/1 and simultaneously unlatching the circuit. In this example B3:0/1 would likely be used in other parts of the program to control other outputs.

An output element can also be used to latch itself on, as in Figure 12-4.

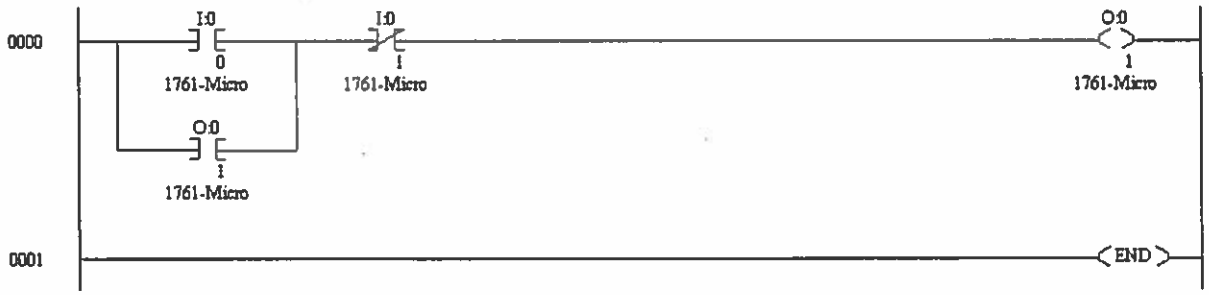


Figure 12-4
Self-Latching Output Element

In this very simple example, input I:0/0, when energized, activates output O:0/1. As with the internal relays, activating output O:0/1 energizes parallel output O:0/1, latching the rung. A separate input I:0/1 is used to unlatch the rung.

In the PLC the instructions for latching and unlatching are called *Output Latch* (OTL) and *Output Unlatch* (OTU). OTL and OTU are retentive output instructions. OTL can only turn on a bit, while OTU can only turn off a bit. These instructions are usually used in pairs, with both instructions addressing the same bit. Your program can examine a bit controlled by OTL and OTU instructions as often as necessary.

Using OTL:

When you assign an address to the OTL instruction that corresponds to the address of a physical output, the output device wired to this screw terminal is energized when the bit is OTL (turned on or latched).

When the rung conditions become false (after being true), the bit remains OTL and the corresponding output device remains energized.

When enabled, the OTL instruction tells the controller to turn on the addressed bit. Thereafter, the bit remains on, regardless of the rung condition, until the bit is turned off (typically by a OTU instruction in another rung).

Using OTU:

When you assign an address to the OTU instruction that corresponds to the address of a physical output, the output device wired to this screw terminal is de-energized when the bit is cleared (turned off or unlatched).

The OTU instruction tells the controller to turn off the addressed bit. Thereafter, the bit remains off, regardless of the rung condition until it is turned on (typically by a OTL instruction in another rung).

Computer Programming Keystrokes

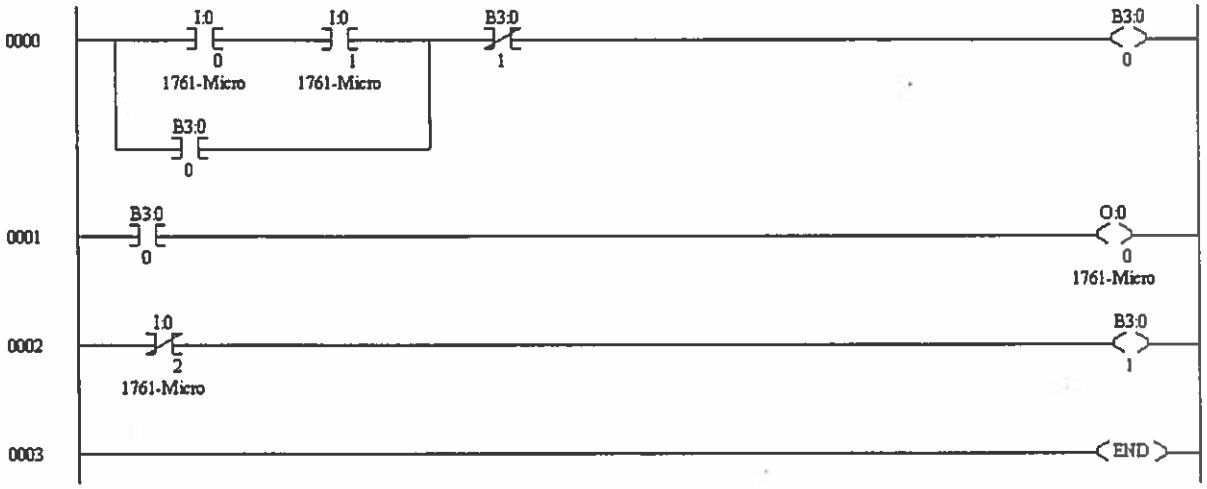
From a programming standpoint a latching relay is merely a specialized use of a standard MicroLogix 1000 internal relay, B3:_ / _. The latching relays coil is entered into the controller using the proper keystrokes for an internal relay coil. The latching input element is programmed as an OR element on the latching rung.

There are several significant points to successful programming of a latching relay (see Figure 12-5):

1. The latching input element must be programmed in parallel (ORed) with the input element(s) which activate the latching coil. The latching input element may be placed in series (ANDed) with additional input elements.

2. The latching relay must be used to control the circuit whose operation is to be held.

3. The unlatching input element must be programmed in series (ANDed) with the latching input element.



New Rung
Examine if Closed I:0/0
Examine if Closed I:0/1
Examine if Open B3:0/1
Rung Branch
Move rung branch to before I:0/0 and after I:0/1
Examine if Close B3:0/0
Output Energized B3:0/0
New Rung
Examine if Closed B3:0/0
Output Energized O:0/0
New Rung
Examine if Open I:0/2
Output Energized B3:0/1

Figure 12-5
Programming a Latching Relay

The program in Figure 12-5 is a simplified example of a circuit with a two-handed push-button start and a single push- button stop or emergency stop. In this example, the start push- buttons would be a normally open momentary switch. The stop push-button would be a normally closed momentary switch. This choice of switches is fairly typical for start-stop push-buttons.

The PLC controller offers a direct means for programming a hold on an operation. The combined latch and unlatch instructions work the same as the latching/unlatching relay pair and are easier to program. The latch and unlatch instructions are each controlled by input elements and are programmed in the output position on the rung. A latch - unlatch pair control one internal relay address, B3:_ / _, or one output address.

The latch rung uses the following keystroke sequence:

(Input controlling latch instruction)

-(L)- Element Address

The unlatch rung uses similar keystrokes:

(Input controlling unlatch instruction)

-(U)- Corresponding Element Address

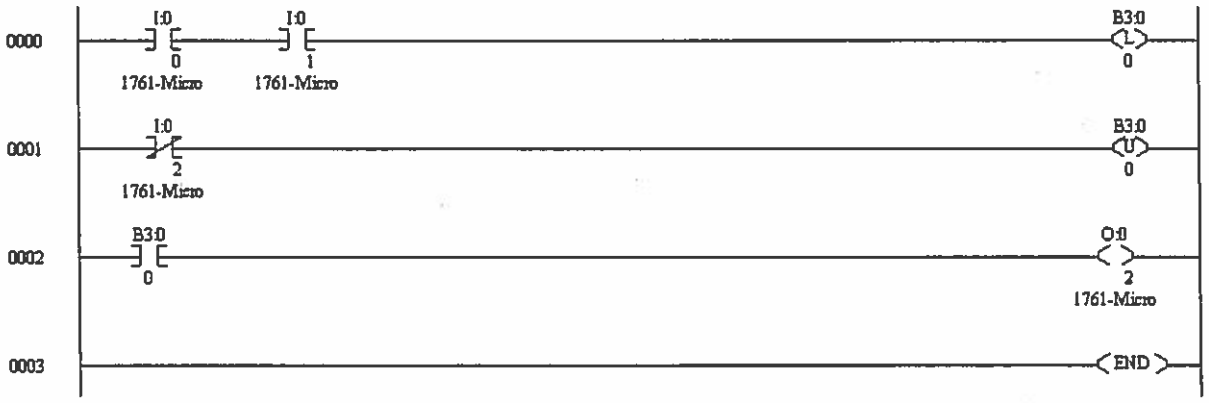
There are several requirements for successful programming of latch and unlatch instructions (see Figure 12-6):

1. The latch and unlatch instructions must be programmed on two separate rungs.

2. Each instruction must be controlled by its own input element(s).

3. The latch and unlatch pair must control the same internal relay B3:_ / _ or the same output address.

4. If an internal relay is latched and unlatched, the relay must be used to activate the circuit whose operation is to be held.



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

Figure 12-6
Programming Set and Reset Rungs

The program in Figure 12-6 is identical in operation to the program in Figure 12-5 but is simpler in design and less cumbersome to enter.

Latch and unlatch rungs may be placed anywhere in a ladder logic diagram. Operation is identical for latching/unlatching rungs and latch/unlatch instructions. If the latching input is the more recently energized, the associated output element or internal relay will be activated. If the unlatching input element is the more recently energized, the associated output element or internal relay will not be energized.

In the Experiment section you will compare operation of latching relays and latch/unlatch instructions.

EXPERIMENT

Purpose

To program latching/unlatching relays and latch/unlatch instructions and compare their operations.

Procedure

1. Make the proper common connections to the controller, switches and lights.

2. Make the input/output connections given in Table 12-1.

Switch	Input	Light	Output
0	I:0	4	O:0
1	I:1	5	O:1
3	I:2	--	--

Table 12-1
Connections for Procedure

3. Prepare the controller for programming.

4. Enter the program in Figure 12-7.

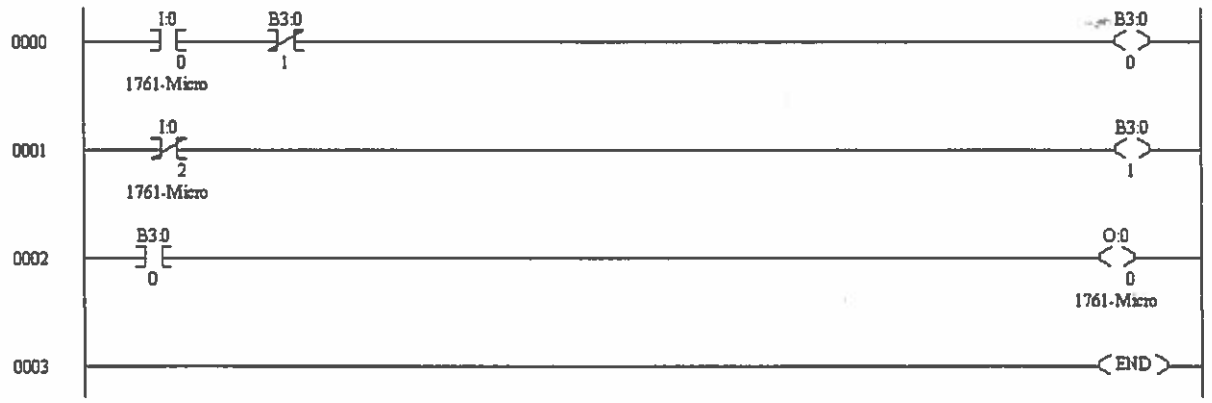


Figure 12-7
Program for Step 4

5. Press switch 0 and release it, observing the output devices. Then press switch 3 and release it, paying attention to the output devices again. Note your observations.

When switch 0 is pressed, light 4 turns on. The light turns back off as soon as switch 0 is released. No lights turn on when switch 3 is pressed or released.

6. Press and hold switch 0. While switch 0 is held down, press and hold switch 3. Release switch 3 before releasing switch 0. Describe the entire output sequence.

Light 4 comes on when switch 0 is pressed. The light turns off when switch 3 is pressed. The light turns back on as soon as switch 3 is released. It turns off as soon as switch 0 is released.

7. Replace the existing program with the new program given in Figure 12-8.

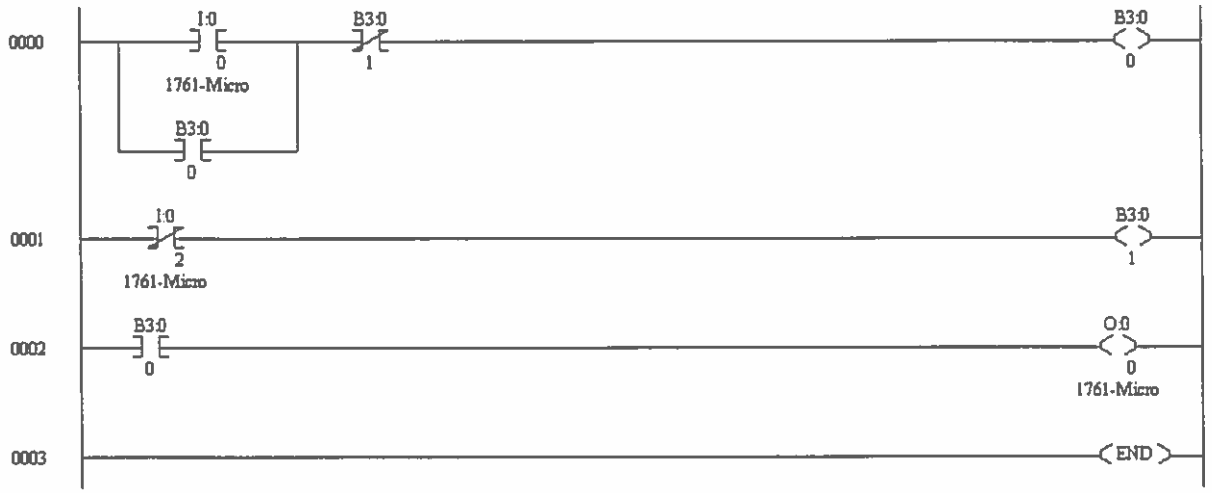


Figure 12-8
Program for Step 7

8. Press and release switch 0. Then press and release switch 3. Describe what you now observe.

Light 4 comes on when switch 0 is pressed. It stays on when switch 0 is released. The light turns off when switch 3 is pressed.

9. Replace the current program with the new program given in Figure 12-9.

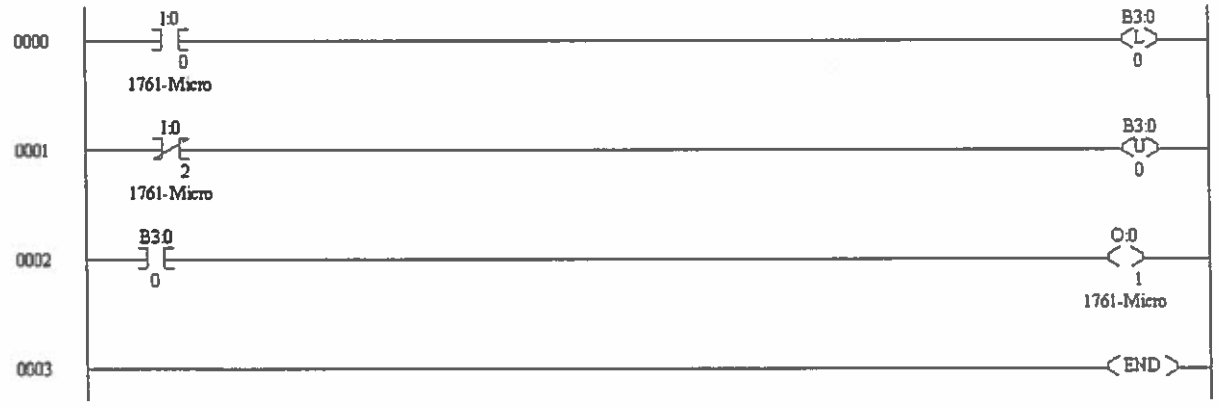


Figure 12-9
Program for Step 9

10. Enter and test the operation of this newest program.

How does its operation compare to the operation of the previous program?

The two programs operate identically. Without seeing the programs on the computer display screen, it is impossible to distinguish them.

11. Clear the program from memory. Study the program in Figure 12-6 and enter it into the controller.

12. Test the program's operation several times, as needed.

    Explain how this program provides extra safety measures, which could be used when controlling dangerous machinery.

    Two inputs must be energized simultaneously before the program will operate. The program cannot be started accidentally by someone bumping a single switch. Only one input must be energized to de-activated the output. Since the output is de-activated immediately, this input can serve as an emergency stop controlled by a single switch.

13. When you have completed the Experiment section, set aside your equipment and complete the Questions which follow.

Questions

1. What is the purpose of a latching instruction?

   A latching circuit can be used to keep a circuit operating when its momentary starter switch is released. An example is the "ON" push-button which starts a machine working.

2. Explain the similarities and differences between latching relays and set instructions.

   Include comments about how each releases its hold on an operation.

   Latching relays and latching instructions both serve as operation holding instructions

and both require separate input elements to release the holds. They may both hold internal relays and external output elements. The latching rung is unlatched by a normally closed internal relay contact which is ANDed with the latching contact. The set instruction is reset by a distinct reset instruction with the same address.

3. Why must there be a separate input element to unlatch a latching relay or latching instruction?

The unlatch instruction must be independently controlled. If an input element were used in common with the latch instructions, the input element could activate the latch/unlatch instructions concurrently. This would result in a program failure.

4. Redraw the ladder logic diagram in Figure 12-10. Use the latching/unlatching instructions and provide complete keystroke sequence.

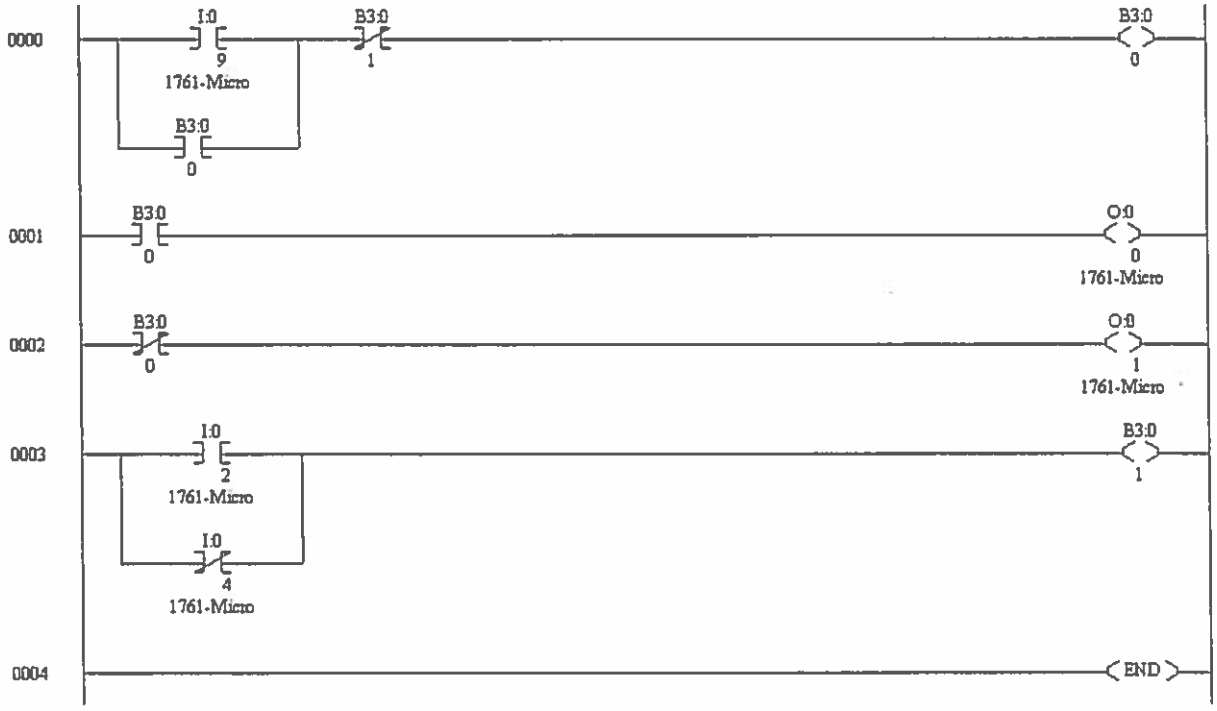
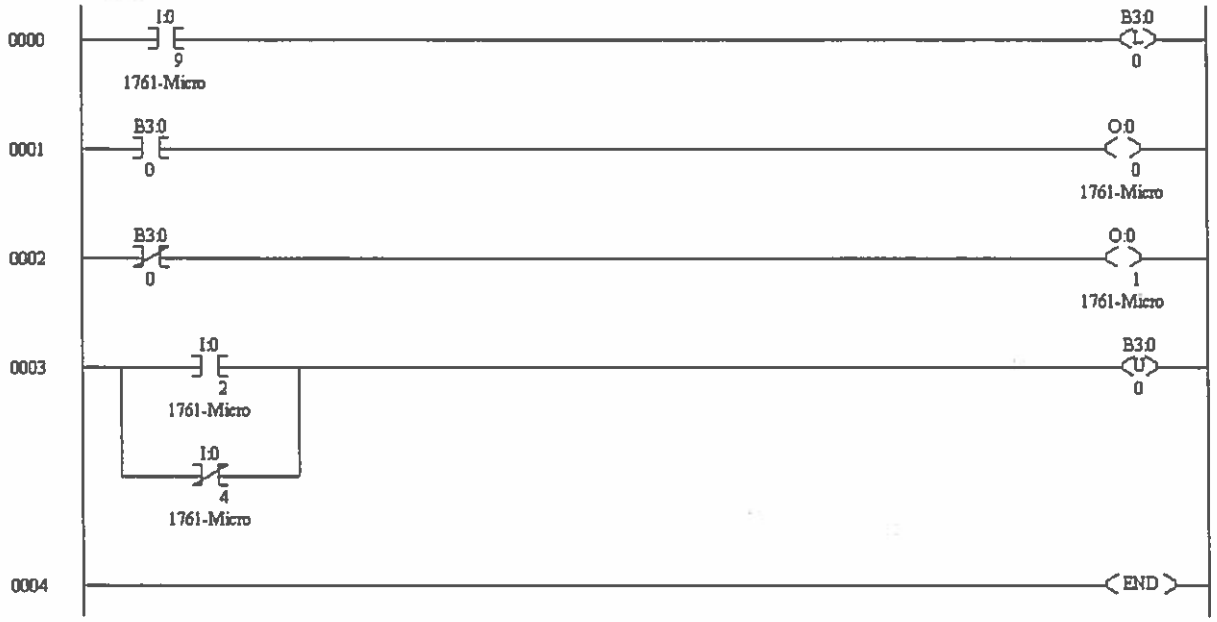


Figure 12-10

ANSWER



New Rung
Examine if Closed I:0/9
Output Latch B3:0/0
Examine if Closed B3:0/0
Output Energized O:0/0
Examine if Open B3:0/0
Output Energized O:0/1
Examine if Closed I:0/2
Rung Branch
Move rung branch to before I:0/2 and after I:0/2
Examine if Open I:0/4
Output Unlatch B3:0/0

5. Explain the operation of the program in Figure 12-10.

Input I:0/9, when energized, holds the internal relay activated. The internal relay, when activated, turns on output O:0/0. Also, when activated, the internal relay turns off output O:0/1. Input I:0/2, when energized, or input I:0/4 when de-energized, de-activates the hold on the operations.